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US DOT OST-R Tier 1 University Transportation Center

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Environmental Impact Assessment of Rail Infrastructure

By

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DISCLAIMER

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TECHNICAL SUMMARY

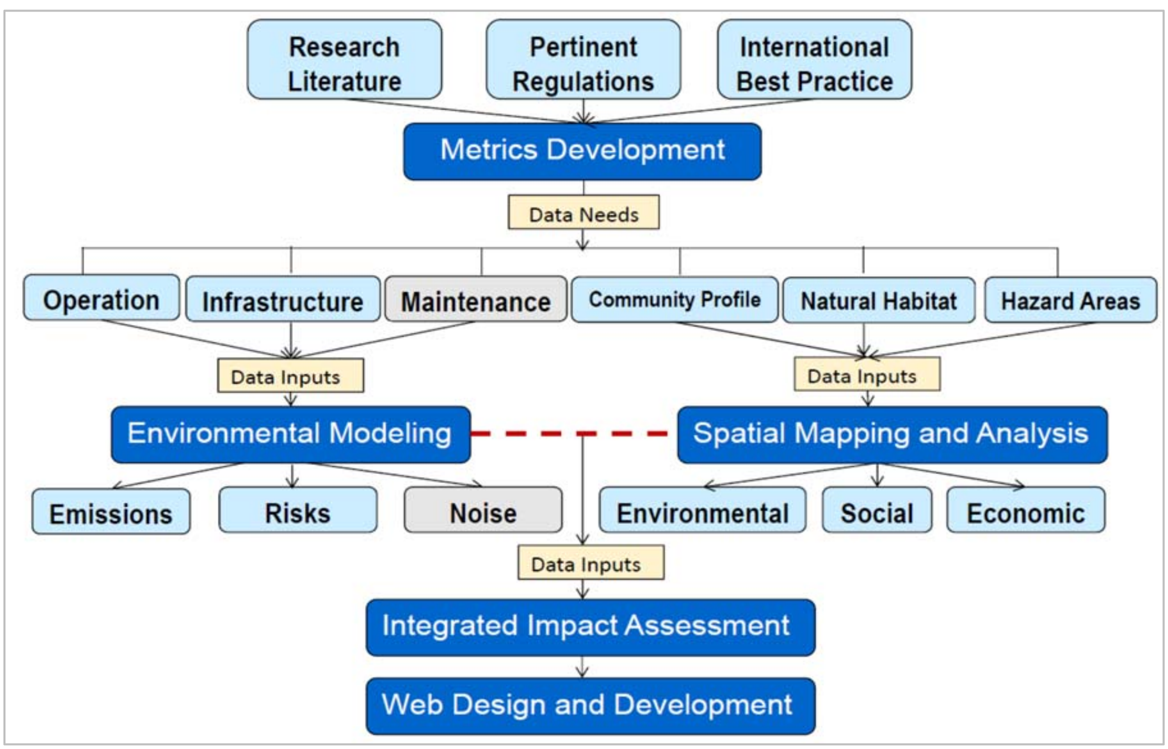
Title

Environmental Impact Assessment of Rail Infrastructure

Introduction

Launched in 2009, the High-Speed Intercity Passenger Rail Program aims to provide 80% of Americans access to an improved national rail network within the next 25 years (White House, 2011). Under the National Environmental Policy Act (NEPA), all proposed rail projects are subject to an environmental evaluation process. While the NEPA process is designed to protect the environment and promote community involvement, it can be lengthy and expensive (Sampson, 2013). A recent audit by the U.S. Department of Transportation (DOT) Office of Inspector General (OIG) also concluded that existing NEPA procedures at the Federal Railroad Administration (FRA) are “outdated and limited” and thus recommended an update of its NEPA procedures to reflect current environmental laws and guidance (OIG, 2013). This study aims to increase the effectiveness and efficiency of environmental impact assessment of rail infrastructure by developing an online one-stop database for sustainable rail planning.

Approach and Methodology



Findings

The interdisciplinary and dynamic nature of the regulatory framework for rail systems presents great challenges in practice and necessitates a common platform for implementation. A system view of sustainable rail management is needed in order to address high priorities across all environmental media (e.g. air, water, land, and noise) and foster effective coordination among multiple agencies and departments towards integrated environmental, social, and economic goals. While spatial metrics can be particularly useful for community-specific assessment, limited statistics have been collected, recorded, or published. In addition, existing studies that model the impacts of rail transportation only focus on high-level (e.g., at the regional level) transportation policy and land use. System models for community-level impact assessment of rail infrastructure planning in the U.S. are yet to be developed and refined.

Conclusions

This project resulted in three products: a comprehensive "Sustainable Rail Checklist," a rail planning GIS database, and a web GIS tool that integrates sustainability metrics and facilitates a rapid assessment before a formal NEPA process is implemented for a rail project. The "Checklist" incorporates current academic research findings, legislation and government guidelines on evaluating the efficiency, safety, public health, ecological stress, emissions, and socioeconomic impacts of rail. The GIS database compiles location-specific data for rail infrastructure planning data through both data mining and environmental modeling. The web tool enables users to specify a geographic area in Illinois and obtain a summary of environmental, demographic, and rail infrastructure data of interest.

Recommendations

Transportation professionals and environmental planners can use the application that is developed in this project for assessing a wide range of impacts early in the decision-making process, before significant funds and time have been devoted to project design. This will alert transportation and environmental professionals of the need to perform a targeted assessment, and/or to coordinate among multiple departments in both rail system planning and operation processes. The tool and metrics developed in this research, if adopted for State Rail Plans, can potentially contribute to the development of an industry-wide database. Transportation professionals can more readily compare rail plans across state lines and over time, identify areas for improvement, and suggest new program directions for DOT. This tool is also anticipated to promote community awareness and involvement. Public citizens can easily obtain information about the potential impacts of proposed or ongoing projects for advocacy in environmental justice in their community. Continuous refinement for community-specific references and the incorporation of data about rail maintenance, meteorology, and noise in a life cycle perspective are recommended for future research.

Publications

Interactive Web Site

- This project developed a web site (NURail.UIC.EDU) that publishes the project information and provides access to the web tool.

Conference Presentations

- 2014 American Association of Collegiate Schools of Planning Conference. 2014. Platform Presentation. Presenter: Dr. Ning Ai.
- 2014 Railroad Environmental Conference. 2014. Platform presentation. Presenter: Dr. Ning Ai.2013 Rail Summit, Chicago, Illinois. October 25, 2013. Platform presentation. Presenter: Dr. Ning Ai.
- 2013 APTA Annual Meeting, Chicago, Illinois. September 29 – October 2, 2013. Poster presentation. Presenter: Marcella Bondie
- 2013 NURail Annual Meeting, Urbana-Champaign, Illinois. September 11-12, 2013. Session presentation and poster. Presenters: Steve Schlickman and Marcella Bondie.
- 2013 Transport Chicago, Chicago, Illinois. June 7, 2013. Platform presentation. Presenter: Marcella Bondie.
- 2013 Joint Rail Conference, Knoxville, Tennessee. April 16-18, 2013. Poster presentation. Presenter: Anthony Grande.

Webcast

- "Sustainability Metrics and Mapping Tool for Environmental Assessment of Rail Infrastructure in Illinois." Center for Urban Transportation Research (CUTR) Webcast Series, University of South Florida. (December 11, 2014). Presenter: Dr. Ning Ai

Graduate Student Educational Sessions

- NURail Annual Meeting 2015 – NURail Graduates in Action, June 4, 2015. Presenter: Marcella Bondie.
- NURail Annual Meeting 2013 – NURail Graduates in Action, April 16, 2013. Presenter: Anthony Grande.

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ACKNOWLEDGEMENT

This project is hosted at the Urban Transportation Center (UTC) at UIC and supported by the National University Rail (NURail) Center, a seven-university consortium of rail-focused, Tier-1 University Transportation Centers under the US Department of Transportation (DOT) Research and Innovative Technology Administration (RITA) program. Funding is also provided by the Canadian National Railway Company (CN). This project would not have been possible without the support of many individuals and organizations. We are especially grateful for the expertise provided by:

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SECTION 1: INTRODUCTION

1.1 Project Overview

This project, "Environmental Impact Assessment of Rail Infrastructure in Illinois," referred to "NURail-GIS" hereafter, aims to increase the effectiveness and efficiency of environmental impact assessment of rail infrastructure by integrating the latest developments in environmental impact studies and developing a system view of sustainability metrics in a one-stop rail planning database.

The performance metrics address the efficiency, safety, public health, ecological stress, emissions, and socioeconomic impacts on local communities. The sustainability metrics are designed to be used in a tiered approach that specifies minimum regulatory requirements or a "best practice" sustainable alternative. In reference to the sustainability metrics, this study simulates and visualizes the potential environmental impacts of existing and proposed rail infrastructure in a Geographic Information System (GIS) framework online. The web GIS tool enables users to specify a geographic area in Illinois and obtain a summary of environmental, demographic, and rail infrastructure data of interest.

Transportation professionals and environmental planners can use the application that is developed in this project for assessing a wide range of impacts early in the decision-making process, before significant funds and time have been devoted to project design. This will alert transportation and environmental professionals of the need to perform a targeted assessment, and/or to coordinate among multiple departments in both rail system planning and operation processes. This tool is also anticipated to promote community awareness and involvement; public citizens can easily obtain information about the potential impacts of proposed or ongoing projects for advocacy in environmental justice in their community. While this research is limited to the scope of Illinois, the generic framework may be replicable in other regions.

1.2 Significance of Integrated Environmental Impact Assessment

Rail projects can have adverse impacts on the local environment (e.g., habitat, waste, public health) and regional and global environment (e.g., traffic congestion, acid rain, climate change) (Uhurek, 2010). This range of various geographic scales, compounded by the spatial complexity of rail infrastructure systems, can make it difficult for transportation planners and public citizens to have an integrated understanding of its potential impacts. However, an overview of environmental impacts are valuable early in the planning process, when opportunities of multi-agency coordination can be identified, when the public can be informed, and when environmentally sensitive areas and socially vulnerable communities can be addressed. All these potential benefits help facilitate regulatory compliance, which can be complex and have direct impacts on project budget, timeline, and society.

Rail transportation is subject to various legislation and regulations that address environmental impacts. The primary legislation requiring environmental assessment of rail projects is the National Environmental Policy Act (NEPA). NEPA guidance documentation for the Federal

Railroad Administration (FRA, 1999) states that NEPA assessments should address environmental, social and economic impacts. Environmental impact assessment should include air and water quality; noise and vibration; solid waste disposal; ecological systems (with a particular focus on wetlands and endangered species); floodplains and coastal zones; land use; use of energy and other natural resources; and parkland and cultural resources. Additionally, the social impact assessment should include aesthetics and design quality, transportation impacts, accessibility, environmental justice, public health and safety, recreation, cultural resources. In addition, the economic impact assessment should include factors such as job creation, resident relocation, and community disruption. Finally, the assessment should consider the impacts of both the finished project and the construction period.

Although the federal NEPA legislation specifies the general steps that must be followed for compliance, each federal administration is responsible for developing and implementing detailed NEPA procedures within its organization. The U.S. Department of Transportation (DOT) has further directed each of the four federal transportation agencies to develop their own NEPA procedures. Thus, specific NEPA requirements differ between transportation agencies. FRA guidance (Procedures for Considering Environmental Impacts, 1999) applies to intercity passenger and freight railroads, including Amtrak and high-speed rail. Federal Highway Authority Administration (FHWA) and Federal Transit Administration (FTA) procedures are codified in 23 CFR 771 (Environmental Impact and Related Procedures, 2006), and apply to highway and public transportation projects, including urban transit rail systems. The Federal Aviation Administration (FAA) Order 5050.4B (NEPA Implementing Instructions for Airport Projects, 2006) applies to airport projects.

Under NEPA, each project is designated with one lead agency, or multiple lead agencies. For example, if a new intermodal freight yard will connect a regional airport and a rail corridor, then FAA and FRA could be designated as joint lead agencies. In addition, the federal agency (e.g., FRA) and the governmental recipient of the federal action (e.g., Illinois Department of Transportation) may serve as the joint lead agencies (AASHTO, 2014). Other governmental administrations, such as the U.S. Fish and Wildlife Service, may serve as a joint lead agency as required. Therefore, the multiplicity of lead agencies and project sponsors for a NEPA assessment can lead to complex coordination issues, particularly if there are differences between the agencies' NEPA procedures.

Recently, the U.S. Department of Transportation (DOT) Office of Inspector General (OIG, 2013) issued a report concerning the FRA's existing NEPA procedures, finding that there is a need for updates and clarified NEPA implementation procedures for proposed rail projects. In addition, DOT and the U.S. Environmental Protection Agency (EPA) have both proposed additional sustainability performance metrics for freight, commuter and transit rail, which exceed the current requirements of NEPA. Therefore, there is a critical need for a streamlined and integrated environmental impact assessment method for rail infrastructure, especially given that the High-Speed Intercity Passenger Rail Program aims to provide 80% of Americans access to an improved national rail network within the next 25 years.

It should be noted, however, that there is currently no long-term dedicated federal funding for high-speed rail projects (Peterman et al., 2013) and the NEPA process only applies to projects that receive federal funding, permits or other actions. According to the American Society of Civil Engineers (ASCE, 2012), the largest freight rail companies typically self-fund their projects. Thus, environmental impact information is not available through the NEPA process for every project. In those cases, publicly accessible and integrated environmental information of rail projects can be particularly valuable for public citizens.

Given the anticipated growth of rail infrastructure in the next decade, the aforementioned barriers and challenges of rail project planning and environmental impact assessment could lead to considerable inefficiencies in both environmental and socioeconomic terms. Both transportation professionals and the general public can benefit from an all-in-one rail planning database that includes comprehensive guidelines for sustainable practices and community-specific data references, and is, importantly, easily accessible to all.

1.3 Project Scope – Illinois Focus

The numerical and spatial analysis is conducted in Illinois, which contains the largest rail network in the United States. Metropolitan Chicago has historically served as a transcontinental transportation hub for people and freight. The first rail line was built in Chicago in 1836, and rail became the dominant mode for freight transportation until the interstate highway system was built in the 1950s (CMAP, 2012).

Today, Illinois is home to one of the largest railroad networks in the United States, with 7,306 miles of freight rail track, operated by forty-one different companies (**Figure 1**). Fifty percent of all U.S. rail freight passes through the Chicago region (CMAP, 2012). Overall rail tonnage is forecasted to increase more than sixty percent between 2007 and 2040, largely due to growth in intermodal container movement (CMAP, 2014). **Figures 2 and 3** depict rail traffic in the Chicago region and Illinois. The most heavily travelled rail track segments are located on east-west rail lines near Chicago and St. Louis.

The Chicago region is also the focus of two new high-speed rail (HSR) projects for intercity passenger transportation. The corridors under development are Chicago-St. Louis and Chicago-Detroit/Pontiac, which will use diesel-electric trains to reach maximum speeds of 110 mph. HSR can be developed by either upgrading existing tracks or building dedicated tracks on new corridors. Currently, both of the Chicago region HSR corridors are upgrading existing tracks (Peterman et al., 2013).

Although Chicago is a rail hub for the nation, the region’s rail operations are challenged by traffic congestion and land use conflicts. Nearly 2,000 at-grade crossings between railroad tracks and roads slow automobile traffic, and present a risk for collisions between trains and automobiles. Traffic congestion is worsened where freight trains and passenger trains share right of way on railroad tracks. Traffic congestion impacts reliability and the cost of operations, and results in decreased economic competiveness for the region (CMAP, 2012).

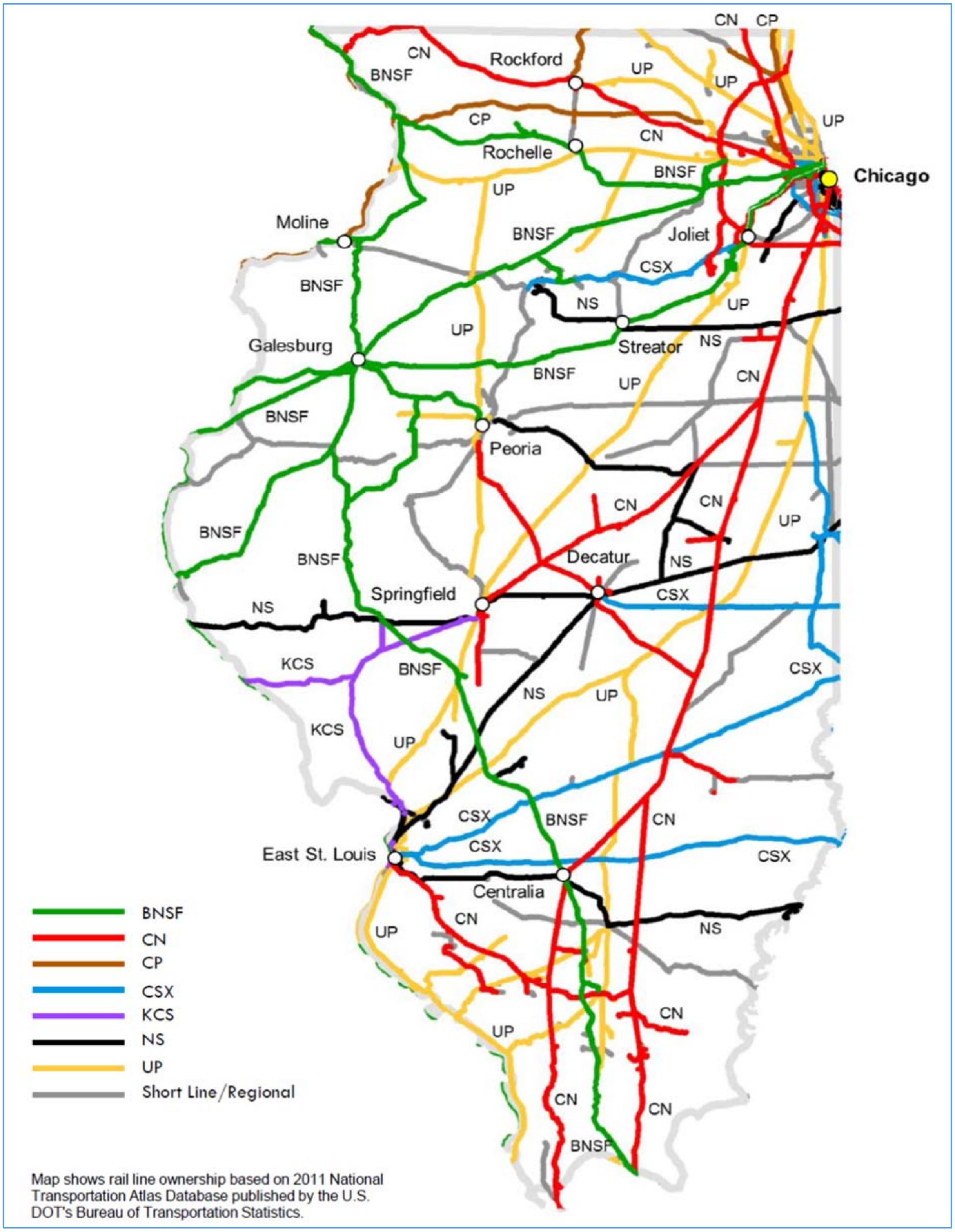
Furthermore, the complexity of the Illinois rail system creates air quality and health concerns. Although trains may not produce high levels of air pollutants as they travel continuously along rail tracks (i.e., line-haul operations), sites of heavy rail activity, such as rail yards and intermodal terminals, are contributors to air pollution (International Union of Railways, 2011). Rail yards are facilities where rail tracks converge, enabling rail cars to be transferred between rail lines (i.e., switching operations). Intermodal terminals are facilities for transferring freight between transport modes. Rail yard data are available for the Chicago metropolitan region (see **Figure 4**), but a comparable statewide data source has not been identified.

Railroad infrastructure development, particularly freight rail, is challenged by local land use issues. Many communities are unwilling to host freight rail due to impacts on noise, traffic congestion, air and water pollution, and public safety, as well as its low ability to generate sales tax (CMAP, 2012). Given the available data for Illinois, the density of rail traffic in the Chicago region, and the known high impact points within rail infrastructure systems, the NURail-GIS tool focuses fine-grained analysis of impacts near at-grade crossings and rail yards in the Chicago metropolitan region, as well as established community areas.

1.4 Research Flow

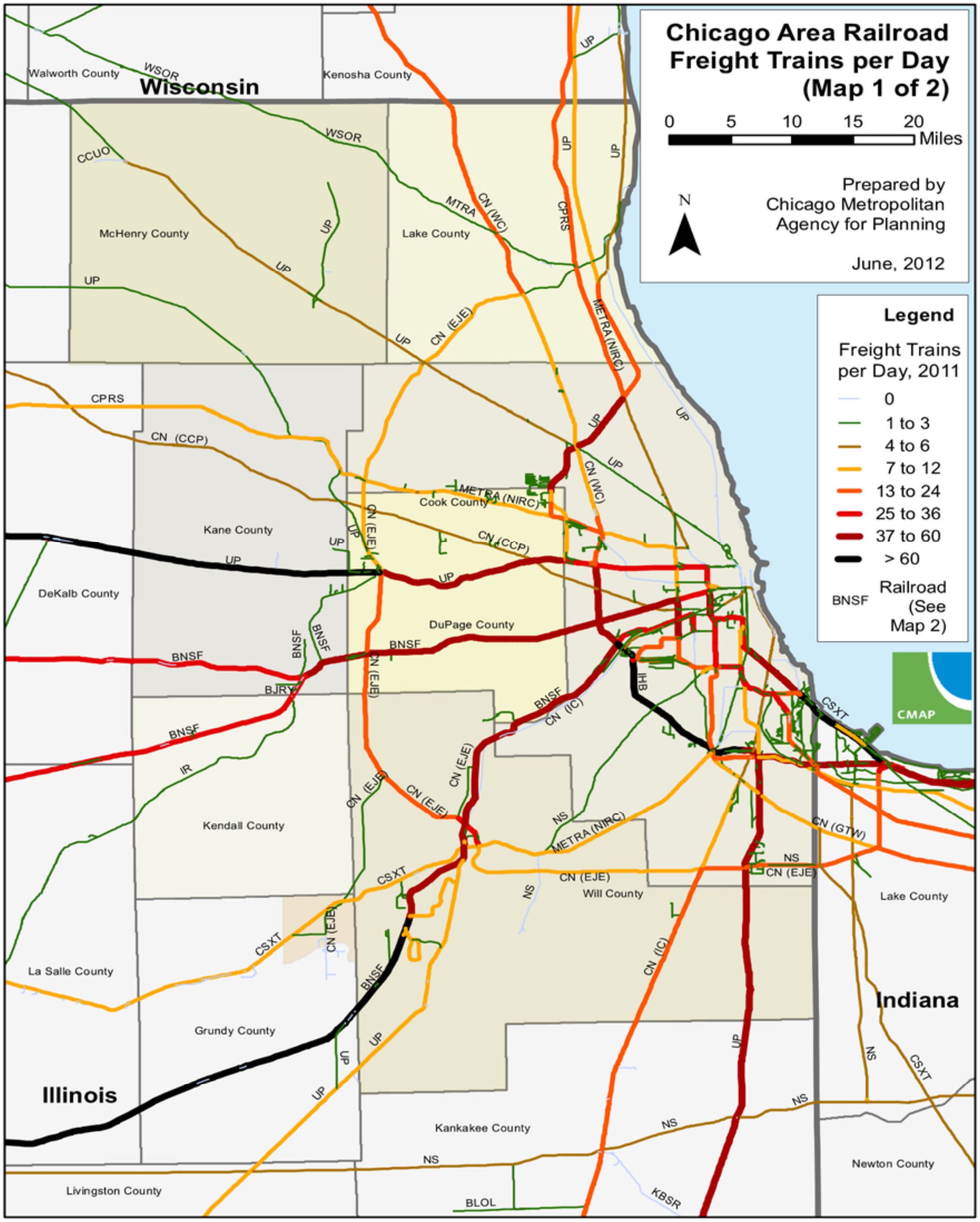
This study began with a literature review of sustainability metrics for rail infrastructure. The literature review incorporated current legislation, government guidelines, academic research, and best practices worldwide. Subsequently, a GIS database was constructed from the subset of the sustainability rail metrics which have a spatial component and can be measured for a specific location. The GIS database includes rail operations, infrastructure and maintenance data; demographics; and land use data. In addition, location-specific models were developed for estimating air pollutant emissions related to rail operation. Other environmental impacts and risks associated with rail infrastructure were discussed and quantified when possible. The results were then overlaid with demography and land use data. Finally, a web tool was built to allow users to access the GIS database and sustainability metrics. Users can specify a geographic area of interest through an online interface and extract maps and data for the customized area. **Figure 5** provides an overview of the research flow of this project. In-depth discussions of research methods and data sets are provided in the following sections, which are conducted by discussions on limitations and future research needs.

Figure 1. Freight Rail Network by Class I Railroad Company in Illinois



Source: AAR (2013).

Figure 2. Chicago Area Railroad Traffic (Freight Only)

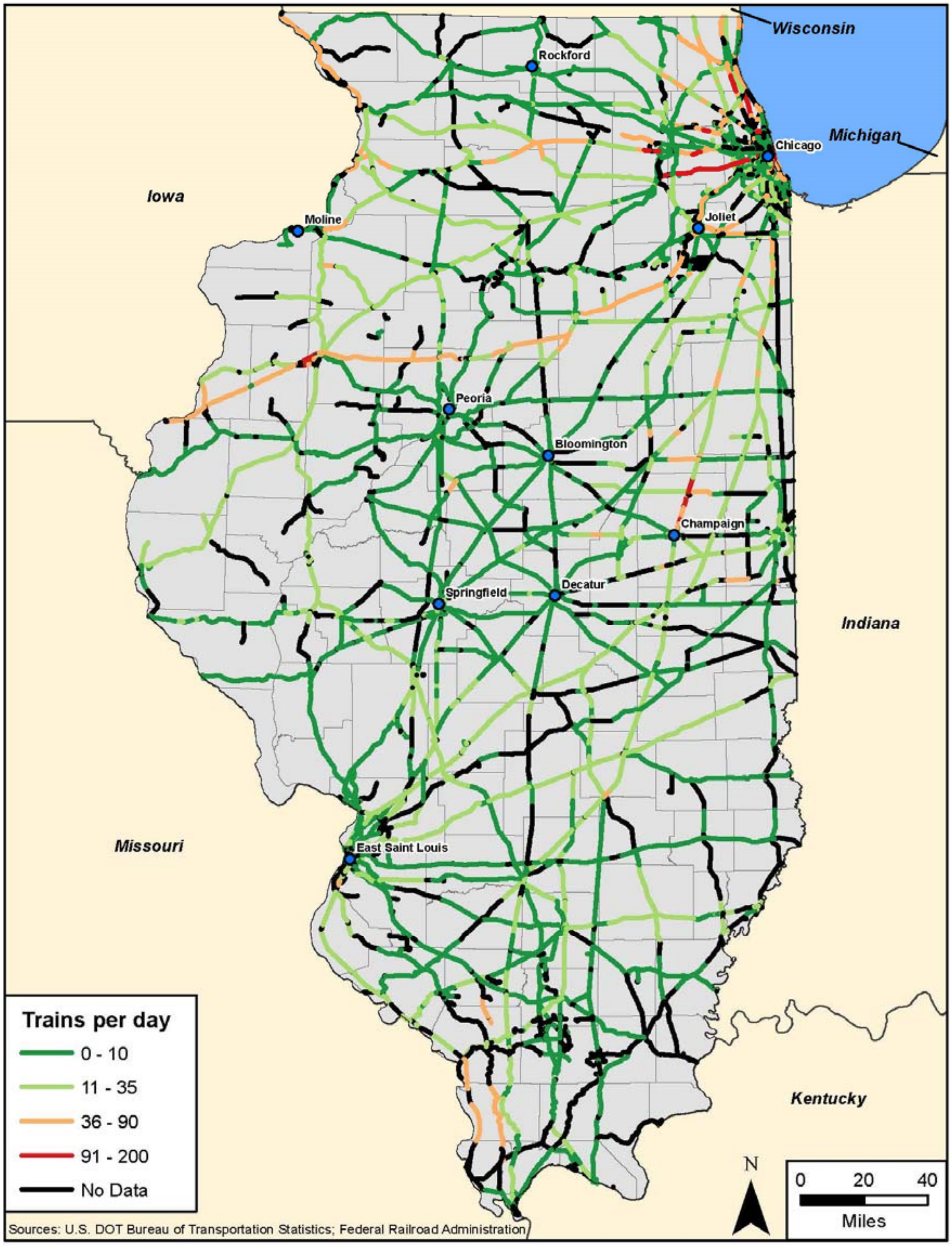


Estimate prepared by CMAP. Source: National Transportation Database, 2011. Updated with information from createprogram.org, Illinois Commerce Commission Grade Crossing Database, Google Earth, and personal communications. Missing data was interpolated.

Note: Figures include overhead trackage rights for many railroads, including Metra, the regional commuter railroad.

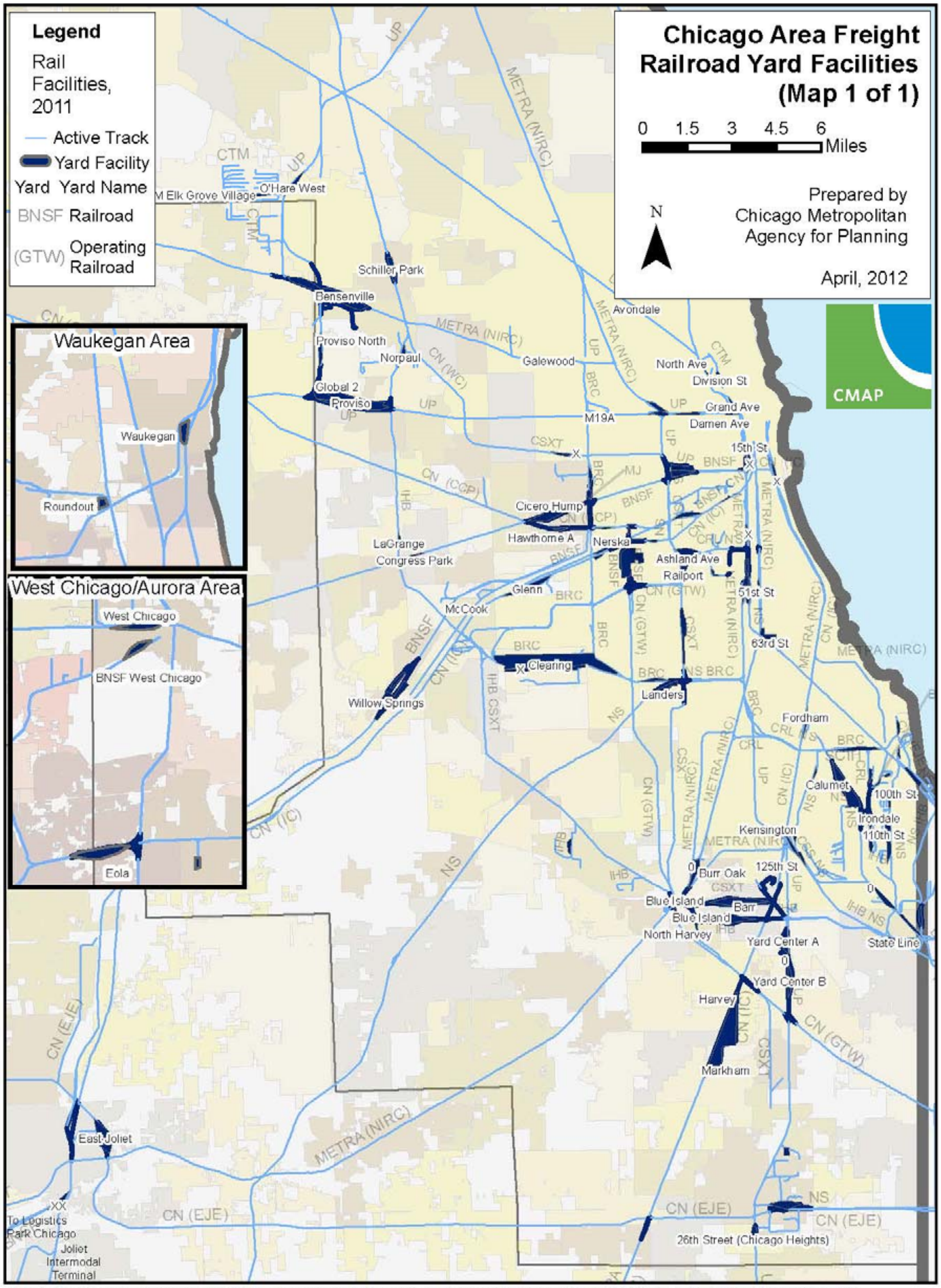
See http://www.cmap.illinois.gov/freight-snapshot.

Figure 3. Chicago Area Railroad Traffic (Daily Train Count)



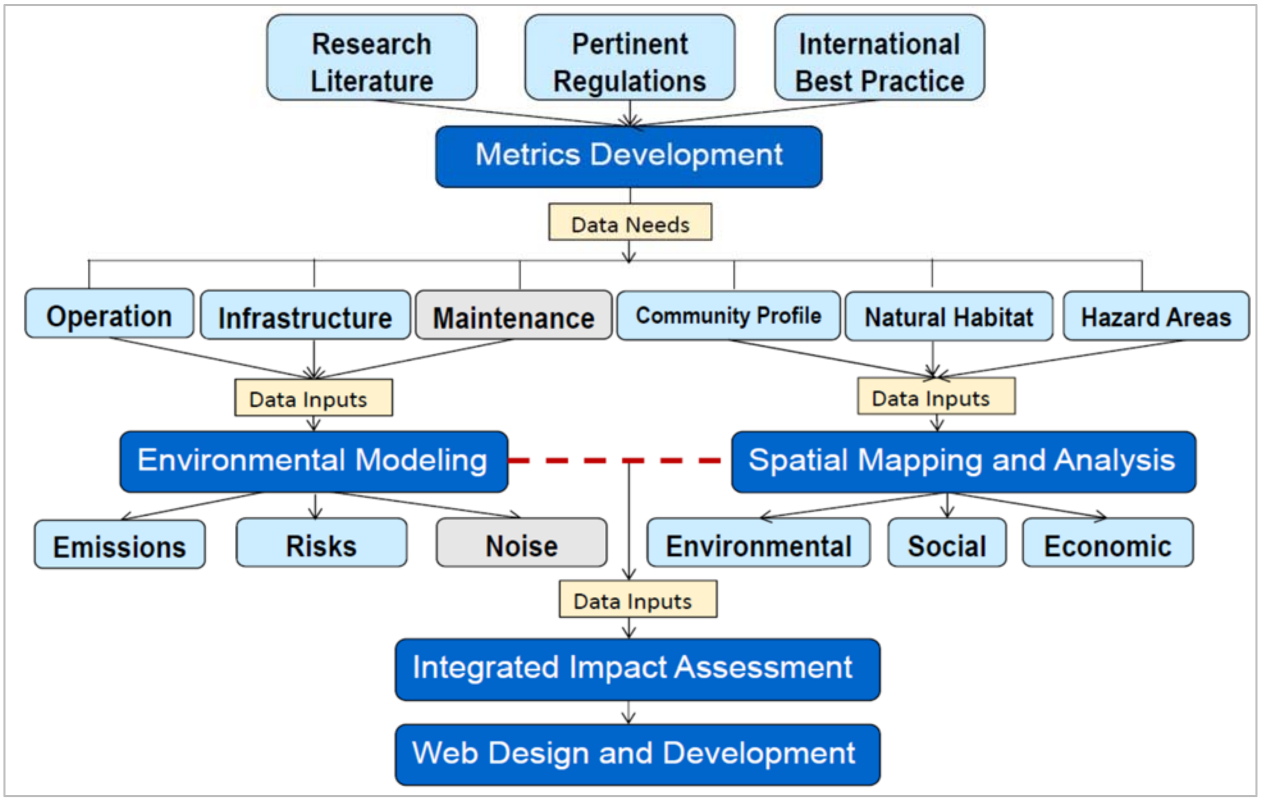
Note: Map prepared by NURail project based on FRA average daily train counts for individual grade crossings

Figure 4. Chicago Area Freight Railroad Yard Facilities



Source: CATS Working Paper 96-05, updated by inspection of Bing and Google Maps aerials, and personal communications.
Note: Shaded areas depict municipal boundaries. For a key to the listed railroads, see http://www.cmap.illinois.gov/freight-snapshot

Figure 5. Research Flow



SECTION 2: LEGISLATIVE REVIEW

Compliance with federal statutes and regulations are required for all Federal and Federally-assisted rail projects. The U.S. Department of Transportation (DOT) has required that each transportation agency adopt procedures and rules to implement federal laws for projects within each agency. The Federal Railroad Administration (FRA) implements programs to improve rail safety, including highway-rail grade crossings, and develop rail networks, including freight, Amtrak and high-speed rail (FRA, June 23, 2009). The Federal Transit Administration (FTA) implements programs for public transit agencies. The State of Illinois and Illinois Department of Transportation have adopted additional statutes, regulations and guidance applicable to rail projects undertaken within Illinois. These laws and regulations address civil rights, environmental policy and resources, cultural resources, pollution, health and safety.

2.1 General Statutes

- *National Environmental Policy Act*

The purpose of the National Environmental Policy Act of 1969 (NEPA) is "to declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality." NEPA applies to major federal actions and other actions requiring federal permits or funding. Procedures for complying with NEPA are set forth by the Council on Environmental Quality (CEQ, 2012 and 2010). The Department of Transportation (DOT) NEPA compliance procedures (DOT, 1985) are codified for Federal Transit Administration (FTA; 23 CFR 771) and Federal Railroad Administration (FRA, 1999) projects. Additional NEPA compliance guidance is provided for specific types of rail projects (FRA, August 13, 2009; FRA, August 14, 2009).

The NEPA process requires public involvement and a systemic, interdisciplinary assessment of likely environmental impacts during the development of a proposed project. Proposed projects must be evaluated based on the need for transportation; possible adverse economic, social, and environmental impacts; and governmental environmental goals. States must provide public hearings on the proposed project and determine whether the project is consistent with local planning goals and objectives. Final decisions must be made in a timely manner (CEQ, March 6, 2012), and in the best overall public interest. Some types of projects are identified as categorically excluded from requiring a NEPA Environmental Assessment (EA) or Environmental Impact Statement (EIS), because the actions do not have significant impact on the environment (FRA, January 14, 2013; FRA, August 13, 2009).

The NEPA EA and EIS process requires the identification and assessment of reasonable alternative actions for the proposed project, to mitigate or avoid adverse environmental impacts (CEQ, January 21, 2011). NEPA assessments may include modal assessments, such comparing the relative impacts of air transportation versus a new high speed rail corridor. However, the restricted range of impacts included by NEPA legislation, and the spatial mismatch between air and rail planning, has resulted the preparation of few detailed modal assessments (TRB, 2013).

USDOT Office of Inspector General recently investigated the adequacy of FRA's existing NEPA procedures and coordination with FTA and FHWA (USDOT OIG, 2013). FRA's usage of the NEPA process has been expanded by the passage of MAP-21 legislation (discussed below), to include the High Speed Intercity Passenger Rail Program. Although outside attendees have advocated for a "one DOT" approach to NEPA implementation, many DOT officials felt this would not adequately reflect the differences between transportation modes. OIG determined that FRA performed adequate NEPA coordination, but recommended that FRA update its NEPA implementing procedures to reflect current environmental law and CEQ guidance, and complete comprehensive internal SOPs for staff administering the NEPA process.

- *Passenger Rail Investment and Improvement Act*

Under the Passenger Rail Investment and Improvement Act (PRIIA), States must prepare a State Rail Plan, including "A general analysis of rail's transportation, economic, and environmental impacts in the State, including congestion mitigation, trade and economic development, air quality, land use, energy use, and community impacts" (49 USC 227). The State of Illinois has also passed legislation governing the assessment of rail projects. The Illinois Highway Code (amended 2003) requires the Illinois Department of Transportation to "embrace principles of context sensitive design and context sensitive solutions in its policies and procedures for the planning, design, construction, and operation of its projects for new construction, reconstruction, or major expansion of existing transportation facilities" (605 ILCS 5/4-219). Context sensitivity requires stakeholder input to consider the impact of transportation projects on communities.

- *MAP-21*

The Moving Ahead for Progress in the 21st Century Act (MAP-21), effective from October 2012 through 2014, authorizes funding for surface transportation programs. MAP-21 replaces the previous funding authorization Act - the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU, 2005). MAP-21 grantees must have a Transit Asset Management plan, and the proposed Transportation Improvement Program must incorporate performance targets for the following: safety, infrastructure condition, congestion reduction, system reliability, freight movement, economic vitality, environmental sustainability and reduced project delivery delays (FTA, 2012). MAP-21 eliminates the environmental reporting requirement for an Alternatives Analysis, although NEPA requirements for alternatives analysis remain in effect (FTA, 2012, web event). MAP-21 authorizes FTA to create and implement safety standards, and grantees must create agency safety plans and comply with new measures for State Safety Oversight rail safety programs (USDOT FTA, 2012).

2.2 Social and Economic Impacts

- *Uniform Relocation Assistance and Real Property Acquisition Act of 1970*

The purpose of the Uniform Relocation Assistance and Real Property Acquisition Act, amended by the Uniform Relocation Act Amendments of 1987, is to ensure property owners and displaced individuals are "treated fairly, consistently, and equitably" and "do not suffer disproportionate injuries as a result of projects." If a rail project includes land acquisition, the procedures codified in DOT regulations will apply (49 CFR 24).

- *Title VI of the Civil Rights Act of 1964*

Title VI states, "No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance" (42 USC 200d). The DOT codified Title VI in its regulations (49 CFR 21). FTA-funded recipients must prepare a Title VI program that addresses requirements such as providing service "in a nondiscriminatory manner" (Circ. FTA C 4702.1B).

The Environmental Justice Executive Order 12898 requires federal programs and projects to avoid causing "disproportionately high and adverse" impacts on the health and environment of minority and low income populations (59 FR 7629). The DOT established processes to incorporate environmental justice into federal transportation programs, policies and actions (DOT Order 5610.2a). Federal rail actions must be evaluated for impacts to minority and low-income population, including a determination of whether adverse impacts can be mitigated or avoided through a "practicable" alternative action. The action may be completed only if mitigation measures or alternatives are not practicable.

Related statutes include Executive Order 13045, which states agencies must "ensure that its policies, programs, activities, and standards address disproportionate [environmental health and safety] risks to children" (62 FR 19885) and Executive Order 13175, which requires agencies to provide Indian tribal governments with the opportunity for "meaningful and timely input in the development of regulatory policies on matters that significantly or uniquely affect their communities" (65 FR 67249).

- *Americans with Disabilities Act of 1990*

The Americans with Disabilities Act of 1990 (ADA) requires equal opportunity and access for persons with disabilities. The U.S. Department of Transportation legislation is provided by 49 CFR 37, which sets standards for accessible vehicles, transportation facilities, paratransit and other modes. These regulations apply to all passenger rail projects, including those under the authority of FTA and FRA.

2.3 Cultural and Historical Resources

- *Historic Sites Act*

The Historic Sites Act of 1935 established a national policy to preserve historic sites, buildings, and objects of national significance. The Archeological and Historic Preservation Act (AHPA), also known as the Moss-Bennett bill, "provide[s] for the preservation of historic American sites, buildings, objects, and antiquities of national significance" that would be impacted by Federal and Federally-assisted projects that alter the terrain (16 USCS 470). The lead federal agency must notify the Department of Interior when a project threatens the loss or destruction of significant historic or archaeological data (McManamon, 2000).

- *Archeological Resources Protection Act*

The Archaeological Resources Protection Act (ARPA) of 1979 protects archaeological resources on Federal or Native American lands. The Federal agency with jurisdiction over the land has authority to issue permits and penalties and establish procedures regarding archeological resources (36 CFR 296). Under ARPA, archeological resources must be identified, evaluated, and mitigated or avoided during the project (McManamon, 2000). The American Indian Religious Freedom Act (AIRFA) of 1978 upholds the right of Native Americans to access traditional sacred places and objects. Similarly, the Native American Graves Protection and Repatriation Act (NAGPRA) of 1990 protects Native American graves and other cultural material located on federal and tribal land. If a land-disturbing project encounters these items, they must be excavated, inventoried and repatriated in accordance with this legislation (McManamon, 2000).

- *National Historic Preservation Act*

The goal of the National Historic Preservation Act (NHPA) of 1966 and the associated Executive Order 11596 is to preserve, restore, and reuse historic cultural resources that may be impacted by Federal or Federally-assisted projects. Section 106 of NHPA regulations requires Federal agencies to "identify historic properties potentially affected by the undertaking, assess its effects and seek ways to avoid, minimize or mitigate any adverse effects on historic properties" (36 CFR 800). Damage to historic properties must be avoided or mitigated to greatest extent possible (McManamon, 2000). Under the Illinois State Agency Historic Preservation Act of 1989, the State must consider the impact of State projects on historic resources and seek to "eliminate, minimize, or mitigate the adverse effect." The State law does not apply if the project is being reviewed under Section 106 of NHPA.

- *Parks, Recreation, Areas, Wildlife and Waterfowl Refuges, and Historic Sites - Section 4(f)*

The legislation commonly known as Section 4(f) states "... the Secretary may approve a transportation program or project...requiring the use of publicly owned land of a public park, recreation area, or wildlife and waterfowl refuge of national, State, or local significance, or land of an historic site of national, State, or local significance... only if (1) there is no prudent and feasible alternative to using that land; and (2) the program or project includes all possible planning to minimize harm to the park, recreation area, wildlife and waterfowl refuge, or historic site resulting from the use" (49 USCS 303). The broad nature of this legislation applies to cultural as well as natural resources, which are discussed below.

2.4 Natural and Agricultural Resources

- *Clean Air Act*

The Clean Air Act of 1970 (CAA) and subsequent Clean Air Act Amendments of 1990 regulate air pollution and sets air quality standards. The CAA Transportation Conformity Rule requires federal-aid highway transportation projects to comply with the State's air quality State Implementation Plan (SIP). The Transportation Conformity Process applies to non-attainment areas, meaning locations which do not meet the national air quality standards, and maintenance areas, meaning locations that used to be non-attainment areas but have now achieved compliance with the air quality standards. CAA sanctions restrict Federal funding and authorizations for transportation projects in States that do not have an adequate SIP. The US EPA has issued standards and regulations for air emissions from locomotives (42 USC 7401 – 7671).

- *Clean Water Act*

The Clean Water Act of 1972 (CWA) addresses water quality standards and pollution discharge. The Environmental Protection Agency (EPA) or State issues Section 402 permits for stormwater discharges associated with construction sites greater than 5 acres. DOT has codified regulations for compliance with CWA (23 CFR B). The Rivers and Harbors Act of 1899 requires projects to first receive permits to perform construction affecting navigable waters of the United States, including dredging, filling and bridges. The Safe Drinking Water Act (SDWA) requires proposed projects to comply with regulations concerning drinking water standards, wellhead protection areas, and sole source aquifers. Projects impacting Illinois' Lake Michigan coastal zone are regulated by the Coastal Zone Management Act of 1972 and amendments, including the discharge of non-point source pollution.

- *Protection of Wetlands*

Executive Order 11990 extended NEPA "to avoid...destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative" (42 FR 23661). New construction is defined as "draining, dredging, channelizing, filling, diking, impounding, and related activities..." (42 FR 23661). Section 404 of CWA concerns dredging and filling of waters of the United States, including wetlands. Section 404 permits are issued by the U.S. Army Corps of Engineers. In cases where a project will create adverse impacts to wetlands, compensation can be provided through performing mitigation, purchasing credits from a wetland mitigation bank (60 FR 58605), or in-lieu-fee payments to a wetland mitigation fund (65 FR 66914).

The Illinois Interagency Wetlands Policy Act of 1989 requires the Illinois Department of Transportation (IDOT) and other state agencies to create an Agency Action Plan and authorizes them to create a wetland compensation account. For State and State-funded construction projects affecting a wetland, the project's sponsor agency must conduct an impact evaluation "to avoid and minimize adverse wetland impacts as the preferred course... [and] document that no other feasible alternative exists before adverse impacts are considered" (20 ILCS 830).

- *Wilderness Act*

The Wilderness Act of 1964 concerns the management of federal wilderness areas. Illinois has a limited number of federal wilderness areas. Projects that affect federal wilderness land must apply for a modification or adjustment of a wilderness boundary. The Wild and Scenic Rivers Act of 1968 created the Nationwide Rivers Inventory (NRI) for national wild, scenic or recreational river areas; if a proposed project could adversely impact these rivers, the sponsoring agency must consult with the National Park Service. Similarly, the National Trails System Act of

1968 established an inventory of national scenic and historic trails; approval to impact this land is given by the Secretary of Interior or Agriculture. The Illinois Natural Areas Preservation Act of 1981 protects Illinois nature preserves and registered natural areas from eminent domain, except by approval from the Illinois Nature Preserves Commission and the Governor.

- *Land and Water Conservation Fund Act*

The Land and Water Conservation Fund Act of 1965 provides funds for the development of State recreation areas. Under the Act, "once [a recreation area] has been funded with L&WCF assistance, it is continually maintained in public recreation use unless NPS approves substitution property of reasonably equivalent usefulness and location and of at least equal fair market value" (36 CFR 59). Therefore, if a proposed rail project will impact one of these areas, the agency must obtain approval from NPS.

- *Endangered Species Act*

The Endangered Species Act of 1973 protects fish, wildlife and plant species facing extinction. If a proposed project could threaten one of these species or its critical habit, the agency must consult with the Secretary of the Interior. The Illinois State Endangered Species Act of 1972 requires state and local agencies to consult the Illinois Department of Natural Resources when determining whether a proposed project could impact threatened or endangered species or habitat. The Fish and Wildlife Coordination Act of 1934 requires agencies to consult with the U.S. Fish and Wildlife Service (FWS) and appropriate State agency to evaluate the impact on fish and wildlife resources if the project will affect a body of water. The Migratory Bird Treaty Act of 1918 declares it unlawful to kill, capture, possess, etc., any migratory bird, including destruction of nests and eggs. If a project will impact nesting areas or otherwise potentially kill birds, the FWS must to review and comment on the proposed project. Executive Order 13112, "Invasive Species," requires agencies to not conduct or assist any actions that could introduce or spread invasive species.

- *Farmland Protection Policy Act*

The Farmland Protection Policy Act of 1981 requires Federal agencies "to ensure that their programs, to the extent practicable, are compatible with State and units of local government and private programs and policies to protect farmland" (7 CFR 658). If a project affects farmland, the Natural Resources Conservation Service (NRCS) will assess the value of the land and the project sponsor agency will use that valuation to determine whether to proceed with farmland conversion. The Illinois Farmland Preservation Act of 1982 requires the Director of Agriculture to evaluate the impact of State-funded projects on prime farmland and determine whether the project is in compliance with agency policy.

2.5 Natural Hazards

- *Flood Disaster Protection Act*

The Flood Disaster Protection Act "requires any federally assisted acquisition or construction project to avoid, or the design to be consistent with, flood-hazard areas identified by the Federal Emergency Management Agency" (69 FR 25451). If a project will be located within a floodplain, DOT must perform a hazard analysis. Executive Order 11988, "Floodplain Management," extended NEPA to include floodplains. Executive Order 11988 directed agencies "to avoid to the extent possible the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative" (42 FR 26951).

- *National Earthquake Hazards Reduction Program*

Earthquake hazards are addressed by Executive Order 12699 "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction" and the National Earthquake Hazards Reduction Program (42 USCS 7704). DOT regulations require seismic safety design, construction and programs for regulated buildings.

2.6 Hazardous Materials and Waste Disposal

- *Resource Conservation and Recovery Act*

The Resource Conservation and Recovery Act of 1976 (RCRA) provides for the management of hazardous waste and non-hazardous solid waste, including a prohibition of open dumping. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act of 1986 concern the cleanup of hazardous substances. If a project encounters hazardous substances during construction, the project must be halted to address the material. If a rail project generates solid waste, including remediation of land or water containing waste, the agency must handle and dispose of it in accordance with RCRA, CERCLA and other applicable federal, state and local regulations.

2.7 Health and Safety

- *Occupational Health and Safety Act*

The Occupational Health and Safety Act of 1970 (OSHA) concerns workplace safety. The Federal Railroad Safety Authorization Act of 1994 (FRSA) authorizes the Secretary of Transportation to create additional railroad safety regulations. DOT has codified regulations for hazardous materials, noise, grade crossing and other safety issues (49 CFR B).

- *Noise Control Act*

The Noise Control Act of 1972 and the Quiet Communities Act of 1978 established a national policy to prevent harmful noise and authorized noise emission standards for various products, including interstate rail carriers (40 CFR 201). The USEPA is tasked with coordinating all federal noise control actions (42 USC 7641), although after 1981, primary responsibility for noise control was transferred to State and local governments. The USEPA continues to perform noise pollution research and evaluate existing federal noise regulations (USEPA, *Noise Pollution)*.

The FRA issued additional noise regulations for noise emissions (49 CFR 210), including the use of train horns and whistle bans for quiet communities (49 CFR 229.129; 71 FR 47614), and guidance for railroad noise measurement and analysis (FRA, 2009). State of Illinois regulations provide noise emission standards based on land use classification (35 IAC H).

2.8 Summary of Legislation

As demonstrated above, rail infrastructure is regulated in a complex and intertwined system. The interdisciplinary and dynamic nature of the regulatory framework for rail systems presents great challenges in practice and necessitates a common platform for implementation. Therefore, a system view of sustainable rail management is needed that can address the highest priorities across all environmental media (e.g. air, water, land, and noise), integrate environmental, social, and economic goals, and foster effective coordination among multiple agencies and departments.

SECTION 3: SUSTAINABILITY METRICS DEVELOPMENT

3.1 Metrics Overview

The sustainability rail metrics developed in this study aimed to provide a systems-based view of rail transport in a comprehensive document. Metrics are designed to quantitatively address the efficiency, safety, public health, ecological stress, emissions, and socioeconomic impacts of rail on local communities. Metrics are classified as spatial or non-spatial, and either Tier 1 or Tier 2. Spatial metrics can be measured in the GIS database for a specific location. Non-spatial metrics are not represented on the GIS maps, but are designed for a system-based evaluation. Tier 1 metrics generally refer to minimum regulatory requirements that are closely approximate to NEPA requirements, or other common rail management goals. Tier 2 criteria refer to best practices for sustainable rail management. The tiered approach allows the user to choose sustainability metrics that correspond to desired level of performance, and subsequently, helps the user determine the scope and priority of rail system evaluation and planning in the area of interest.

Numerous studies and guidelines have been published about the development of indicators and metrics for sustainable transportation. Selection of appropriate indicators is a difficult and context-specific process. Our sustainability performance metrics for Illinois rail infrastructure were determined based on the availability, quality and measurability of data; relevance and ease of understanding; and alignment with existing transportation sustainability initiatives, such as the *Illinois Livable and Sustainable Transportation Rating System and Guide* (I-LAST). They are also aligned with the goals of the U.S. DOT *2012-16 Strategic Plan*: Safety, State of Good Repair, Economic Competitiveness, Livable Communities, and Environmental Sustainability.

Recommendations from previous studies on metric design were also considered. For example, indicators must be able to produce valid, reproducible and understandable results; be relevant to users' needs and compatible with users' existing tools; and have a transparent methodology (Svensson, 2006). Indicators must meet standards of data quality, availability, measurability and ethics (Haghshena & Vaziri, 2012). Indicators which are intended to influence policy should also be comprehensive, actionable, cost effective, suitable as performance targets, and able to differentiate between net impacts and shifted impacts (Dobranskyte-Niskota et al, 2007).

The metrics that are presented in this paper also incorporated suggestions from the attendees that we invited for a focus-group discussion on the initial results. Based on stakeholder feedback (see **Section 7**), we decided not to weigh or integrate multiple categories of the metrics at this stage. And separate metrics have been developed for passenger rail and freight rail, as presented in the sub-sections below.

3.2 Passenger Rail Metrics

Passenger Rail Tier 1 metrics address environmental regulations and guidelines that are closely related to rail passenger safety and accessibility, as well as emissions, environmentally sensitive areas, social justice, and community development. Transit Rail Tier 2 metrics cover additional goals, such as brownfield redevelopment, urban heat island effects, and life cycle waste management. For each tier, spatial and non-spatial metrics were developed separately. In other words, there are four tables that summarize passenger rail metrics: Tier 1 Spatial, Tier 1 Non-Spatial, Tier 2 Spatial, and Tier 2 Non-Spatial (**Tables 1-4**). Surrounding legislation and/or guidance is also provided along with each metric in the table to facilitate future reference and update.

3.3 Freight Rail Metrics

Compared to passenger rail, freight rail involves several unique characters, and in some ways, more complex challenges, such as higher safety risks associated transporting hazardous goods, stronger interest in economic efficiency and competitiveness, and more interactions among both private and public sectors. These factors were incorporated in the freight rail metrics that are summarized in **Tables 5-8**.

3.4 Metrics Summary

Understandably, passenger rail and freight rail metrics share several common categories, such as safety, emissions, ecological impacts, and livable communities, as referred in Tier 1 metrics. Meanwhile, they do have unique priorities. For example, freight rail metrics focus more on safety and economic competitiveness, but less on accessibility (which is a major component for transit and commuter passenger rail). Consequently, when both passenger and freight rail infrastructure are present, simply combining two sets of metrics for system planning may not be enough. Further assessment that involves various stakeholder groups and incorporations of location- and project-specific characteristics may be needed.

All metrics that were discussed in this section were designed to be quantitative with high feasibility for implementation, strong legislative support, and potential data availability. The spatial metrics can be particularly useful for community-specific assessment. However, limited statistics have been collected, recorded, or published. In the following sections, we will discuss the literature and ensuing datasets that are publicly accessible, and when possible, demonstrate the feasibility of adopting the metrics at the community level.

Table 1. Passenger Rail: Tier 1 Spatial Metrics

SPATIAL INDICATORS			
DOT Goal	**Strategy**	**Metric**	**Legislation or Guidance**
Safety	Improve rail safety performance	Passenger fatality and injury rate	MAP-21; OSHA; FRSA; 49 CFR B; DOT *Strategic Plan 2012 - 2016*
	Avoid natural hazard areas	Acres in high flood hazard area	Flood Disaster Protection Act
		Acres in high seismic hazard area	49 CFR 41 Seismic Safety
		Acres in historical tornado hazard area	Disaster Mitigation Act (PL 106-390)
Environmental Sustainability	Reduce air emissions	Pounds of greenhouse gases emitted per capita-mi	MAP-21
	Protect high-quality wetlands and water resources	Acres on or near wetlands or water resources	Clean Water Act; Fish and Wildlife Coordination Act; Illinois Interagency Wetlands Policy Act
	Protect high-quality habitat for threatened and endangered species, and species of concern	Acres on or near critical habitat	Endangered Species Act; Illinois Endangered Species Act
	Protect high-quality natural & agricultural landscapes	Acres on or near natural and agricultural lands	Farmland Protection Policy Act; Illinois Farmland Preservation Act; Illinois Natural Areas Preservation Act
Livable Communities	Improve rail accessibility	Population density within a half-mile of rail transit station	USEPA *Guide to Sustainable Transportation Performance Measures* (2011)
		Employment density within a half-mile of rail transit station	USEPA *Guide to Sustainable Transportation Performance Measures* (2011)
	Locate stations and service frequency equitably throughout service area	Percentage of minority individuals within service area of station	Title VI; 49 CFR 21; FTA C 4702.1B
		Percentage of low-income households within service area of station	Title VI; 49 CFR 21; FTA C 4702.1B
	Avoid disproportionate adverse impacts to minority and low-income populations	Percentage of service reductions in low-income or minority communities	Title VI; 49 CFR 21; FTA C 4702.1B
		Acres within or near low-income or minority community area	Uniform Relocation Assistance and Real Property Acquisition Act; EO 12898; 49 CFR 24
	Protect cultural and recreational resources	Acres on or partitioning national trails or other greenways	National Trails System Act; Land and Water Conservation Fund Act
		Acres on or near parks and recreational land	49 USC 303 Sec. 4(f); Land and Water Conservation Fund Act
		Acres on or near historical or cultural areas	National Historic Preservation Act; 49 USC 303 Sec. 4(f); Archeological and Historic Preservation Act; American Indian Religious Freedom Act; Illinois Historic Preservation Act
	Protect community cohesion	Acres partitioning residential or commercial districts	NEPA; Passenger Rail Investment and Improvement Act; Illinois Highway Code

Table 2. Passenger Rail: Tier 1 Non-Spatial Metrics

NON-SPATIAL INDICATORS			
DOT Goal	**Strategy**	**Metric**	**Legislation or Guidance**
State of Good Repair	Maintain rail assets in a state of good repair	Percentage of rail assets evaluated as adequate condition or better	DOT *Strategic Plan 2012 - 2016*
	Perform sustainable economic investment in rail	Capital funds expended per vehicle revenue mile	RTA *Subregional Peer Report* (2011)
		Operating cost per passenger mile	RTA *Subregional Peer Report* (2011)
Livable Communities	Improve rail access for limited-mobility passengers	Percentage of passenger rail stations compliant with ADA	American Disabilities Act; 49 CFR 37
	Reduce road traffic congestion	Average daily number of congested hours of weekday travel	Haghshenas, et al. *Urban sustainable transportation indicators for global comparison.* Ecological Indicators (2012)
	Provide high-quality service for all passengers	Percentage of "very satisfied" survey responses	FRA *Metrics and Standards for Intercity Passenger Rail Service* (2009)
	Provide all stakeholders with opportunity for meaningful input on projects and operations	Number of public meeting attendees and comments	NEPA; EO 13045; EO 13175
Economic Competitiveness	Increase rail mode share	Mode share of trips	USEPA *Guide to Sustainable Transportation Performance Measures* (2011)
		Transit rail system passenger miles per capita	DOT *Strategic Plan 2012 - 2016*
	Maximize economic returns on rail investment	Operating expense per vehicle revenue-mi	Dobranskyte-Niskota, et al. *Indicators to assess sustainability of transport activities.* European Commission (2007)
Environmental Sustainability	Protect wetlands and habitat	Survival rate of nearby wetland plants and habitat	EO 11990; Robin Environmental Consultants *California high speed rail ecosystem management plan* (2012)
	Prevent growth of invasive species	Percent cover of invasive species	EO 13112; Robin Environmental Consultants *California high speed rail ecosystem management plan* (2012)
	Protect rare, threatened or endangered plants and animals	Survival rate of protected species	Endangered Species Act; Robin Environmental Consultants *California high speed rail ecosystem management plan* (2012)
	Avoid adverse noise impacts	Frequency of noise exceeding standard	OSHA; Noise Control Act; 49 CFR 210; FTA *Transit Noise and Vibration Impact Assessment* (2006)
	Avoid adverse vibration impacts	Frequency of vibration exceeding standard	FTA *Transit Noise and Vibration Impact Assessment* (2006)
	Reduce energy usage	Energy intensity of operations	MAP-21; International Union of Railways *Railway specific environmental performance indicators* (2008)
	Increase the share of renewable energy	Percent renewable energy used for operations	International Union of Railways *Railway specific environmental performance indicators* (2008)

Table 3. Passenger Rail: Tier 2 Spatial Metrics

SPATIAL INDICATORS			
DOT Goal	**Strategy**	**Metric**	**Legislation or Guidance**
Livable Communities	Provide rail facilities and service in public transportation-dependent communities	Percentage of households without cars	UIC Voorhees Center *Transit Equity Matters* (2009)
		Percentage of workers commuting >60 min	UIC Voorhees Center *Transit Equity Matters* (2009)
		Percentage of disabled individuals	UIC Voorhees Center *Transit Equity Matters* (2009)
		Percentage of elderly individuals	UIC Voorhees Center *Transit Equity Matters* (2009)
	Promote urban infill and minimize greenfield development	Acres built on impervious land cover	USEPA *Guide to Sustainable Transportation Performance Measures* (2011)
Environmental Sustainability	Protect high-quality habitat for threatened and endangered species and species of concern	Acres of habitat fragmented per capita-mi	Dobranskyte-Niskota, et al. *Indicators to assess sustainability of transport activities* (2007)

Table 4. Passenger Rail: Tier 2 Non-Spatial Metrics

NON-SPATIAL INDICATORS			
DOT Goal	**Strategy**	**Metric**	**Legislation or Guidance**
Safety	Accommodate pedestrians and bicycles	Percentage of grade crossings assessed for pedestrian and bicycle safety	MAP-21; DOT *Strategic Plan 2012 - 2016*
Livable Communities	Improve transportation affordability	Percentage of household income spent on transportation	USEPA *Guide to Sustainable Transportation Performance Measures* (2011)
	Increase employment	Number of jobs created per capita-mi	Carpenter, T. *The environmental impact of railways* (1994)
	Protect community property values	Percent change in property values along rail corridor	Carpenter, T. *The environmental impact of railways* (1994)
Environmental Sustainability	Determine most sustainable transportation mode	Mode-shift analysis index	Shiau & Peng *Mode-based transport sustainability: A comparative study of Taipei and Kaohsiung cities* (2012)
	Reduce urban heat island effect	Percentage of infrastructure with high RFI rating	LEED
	Protect trees and desirable vegetation	Survival rate of protected trees and plants along rail corridor	Illinois DOT *D&E 18: Preservation & Replacement of Trees*
	Protect wildlife migration corridors	Acres of wildlife corridors fragmented per capita-mi	Robin Environmental Consultants *California high speed rail ecosystem management plan* (2012)
	Achieve zero-waste operations	Percentage of out-of-service equipment, debris and waste disposed to a landfill	Dobranskyte-Niskota, et al. *Indicators to assess sustainability of transport activities* (2007)
	Reduce lifecycle waste	Tons of waste generated per capita-mi	

Table 5. Freight Rail: Tier 1 Spatial Metrics

SPATIAL INDICATORS			
DOT Goal	**Strategy**	**Metric**	**Legislation or Guidance**
Safety	Improve rail safety performance	Accident and injury rate	MAP-21; OSHA; FRSA; 49 CFR B; DOT *Strategic Plan 2012 - 2016*
		Hazardous materials incidents rate	RCRA; CERCLA
	Avoid siting rail infrastructure in hazardous areas	Acres in high flood hazard area	Flood Disaster Protection Act
		Acres in high seismic hazard area	49 CFR 41 Seismic Safety
		Acres near historical tornado hazard area	Disaster Mitigation Act (PL 106-390)
Environmental Sustainability	Reduce air emissions produced by rail	Pounds of air pollutants emitted per capita-mile or ton-mile	Clean Air Act; 40 CFR 1033
		Pounds of greenhouse gases emitted per capita-mile or ton-mile	MAP-21
	Protect high-quality wetlands and water resources	Acres on or near wetlands or water resources	Clean Water Act; Fish and Wildlife Coordination Act; Illinois Interagency Wetlands Policy Act
	Protect high-quality habitat for threatened and endangered species, and species of concern	Acres on or near critical habitat	Endangered Species Act; Illinois Endangered Species Act
	Protect high-quality natural & agricultural landscapes	Acres on or near natural and agricultural lands	Farmland Protection Policy Act; Illinois Farmland Preservation Act; Illinois Natural Areas Preservation Act
Livable Communities	Avoid disproportionate adverse impacts to minority and low-income populations	Acres in or near to low-income or minority community area	Uniform Relocation Assistance and Real Property Acquisition Act; EO 12898; 49 CFR 24
	Protect cultural and recreational resources	Acres on or partitioning national trails or other greenways	National Trails System Act; Land and Water Conservation Fund Act
		Acres on or near parks and recreational land	49 USC 303 Sec. 4(f); Land and Water Conservation Fund Act
		Acres on or near historical or cultural areas	National Historic Preservation Act; 49 USC 303 Sec. 4(f); Archeological and Historic Preservation Act; American Indian Religious Freedom Act; Illinois Historic Preservation Act
	Protect community cohesion	Acres partitioning residential or commercial districts	NEPA; Passenger Rail Investment and Improvement Act; Illinois Highway Code

Table 6. Freight Rail: Tier 1 Non-Spatial Metrics

NON-SPATIAL INDICATORS			
DOT Goal	**Strategy**	**Metric**	**Legislation or Guidance**
Livable Communities	Reduce road traffic congestion	Average daily number of congested hours of weekday travel	Haghshenas, et al. *Urban sustainable transportation indicators for global comparison.* Ecological Indicators (2012)
	Provide all stakeholders with opportunity for meaningful input on projects and operations	Number of public meeting attendees and comments	NEPA; EO 13045; EO 13175
Economic Competitiveness	Increase rail mode share	Freight rail mode share per ton-mile	DOT *Strategic Plan 2012 - 2016*
	Maximize economic returns on rail investment	Freight rail load factor	Dobranskyte-Niskota, et al. *Indicators to assess sustainability of transport activities.* European Commission (2007)
		Freight trail empty trip factor (mi empty/mi loaded)	
Environmental Sustainability	Protect wetlands and habitat	Survival rate of nearby wetland plants and habitat	EO 11990; Robin Environmental Consultants *California high speed rail ecosystem management plan* (2012)
	Prevent growth of invasive species	Percent cover of invasive species in or near rail infrastructure	EO 13112; Robin Environmental Consultants *California high speed rail ecosystem management plan* (2012)
	Protect rare, threatened or endangered plants and animals	Survival rate of protected species	Endangered Species Act; Robin Environmental Consultants *California high speed rail ecosystem management plan* (2012)
	Avoid adverse noise impacts	Frequency of rail noise exceeding applicable standard	OSHA; Noise Control Act; 49 CFR 210; FTA *Transit Noise and Vibration Impact Assessment* (2006)
	Avoid adverse vibration impacts	Frequency of rail vibration exceeding applicable standard	FTA *Transit Noise and Vibration Impact Assessment* (2006)
	Reduce energy usage	Energy intensity of rail operations	MAP-21; International Union of Railways *Railway specific environmental performance indicators* (2008)
	Increase the share of renewable energy	Percent renewable energy used for rail operations	International Union of Railways *Railway specific environmental performance indicators* (2008)

Table 7. Freight Rail: Tier 2 Spatial Metrics

SPATIAL INDICATORS			
DOT Goal	**Strategy**	**Metric**	**Legislation or Guidance**
Safety	Minimize community risk from hazardous materials transportation	Number of potential evacuees per ton-mi	Kawprasert & Barkan *Communication and interpretation of results of route risk analyses of hazardous materials transportation by railroad* (2009).
Economic Competitiveness	Appropriately locate cargo-oriented development rail projects	COD Optimizer Tool index	Center for Neighborhood Technology *New Growth in Older Communities*
Environmental Sustainability	Protect groundwater resources from hazardous materials spills	Acres over shallow aquifers per ton-mi	Anand & Barkan *Exposure of soil and groundwater to spills of hazardous materials transported by rail: A geographic information system analysis* (2006)
	Protect high-quality habitat for threatened and endangered species and species of concern	Acres of habitat fragmented per ton-mi	Dobranskyte-Niskota, et al. *Indicators to assess sustainability of transport activities* (2007)

Table 8. Freight Rail: Tier 2 Non-Spatial Metrics

NON-SPATIAL INDICATORS			
DOT Goal	**Strategy**	**Metric**	**Legislation or Guidance**
Safety	Accommodate pedestrians and bicycles	Percentage of grade crossings assessed for pedestrian and bicycle safety	MAP-21; DOT *Strategic Plan 2012 - 2016*
Livable Communities	Increase employment	Number of jobs created per ton-mi	Carpenter, T. *The environmental impact of railways* (1994)
	Protect community property values	Percent change in property values along rail corridor	Carpenter, T. *The environmental impact of railways* (1994)
Environmental Sustainability	Reduce urban heat island effect	Percentage of infrastructure that has a high RFI rating	LEED
	Protect trees and desirable vegetation	Survival rate of nearby protected trees and plants	Illinois DOT *D&E 18: Preservation & Replacement of Trees*
	Protect wildlife migration corridors	Acres of wildlife corridors fragmented per ton-mi	Robin Environmental Consultants *California high speed rail ecosystem management plan* (2012)
	Achieve zero-waste operations	Percentage of out-of-service equipment, debris and waste disposed to a landfill	Dobranskyte-Niskota, et al. *Indicators to assess sustainability of transport activities* (2007)
	Reduce lifecycle waste	Tons of waste generated per ton-mi	

SECTION 4: ENVIRONMENTAL IMPACT REVIEW AND MODELING

4.1 Overview

NEPA Environmental Assessments (EA) and Environmental Impact Statements (EIS) involve a mix of qualitative and quantitative methods to evaluate the construction and operation impacts specified by regulatory requirements. To evaluate the impacts of rail transportation, a number of models have been developed worldwide, such as EcoTransIT (ifeu, 2010), EcoPassenger (ifeu, 2011), ExternalCost (UIC, 2012), and the Rapid Fire and Urban Footprint models used by the State of California for scenario analysis (Calthorpe Associates, 2000 & 2001). These models, sometimes developed in collaboration with private rail companies, provide quantitative assessment of a variety of impacts, such as carbon emissions, energy intensity, pollution, climate change, accidents and public health, economic activity, water and land usage, infrastructure cost, and travel mode share. However, the existing models only provide high-level measurements of the impacts of regional transportation policy and land use. There does not appear to be one model tailored to the needs of rail infrastructure planning in the U.S. which provides community-level impact assessment.

This project has focused on four specific types of environmental impacts: (1) air emissions, (2) accident risk and public safety, (3) noise, and (4) life cycle impacts. Due to data availability, quantitative analysis was conducted for *emission*s (**Section 4.2**) and *accident risks* (Section 5.3) only. Qualitative discussions of noise impacts (**Section 4.3**) and life cycle impacts (Section 5.4) were provided for reference in future studies.

4.2 Air Emissions and Energy Use

4.2.1 General Literature Review

The transportation sector is one of the largest consumers of energy in the United States (McGraw, et al, 2010). Nationally, locomotives consume billion gallons of diesel annually (U.S. EPA, 2009), which results in polluting air emissions. A number of methods have been developed to calculate the air emissions of rail transport. The U.S. Environmental Protection Agency (USEPA) has published guidance for conducting a greenhouse gas inventory, although it has been criticized for methodological flaws and insufficient data availability (Rose, et al., 2005). Several studies have used an LCA approach to calculate the emissions and energy intensity of transportation (Burgess, 2011; Ueda, 2003; Schwab Castella et al., 2009; Wang & Sanders, 2012; Horvath, 2006).

Regional emissions inventories have been completed for a number of rail systems, but there is a lack of community-level emissions studies that indicate where emissions are heaviest in the system. This fine-grained information is necessary to support community land use and transportation planning. Location-specific emissions inventories can be calculated from local fuel consumption and emissions factor data. Local fuel consumption is dependent on geographic- and rail- specific factors such as trip distance, terrain, speed, vehicle weight, and fuel efficiency. For example, mountainous terrain will lead to lower fuel efficiency than flat terrain, and line-haul rail operations are more fuel efficient than switching operations (U.S. EPA, 2009). The age of the vehicle also affects emissions rates; technological improvements in diesel engines have dramatically reduced air emissions from locomotives since 2001 (Aoyagi et al., 2011; Surawski et al., 2013). Some of this variation is captured by the U.S. EPA's published emissions factors for diesel fuel (2013, Annex 2, Table A-45; 2009), which provide different factors for line-haul and switching rail operations, and sets locomotive emissions standards relative to the year of vehicle manufacture.

Emissions inventory methods may be classified as either consumption-based or production-based (Erickson et al. 2012). Consumption-based methods estimate rail air emissions from fuel sales, but there is some concern about the use of fuel consumption data from the U.S. EIA and U.S. EPA. The data rely on estimated disaggregation by sector, mode and geographic area (Davies et al. 2007). The top-down approach, used by the U.S. EIA, consistently yields underestimates, as compared with bottom-up approaches, which are considered more accurate (Davies et al. 2007). Nonetheless, air emissions from rail occur at the point of consumption (IPCC, 2006); other emissions-producing parts of the system would be captured in a national inventory (Davies et al. 2007). Therefore, NURail-GIS focuses on identifying localized air emissions from rail vehicles.

4.2.2 NURail-GIS Emissions Model

NURail-GIS developed a model to calculate local air emissions generated by rail transportation. The accuracy of transportation emission models is sensitive to a number of elements, including fuel efficiency and emission factors (Horvath, 2006), and passenger ridership and freight load factors (TRB, 2013). Therefore, the NURail-GIS emissions model was developed using available data for fuel efficiency, fuel emissions, rail traffic, and rail operations.

Fuel Efficiency and Emissions

Fuel efficiency refers to the amount of energy can be extracted from a unit of fuel, as compared to the amount of chemical energy contained in a unit of fuel. The Association of American Railroads (2012a) reports the 2011 nationwide average freight locomotive fuel efficiency was 469 ton-miles per gallon. However, a vehicle's fuel efficiency varies according to internal and external factors. Internal factors include the vehicle age, type and operations, as measured in bhp-hour/gallon. External factors include track gradient and freight tonnage, as measured in ton-miles/gallon.

Fuel emissions factors express the quantity of air pollutants generated by a vehicle's use of fuel while accounting for technological factors other than fuel efficiency. The NURail-GIS emissions model relies on U.S. EPA's (2013) published fuel emissions factors for line-haul and switching locomotives. U.S. EPA emissions factors were also used to develop estimates of the fuel efficiency of line-haul and switching locomotive operations. Line-haul rail operations are estimated to be approximately 28.6% fuel efficient. Switching rail operations are estimated to be approximately 20.9% fuel efficient.

U.S. EPA (2009) has set locomotive emissions standards according to the year of vehicle manufacture. Using the AAR (2012b) information on the age structure of the national rail fleet, the proportion of the rail fleet that falls within each of the U.S. EPA's emissions standard tiers can be estimated (**Table 9**). The national fleet age structure was used as a proxy for the Illinois rail fleet.

Table 9. Freight Rail: Tier 2 Non-Spatial Metrics

Tier	Line-Haul		Switching	
	Manufacture Year	Proportion (%)	Manufacture Year	Proportion (%)
Tier 3	--	--	2011-2014	2
Tier 2	2005-2011	20	2005-2010	18
Tier 1	1993-2004	40	2002-2004	11
Tier 0	Before 1993	40	Before 2002	69

Source: AAR 2012b

The published U.S. EPA emission factors are reported as grams per bhp-hr for particulate matter (PM10), hydrocarbons (HC), nitrous oxides (NOX), and carbon monoxide (CO). For the purpose of this study, U.S. EPA emission factors were converted to grams per ton-mile, using national fuel efficiency data (AAR 2012a). Subsequently, national rail fleet age data were used to calculate augmented emissions factors based on the U.S. EPA's tiered emission standards (see **Table 10**).

Table 10. Augmented Diesel Emission Factors for Regulated Emissions (grams/ton-miles)

Operations Type	PM_{10}	HC	NO_X	CO
Line-Haul	0.00782	0.01164	0.2911	0.05689
Switching	0.006647	0.01644	0.317379	0.059223

Calculated by NURail-GIS Team.

Rail Traffic

Rail traffic was calculated by joining spatial railroad data (FRA National Transportation Atlas Database) with tabular traffic count data for grade crossings (FRA, 2012) within the NURail-GIS database. The rail traffic for a given grade crossing was extrapolated to estimate the rail traffic for intersecting tracks. Some grade crossings have no reported rail traffic data, and some track segments do not have grade crossings. Therefore, a method was developed to "smooth out" the grade crossing data. The rail network was defined for each county in the MPO region, and each county-level rail system was split into equal segments. Each segment was spatially joined with the nearest grade crossing to create approximately equal rail line segments. The resulting spatial database associates each rail line segment with one grade crossing.

Regional Emissions Inventory

A regional carbon emissions inventory was prepared for the Chicago metropolitan rail transportation system, defined as the boundary of the Chicago Metropolitan Agency for Planning (CMAP). The quantity of diesel fuel consumed by Illinois rail was estimated from fuel consumption data. The EIA reports the volume of fuel consumed by the Illinois transportation sector. To identify the amount of diesel fuel consumed by rail transportation, the national diesel fuel consumption statistics for each mode of transportation was applied. Finally, the U.S. EPA emission factors were applied to the diesel fuel consumption to estimate the total annual air emissions. **Table 11** outlines the methodology used to complete a carbon emissions inventory for rail transportation in the Chicago region. Approximately 157,631 tons of CO_2 equivalents were emitted by the Chicago region rail system in 2010.

Location-Specific Emissions Estimate

Location-specific emissions analysis requires identification of locomotive operations and vehicle age. Locomotive operations were identified using rail traffic data. Locomotive vehicle ages were estimated using national fleet data.

Table 11. Chicago Region Carbon Emissions from Rail Transportation

Step	Description	Value	Data Source
1	Diesel fuel consumed by Illinois transportation sector	210.2 trillion BTUs	U.S. Energy Information Administration: State Energy Data 2010: Consumption
2	National rail proportion of transportation sector diesel fuel consumption	8.3%	U.S. Energy Information Administration: Transportation Sector Energy Use by Fuel Type with a Mode
3	Diesel fuel consumed by Illinois rail transportation sector	17.4 trillion BTUs	Step 1*Step 2
4	Proportion of Illinois rail activity in the MPO region	40.7%	Estimate using rail traffic activity from U.S. DOT daily traffic data for grade crossings
5	Diesel fuel consumed by transportation sector in MPO region	7.1 trillion BTUs	Step 3*Step 4
6	Diesel emissions factor	0.02017 teragrams of CO_2 equivalents per trillion BTU	U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011
7	Total carbon emissions from Chicago region rail transportation	157,631 tons of CO_2 equivalents	Step 5*Step 6

Table 12 provides the methodology used to develop the location-specific emissions model. Train-miles for each segment of the rail network were calculated from local rail traffic data and used to derive ton-miles. The augmented diesel emissions factors (**Table 10**) were applied to ton-miles to incorporate the relative efficiencies of different locomotive operations and vehicle ages. The PM emission calculation procedures are provided as an example.

Hot Spot Analysis

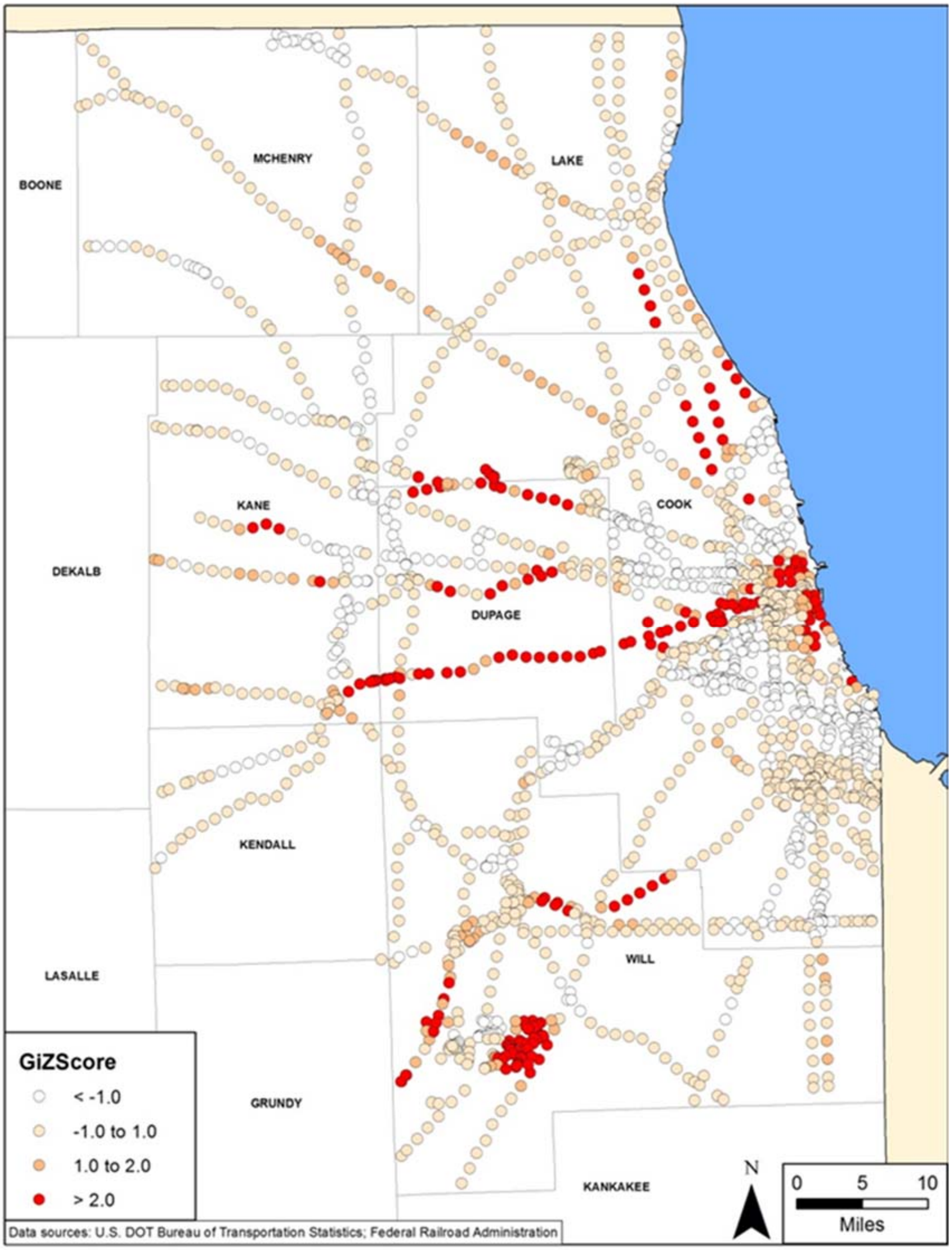
A weighted metric was further developed to identify "hot spots," i.e., priority areas for assessment, based on rail operations that have high impact on emissions. The hot spot map incorporated rail network locations, land use data, demographic data and rail tonnage and operations data. Air emissions were calculated for specific grade crossings using the methodology for location-specific emissions and the weighted metric. The weighted metric incorporates the number of trains, line haul operations, switching operations, and train speed. This study develops a scenario that weights the train speed by 20 percent, switching rail traffic by 45 percent, and line-haul rail traffic by percent. Finally, a Getis-Ord GI statistic was calculated to measure spatial clustering and visualize the "hot and cold spots" as Z-values. The shaded dots on **Figure 6** illustrate that hot spots are clustered along busy rail lines, intermodal stations and rail yards.

Table 12. Location-Specific Particulate Matter Emissions from Freight Rail

Step	Description	Data Source
1	Calculate train-miles within a one mile of the specified grade crossing.	Estimate using freight rail traffic activity from U.S. DOT daily traffic data for grade crossings
2	Calculate carloads per train. Divide number of freight cars in service by the number of locomotives in service.	AAR Class Railroad Statistics.
3	Calculate carload-miles.	Step 1*Step 2
4	Calculate tons per carload.	Divide total tons by the total number of carloads for originated and terminated freight in Illinois. AAR. Freight Railroads in Illinois: Rail Fast Facts for 2011.
5	Calculate ton-miles.	Step 3*Step 4
6	Multiply ton-miles by Augmented Diesel Emissions Factor for PM.	U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011. U.S. EPA Emissions Factors for Locomotives. AAR Railroad Facts: 2012 Edition.
7	Total PM emissions at the specified grade crossing.	Step 5*Step 6

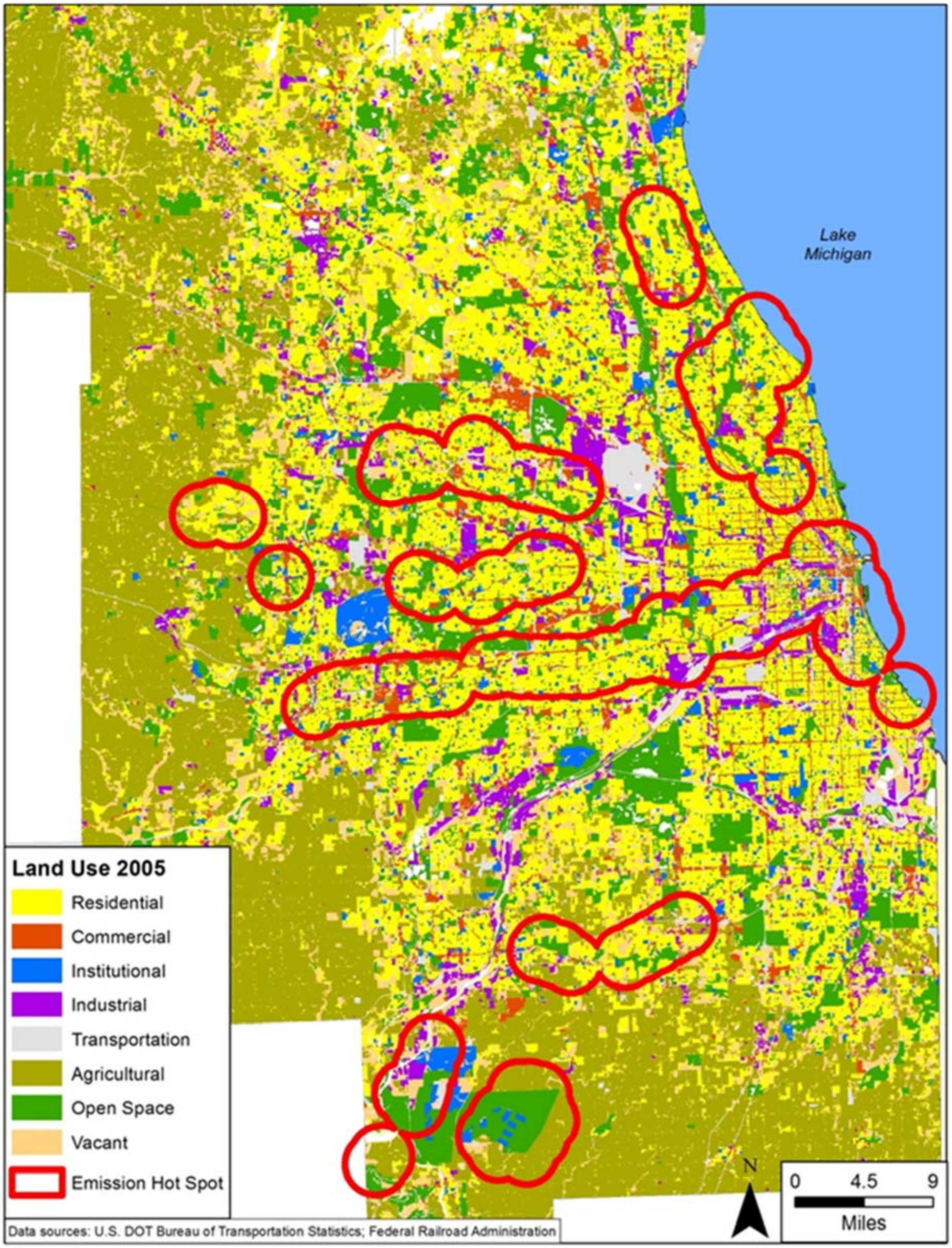
Figures 7 and 8 illustrate the initial results for modeling community exposure to rail emissions. **Figure 7** depicts the buffered emissions hot spots overlaid on a land use map for the Chicago region. **Figure 8** depicts the buffered emissions hot spots over a median household income map. Lighter shades of green indicate lower income. As shown, Chicago's west and south neighborhoods show significant burden of emissions on very low income populations, indicating a need for further study in these locations to evaluate environmental justice concerns.

Figure 6. Hot Spot Analysis of Rail Emissions in the Chicago Region



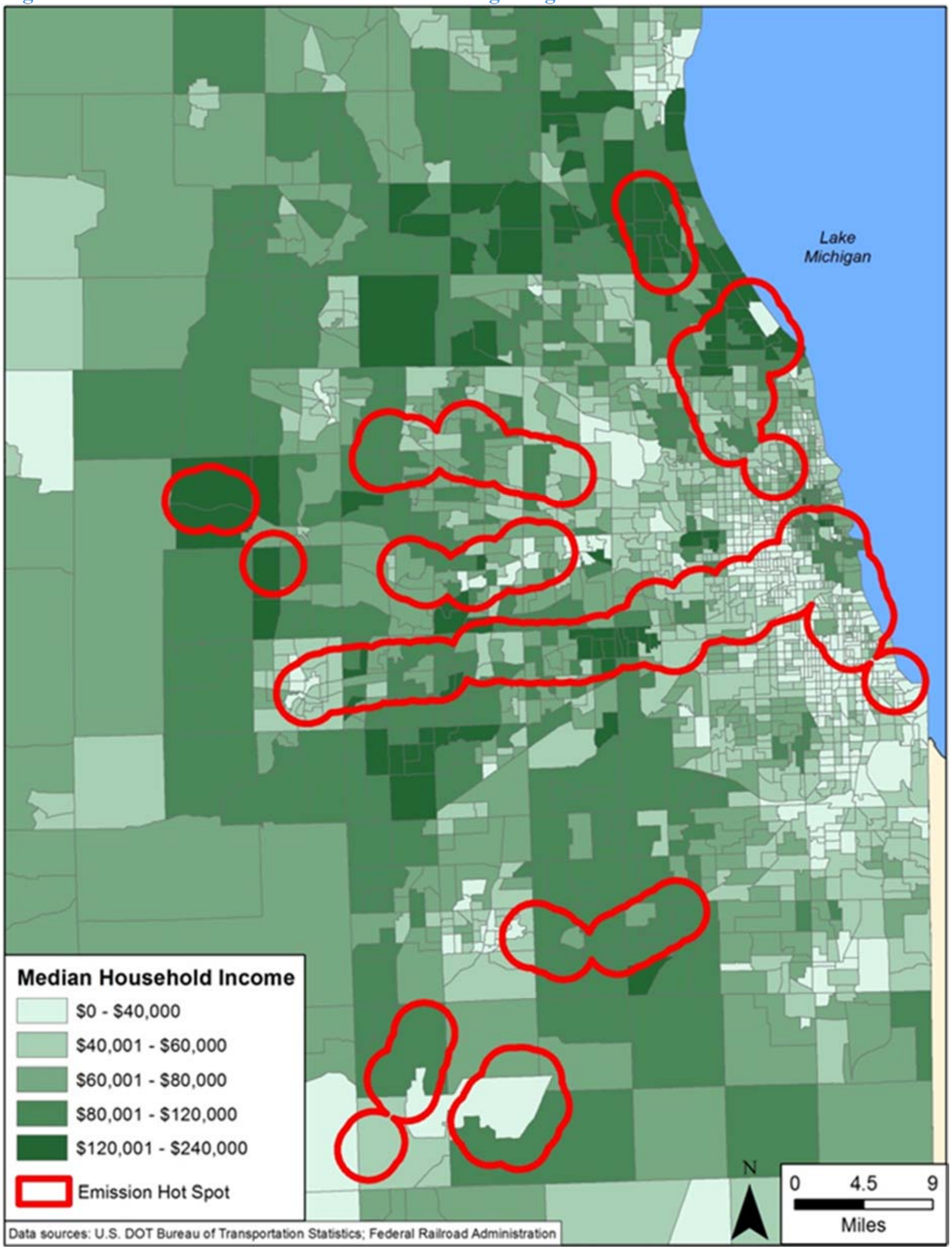
Map by NURail-GIS Team.

Figure 7. Rail Emissions and Land Use in the Chicago Region



Map by NURail-GIS Team.

Figure 8. Rail Emissions and Income in the Chicago Region



Map by NURail-GIS Team.

4.3 Accident Risk and Public Safety

As represented in NURail-GIS Tier I and Tier II metrics, rail derailment risk and public safety impacts are important components of rail sustainability. Numerically, the NURail-GIS project has referred to advanced risk models that have been developed by RailTEC at the University of Illinois-Urbana Champaign, part of the NURail consortium. The RailTEC model suggests that a high train derailment rate is associated with lower FRA track class, non-signaled track, and low traffic density (i.e., gross tonnage) (Liu, 2013; Liu, Saat and Barkan, 2010, 2011, and 2013). **Table 13** below presents their modeling results of estimated derailment rate.

Table 13. Estimated Class I Mainline Freight-Train Derailment Rate (per billion gross ton-miles)

		FRA Track Class				
Annual Traffic Density (MGT)	Method of Operation	Class 1	Class 2	Class 3	Class 4	Class 5
<20	Non-Signaled	1.29 *(1.086, 1.534)*	0.66 *(0.574, 0.768)*	0.34 *(0.295, 0.395)*	0.18 *(0.148, 0.209)*	
	Signaled	0.92 *(0.737, 1.151)*	0.47 *(0.395, 0.568)*	0.24 *(0.208, 0.286)*	0.13 *(0.106, 0.147)*	0.06 *(0.053, 0.078)*
≥20	Non-Signaled	0.61 *(0.495, 0.747)*	0.31 *(0.260, 0.376)*	0.16 *(0.134, 0.194)*	0.08 *(0.067,0.102)*	0.04 *(0.033, 0.055)*
	Signaled	0.43 *(0.361, 0.521)*	0.22 *(0.195, 0.255)*	0.11 *(0.104, 0.127)*	0.06 *(0.053, 0.066)*	0.03 *(0.026, 0.035)*

Source: Xiang Liu. Optimal Strategies to Improve Railroad Train Safety and Reduce Hazardous Materials Transportation Risk. Unpublished Doctoral Dissertation at the University of Illinois Urbana Champaign. December 2013.
Note: The numbers in the parenthesis represent 95% confidence interval. Data estimates are based on data 2005-2009.

Based on the modeling parameters in **Table 13** and discussions with the RailTEC team, NURail-GIS project extracted the five latest years of historical data (2009-2013) about rail track class, operation method (i.e., whether signaled) and traffic density (i.e., gross tonnage) from the FRA rail equipment accident/incident database. Java scripts were developed to facilitate data extraction and preparation. In addition, the NURail-GIS web tool displays the location of historical derailment accidents and the estimated derailment risk for existing rail infrastructure locations. Accidents without geographic coordinate information in the FRA database were not included in the web display.

4.4 Noise

Accurate rail noise modeling requires detailed data that accounts for specific project and site characteristics. Project-specific characteristics include distinct noise profiles of freight, commuter diesel, electric rapid transit and intercity high-speed rail. Freight and commuter diesel rail noise profiles are distinguished by the presence of engine noise and the importance of service frequency, which impacts the modeled day-night average sound level (Shiffer, 2014; U.S. Department of Housing and Urban Development, 2010). Shiffer (2014) found four distinct kinds of noise for electric rapid transit: thump, structural roar, rumble, and squeal. "Thump" was produced from flat spots on wheels, "roar" was caused by small pits in the surface of the rail, "rumble" was caused by the rail track structure, and "squeal" was caused by the motion of wheels against curved tracks. Thump, roar, and squeal can all be addressed by maintenance programs which are not readily captured in a high-level modeling program. Rumble is addressed by rail construction techniques or small noise walls. Noise impacts for high speed rail, however, are generally expected to be greater along the route than at the stations, because of noise mitigation at stations, the presence of population along the corridor, and operational factors (TRB, 2013).

Several European research studies have been conducted in response to the European Union's Environmental Noise Directive (END), which requires noise impact assessment for communities. These studies typically involved fieldwork combined with detailed GIS analysis to create noise profiles for specific rail corridors. Academic research found similar causal factors for noise production to those discussed above (Pronello, 2003; Beuving, Hemsworth & Jones, 2008; Dittrick and Zhang, 2006; King & Rice, 2009; Murphy & Rice, 2011; Brainerd, et al., 2004; Anderson and Webber, 2008). Causal factors were categorized as either train type or train operations. Train and rail system type factors influence rail track and vehicle noise. Operational noise factors impacting noise level include acceleration, speed, horn, and traction type. Many noise mapping models relied on project-specific data, field measurements, and commercial noise modeling software. The studies validated noise models by comparing results to commercial software packages and/or field measurements. However, large variations (over 10 dB) were observed when different methods or commercial software were used to evaluate the same source (King, Murphy & Rice, 2011; Murphy & King, 2010).

Although many studies focus on a quantifying the noise level, it is important to note that actual noise impact on a community is influenced by residents' noise perception and annoyance. Causal factors influencing noise annoyance include land use type, existing community noise level and type, tonal and impulsive characteristics of noise, distance between noise receptor and noise source, height of noise receptor, barriers between receptor and noise source, topography and ground characteristics, meteorological conditions and air absorption, and community-specific values. The FTA (2006) method for assessing the noise impact of a proposed transit project is based on the noise sensitivity of various types of land. The FTA's noise impact methodology requires assessment for noise-sensitive land uses, such as places that must be quiet to maintain essential functions (e.g., concert halls); places sensitive to nighttime noise (e.g., homes); and institutions sensitive to daytime noise (e.g., schools). FTA methodology accounts for the influence of existing community noise, the cumulative impact of the proposed additional transit noise, the land use category, and the perceived noise annoyance. The FTA methodology requires identification of noise-sensitive receptors within the 50 dBA noise contour of the project; the contour is developed using project-specific data and the provided default values for train speed and operations.

Policy factors also impact the accuracy and efficacy of a rail noise model. Noise mitigation is usually done in coordination with other higher priority capital investments, e.g., safety improvements and repairs (Shiffer, 2013), so newly upgraded rail lines may have lower noise impacts than older rail lines with similar physical characteristics. In addition, municipalities will likely select noise mitigation projects by choosing locations near sensitive receptors (including residential areas), rather than begin the selection process by identifying the highest noise level in the system.

Based on the suggestions of the literature review and stakeholder comments, the NURail-GIS Sustainability Metrics incorporates noise impacts within the Tier 1 metrics (see **Section 4**). The Metrics may be used to track the results of project-specific noise modeling conducted by transportation professionals. Although several attempts were made by NURail-GIS to obtain noise impact data from DOT, in order to develop a high level noise mapping tool, no data was available. Therefore, because accurate noise modeling is project- and site-specific, and noise impact assessment is a well-established part of the existing NEPA process, a noise model was not incorporated in this version of the NURail-GIS web tool.

4.5 Lifecycle Assessment

The lifecycle assessment (LCA) approach evaluates a broad range of impacts by evaluating the rail project from "cradle to grave." LCA quantifies the energy and other resources used to construct, operate, maintain, and dispose of the project (TRB, 2013). LCA may or may not incorporate the lifecycle of the energy consumed by the rail project (i.e., the resources needed to extract, process, and distribute energy). LCAs also evaluate the environmental, financial, and/or social impacts resulting from the project. Typical impact assessment categories include air emissions, waste, acid rain, ozone, climate change, ecotoxicity, eutrophication, fossil fuel usage, and public health impacts (Bare, Gloria & Norris, 2006). LCAs may consider local (e.g., air quality), regional or global (e.g., climate change) impacts.

There are four steps for performing LCA: definition of goal and scope, inventorying, impact analysis, and interpretation of results (Labutong et al., 2012). The goal defines the intended purpose and audience of the LCA (Labutong et al., 2012). The scope defines the temporal and spatial boundaries of the LCA, the impacts categories, and any limitations or assumptions (Labutong et al., 2012). If the scope of the LCA includes the potential future impacts of a project the LCA may develop alternate scenarios to address uncertain future conditions such as technological, economic or regulatory changes (Labutong et al., 2012). The spatial boundary of the LCA may include door-to-door impacts, which consider how passengers (or freight) access the transportation system, or the boundary can be limited to a line-haul assessment, which evaluates the trip but excludes transportation access and egress (TRB, 2013). The selected impact categories are defined by the user's priorities and applicable regulations, policies and modeling feasibility (USEPA, 2012).

Several studies have used LCA methodology to compare the relative impacts of competing travel modes, such as aircraft and high-speed rail (TRB, 2013). This can complicate the LCA scoping process, as there may be spatial incompatibility between the projects under comparison. For example, air travel is based on nodes (i.e., airports), while high speed rail is based on nodes and links (i.e., rail stations and corridors) (TRB, 2103). LCA assessments that compare rail corridors are also complicated by the site-specific engineering requirements of different landscapes (TRB, 2013). In addition, comparison LCAs must distinguish between an attributional assessment, which identifies impacts caused directly by a travel mode, and a consequential assessment, which identifies the regional impact of changing from travel mode to another (Chester & Horvath, 2012).

The second step, inventorying, requires the quantification of materials and energy consumed and produced by the project (Labutong et al., 2012). The third step, impact analysis, assigns each material or energy to an impact category, and quantitatively models the size of the impact (Labutong et al., 2012).

The final step interprets the quantitative results to identify the greatest impacts, and locate areas where the project can be redesigned to lessen impacts (Labutong et al., 2012). The interpretation step may include normalization, which compares the quantified impacts against a baseline inventory of impacts for the appropriate spatial and temporal scale. This determines the "relative contribution" of the modeled project to a geographic region (Bare, Gloria & Norris, 2006). Normalized results can be used to create a weighted index of impacts. Weighted indexes establish the relative importance of each type of impact, facilitating comparison between tradeoffs (e.g., water use versus air emissions). However, the weighting process is subjective and open to uncertainty (Bare, Gloria & Norris, 2006).

LCA studies have been published for specific rail vehicles and infrastructure projects (Ueda, 2003; Schwab Castella et al., 2009). Chester (2008) constructed a detailed inventory from a wide variety of public and private data sources to perform a LCA of several regional rail systems, including the Chicago region. The authors found that environmental impact was contingent on fuel consumption, emission controls, occupancy rates, electricity mixes, vehicle age, and other factors specific to the rail system. The authors also cautioned that calculations performed for one rail system should not be simply applied to another region, and that an "average train" cannot be calculated.

Chester and Horvath (2012) compared the relative impacts of aircraft, high-speed rail, and emerging automobiles, by developing an air emissions inventory for each travel mode. Chester and Horvath (2012) then used the Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) model to quantify the impact of emissions on public health and the environment. The impact categories included in the TRACI model are ozone depletion, global climate change, acidification (e.g., acid rain), eutrophication (i.e., excess nutrients in water bodies), smog formation, human health – particulates, human health – cancer, human health – non-cancer, and eco-toxicity (USEPA, 2012).

Whereas many LCA studies rely on detailed project-specific inventories, the Economic Input–Output–Life-Cycle Analysis (EIO-LCA) method uses a more high-level approach to quantify regional impacts. EIO-LCA does not require an inventory of material inputs and outputs for a system. Instead, estimated project costs for construction, infrastructure, vehicles, and power supply are entered into the EIO-LCA modeling software. The software uses the project's costs to estimate lifecycle energy and emissions for the project. However, the EIO-LCA model is limited in the number of indicators produced and, admittedly, does not fully account for the lifespan of the overall rail project (Wang & Sanders, 2012).

The NURail-GIS Sustainability Metrics incorporate lifecycle impacts within the Tier 2 metrics (see **Section 4**). The user may employ the metrics to assist with tracking the results of a project-specific LCA analysis. As discussed below, the user's priorities greatly impact the specific methodology developed for an LCA study. Therefore, the user may adopt the LCA methodology that best meets the goals of his or her individual project.

Potential next steps for NURail-GIS could include integrating existing LCA databases or providing a newly created user interface tailored to rail projects. It may also be helpful to expand NURail-GIS to allow the comparison of competing transportation modes, as required by the NEPA process. It should be noted, however, that rail industry professionals and consultants do not typically have a LCA mindset. Consultants may be concerned with the NEPA process or engineering design, which do not have mandated LCA requirements. Industry professionals may be focused on efficiency and safety concerns, or feel that procurement procedures or regulations prevent them from considering LCA issues (Svensson, 2006). Therefore, LCA functionality should be developed in consultation with regulatory agencies as well as industry procurement and environmental management staff.

4.6 Limitations and Next Steps

The following uncertainties are present in the available data for the regional carbon emissions estimate for Chicago-area rail transportation. The estimate was based only on diesel fuel consumption, and does not consider other fuel types or lifecycle carbon emissions. The proportion of diesel fuel consumed by the rail sector, in comparison to the overall transportation sector, was derived from national data, which are used as a proxy for Illinois. If these data were available at the state level, it would increase the accuracy of the estimate. To estimate the rail activity occurring in the Chicago region compared with the state as a whole, grade crossing traffic data for the MPO region was summed and compared to state traffic data. However, some segments of the rail network had no reported traffic data.

In addition, there are potential biases with applying the national level data to the state of Illinois. In particular, there is no guarantee that the mix of modes in Illinois matches the mix across the U.S. In fact, Illinois is known as a "rail hub," meaning that there is likely a higher proportion of rail transport in this state than in the nation. The inaccuracy in the application of the national average could be reduced by developing a variant proportion, based on the sizes of the truck transportation and rail transportation industries, according to census data.

A passenger rail calculation could be developed following this methodology, but several data inputs would be different, including the number of cars per train and the weight per car. The tons per carload calculation relies on data that are likely underestimates of the freight weight, and the calculation also does not include the weight of either the cars themselves or the locomotive. It is important to note that the GIS-based hot spot analysis did not take into account the distinction between freight and passenger rail. Using the current method, it is not possible to calculate the overall emissions in the state because of the missing segments of rail traffic data.

In order to more accurately incorporate fuel efficiency into the air emissions model, it would be useful to know which types of fuels, combustion technology, and injection technology are implemented in locomotives operating in the Chicago region, to allow for better estimates of bhp-hr/gal. Other site-specific factors, such as topography, could be included in a refined emissions model.

Some advanced aspects of the methodology, as noted in light grey boxes, could not be completed within the time and budget constraints of this project. Potential next steps for the NURail-GIS air emissions model include connecting fuel emissions to air quality impacts by incorporating meteorological and topographic data into a pollution dispersion model. A further consideration is the connection between air quality and human health risks.

SECTION 5: GIS DATABASE DEVELOPMENT

In reference to the sustainability metrics, in particular those that have spatial components and can be measured for a specific location, a GIS database was constructed and included about 40 layers of environmental, socioeconomic, demographic, and transportation data. A "layer" used in the GIS community refers to a data source that defines how spatial data are visually represented on the map. Examples include: railroads (lines), wetlands (polygons), and locations (points) of grade crossings. **Table 14** below provides a full list of data layers that were included in the GIS database for this project and the sources of each data layer.

The GIS database includes both base data layers and advanced data layers. Base data layers, such as rail operations, infrastructure, demographics, land use, natural hazard areas, cultural and historical resources, and environmentally sensitive areas, were compiled from various datasets published by governmental agencies and other organizations, such as DOT, EPA, FRA, and AAR. In addition, the GIS database also includes advanced data layers that interact with base layers and were generated by the NURail-GIS project team as discussed in Section 5, such as criteria air pollutant emissions, derailment risks, and Potential High Adverse Impact Areas. **Figure 9** illustrates how sustainability metrics and GIS databases are connected.

Figure 9. Connecting Sustainability Metrics with Spatial Mapping Tools in GIS Database

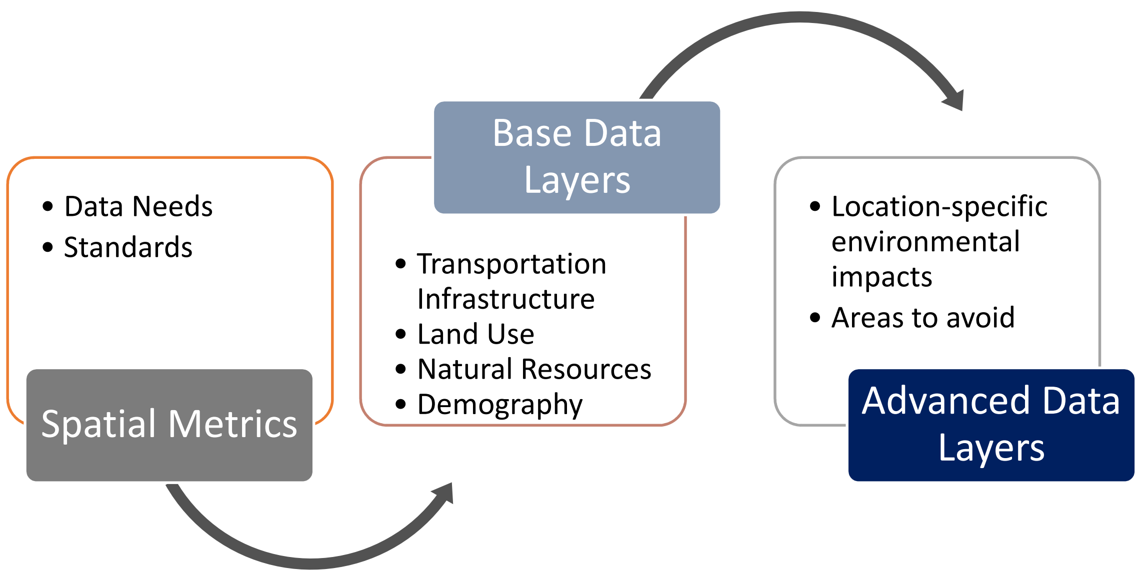


Table 14. Data Layer Definition and Data Source

Data Layer Name	Annotation	Data Source
"Agriculture"	Agriculture land use	Chicago Metropolitan Agency for Planning (CMAP)
"Alluvial/Glacial Aquifer"	Extent of the alluvial and glacial aquifers north of the southern-most line of glaciation	USGS and the National Atlas of the United States (2002)
"Archeologic Resource"	Areas believed to possess a high archaeologic potential	Illinois State Museum. Downloaded from Illinois Geospatial Clearinghouse [http://www.isgs.illinois.edu/nsdihome/webdocs/browse.html]
"Bird Presence"	Areas with the presence of birds that are vulnerable or near threatened	BirdLife International
"Carbon"	Carbon dioxide emissions (in grams) from rail operation	NURail Team's estimate. Refer to full report for details.
"Carbon Monoxide"	Carbon Monoxide emissions (in grams) from rail operation	NURail Team's estimate. Refer to full report for details.
"Commercial/Office"	Commercial or office land	Chicago Metropolitan Agency for Planning (CMAP)
"County Boundary"	Geographical boundary of counties.	U.S. Census Bureau
"Critical Habitat"	Areas where final critical habitat exists for species listed as endangered or threatened	US Fish and Wildlife Service
"CTA Blue Line"	Blue line train branch by **Chicago** Transit Authority	City of Chicago Data Portal
"CTA Brown Line"	Brown line train branch by **Chicago** Transit Authority	City of Chicago Data Portal
"CTA Green Line"	Green line train branch by **Chicago** Transit Authority	City of Chicago Data Portal
"CTA Orange Line"	Orange line train branch by **Chicago** Transit Authority	City of Chicago Data Portal
"CTA Pink Line"	Pink line train branch by **Chicago** Transit Authority	City of Chicago Data Portal
"CTA Purple Line"	Purple line train branch by **Chicago** Transit Authority	City of Chicago Data Portal
"CTA Red Line"	Red line train branch by **Chicago** Transit Authority	City of Chicago Data Portal
"CTA Yellow Line"	Yellow line train branch by **Chicago** Transit Authority	City of Chicago Data Portal
"Derailment Accident Risk"	Derailment risk level estimated based on track class, mode of operation, track density, and tonnage	NURail Team's estimate based on the model developed by Drs. Xiang Liu, Rapik Saat, Chris Barkan at UIUC. Input data are from FRA.

Table 14: Data Layer Definition and Data Source (cont'd)

Data Layer Name	Annotation	Data Source
"Emission Hotspots"	Areas with potentially high level of emission rates (e.g., high volume of traffic). Priority areas for in-depth assessment.	NURail Team's estimate. Refer to full report for details.
"Employment Density"	Gross employment density (jobs/acre) on unprotected land at Census blockgroup level	U.S. EPA SmartLocation Database
"Flood Hazard"	Areas that will have a 1% (100-year) and .2% (500-year) or higher chance of being inundated by the flood event in any given year	Illinois State Geological Survey (ISGS)
"Forest/Grassland"	Forest and grassland land	Chicago Metropolitan Agency for Planning (CMAP)
"Grade Crossing"	Information about grade crossings (rail tracks intersecting roads) and surrounding environment, e.g., traffic counts, max speed, land use, operating company	NURail team (spatial joined data provided by US DOT and FRA)
"Historical Site"	Buildings and districts in Chicago which are listed on the National Register of Historic Places (NRHP) or designated as National Historic Landmarks (NHL)	City of Chicago Data Portal
"Hydrocarbon"	Hydrocarbon emissions (in grams) from rail operation	NURail Team's estimate. Refer to full report for details.
"Industrial"	Land for industrial uses	Chicago Metropolitan Agency for Planning (CMAP)
"Institutional"	Land for institutional uses	Chicago Metropolitan Agency for Planning (CMAP)
"Intermodal Terminal"	Different modes of DOT, supervised by RITA/BTS	National Transportation Atlas Databases (NTAD) 2011
"Median Household Income"	Median Household Income at Census blockgroup level	U.S. Census Bureau
"Metra Lines"	Northeast Illinois **commuter rail** system	City of Chicago Data Portal
"Natural Area"	"Area of land or water in public or private ownership that is formally dedicated pursuant to the terms of the law, to be maintained in its natural condition"	Illinois Natural History Survey
"NOx"	NO emissions (in grams) from rail operation	NURail Team's estimate. Refer to full report for details.
"Open space"	Open spaces	Chicago Metropolitan Agency for Planning (CMAP)
"PM10"	Particular matter emissions (in grams) from rail operation	NURail Team's estimate. Refer to full report for details.

Table 14: Data Layer Definition and Data Source (cont'd)

Data Layer Name	Annotation	Data Source
"Population Density"	Gross population density (people/acre) on unprotected land at Census blockgroup level	EPA SmartLocation Database
"Public Transit Facility"	Transit station information	Data originally provided by BTS and MPO, and compiled in the National Transportation Atlas Database
"Railroad Speed"	Maximum allowed train speed	National Transportation Atlas Database
"Residential"	Residential land use	Chicago Metropolitan Agency for Planning (CMAP)
"Riparian Zone"	Extent of riparian areas; Classification of Wetlands and Deepwater Habitats	U.S. Fish and Wildlife Service
"Seismic Hazard"	Extent of seismic hazard; probability that ground motion will reach a certain level	National Atlas, Department of the Interior, and U.S. Geological Survey
"Shallowest Principal Aquifer"	Extent of Shallowest Principal Aquifers. Partially represent ground water withdrawal point	USGS
"Tornado Hazard"	Tornado touchdown points 1950-2008	National Weather Service, Storm Prediction Center
"Trail"	"Trails element and land-based greenways for the Northeastern Illinois Regional Greenways and Trails Plan - 2009 Update, adopted in October. An integral element of the Bikeway Information System."	Chicago Metropolitan Agency for Planning (CMAP)
"Transportation"	Land for transportation uses	Chicago Metropolitan Agency for Planning (CMAP)
"Vacant"	Vacant lands	Chicago Metropolitan Agency for Planning (CMAP)
"Water"	Water	Chicago Metropolitan Agency for Planning (CMAP)
"Wetland"	Wetlands	Chicago Metropolitan Agency for Planning (CMAP)

SECTION 6: INTERACTIVE WEB TOOL DEVELOPMENT

One of the final products of this project is a web tool that allows users to access the GIS database and sustainability metrics. The web tool is freely available to the general public. Users can specify a geographic area of interest through an online interface and extract maps and data for the customized area. Rather than providing precise data for engineering studies, it is designed to facilitate a rapid assessment before a formal NEPA process is implemented. This section provides a brief documentation of the web development structure and inquiry functions supported by the web tool. Two specific examples are provided in the presentation prepared for the Center for Urban Transportation Research (CUTR) Webcast Series that was recorded and remains available online.

6.1 Web Structure

The web application consists of four supporting components as follows:

- Front-end static webpages – They include the Home page of the project and text/table descriptions about this project, such as the introduction of the project, the methodologies we used, the introduction of the interactive web tool, metrics, the project team, and frequently asked questions. From here users can access the web tool. **Figure 10** provides a snapshot of this project's Home page.
- Front-end interactive mapping tool - This is the major interface that users will access for the maps. **Figure 11** provides a snapshot of the main interface of the web mapping tool.
- Back-end hosting server – Initially UIC virtual server [http://accc.uic.edu/service/virtual-servers] was used. When the project was completed, the web page was migrated to an external vendor.
- Back-end GIS server - GIS servers are special servers for Geographic Information Systems. It provides convenient way to host, manage, edit and query about geographic information data. A GIS server is different from an ArcGIS application. In this project, Geoserver, an open source software, was chosen as the GIS server.

Figure 12 below illustrates the architecture of the web application. Static Webpages and interactive mapping tool are supported by both a web hosting server (initially at the UIC virtual server and then migrated to an external vendor) and an additional GIS server (Geoserver).

6.2 Web Tool Functionality

The interactive mapping tool allows users to select one or multiple data layers for visual display and summary analysis, specify a geographical area of interest by drawing on the map, opt to add a buffering area of relevance, visualize the overlay of multiple data layers, and obtain summary data of selected data layers. Designed to be intuitive, the user is automatically guides through the process below.

Figure 10. NURail-GIS Web Home Page

Figure 11. NURail-GIS Web Tool – Web Snapshot

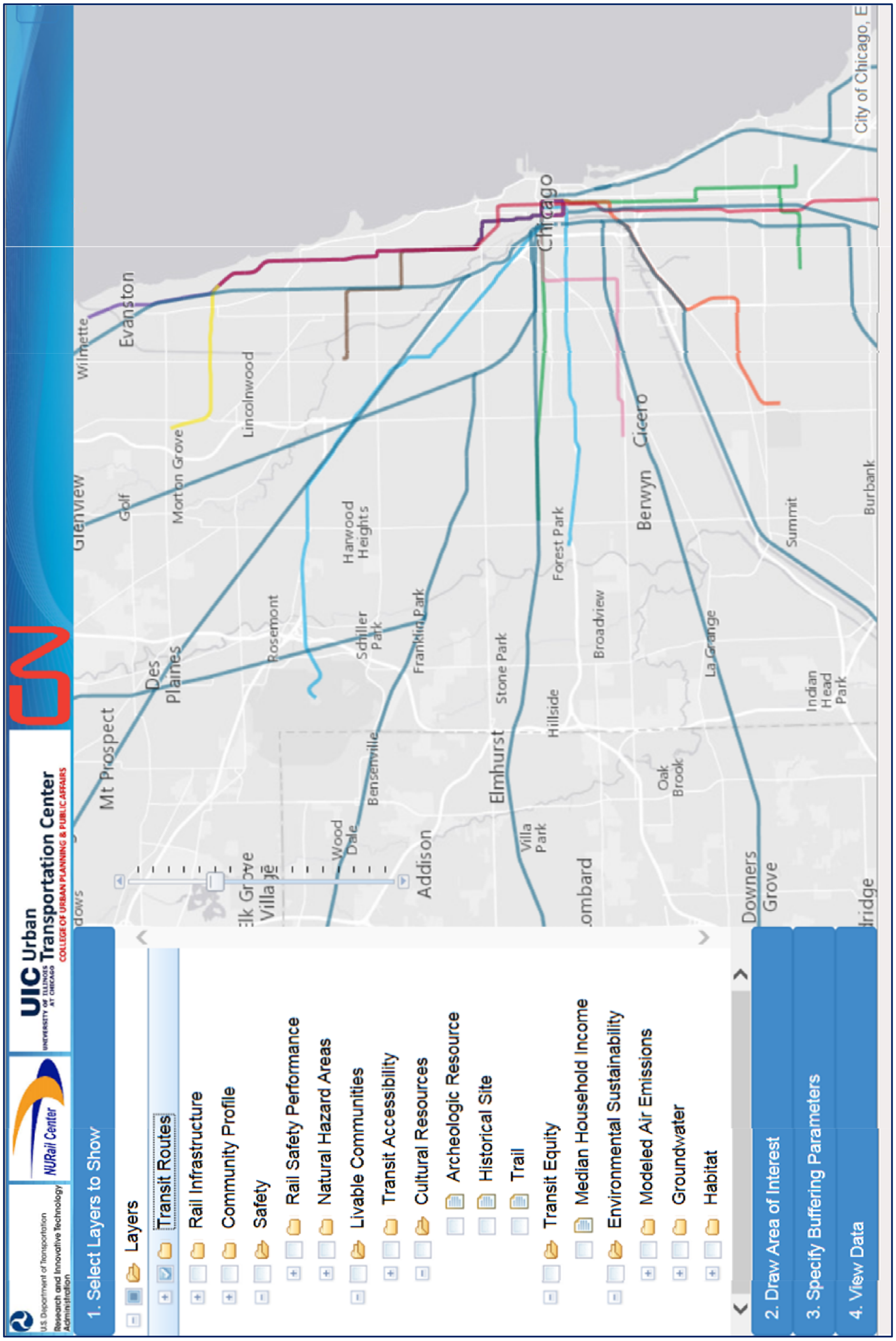
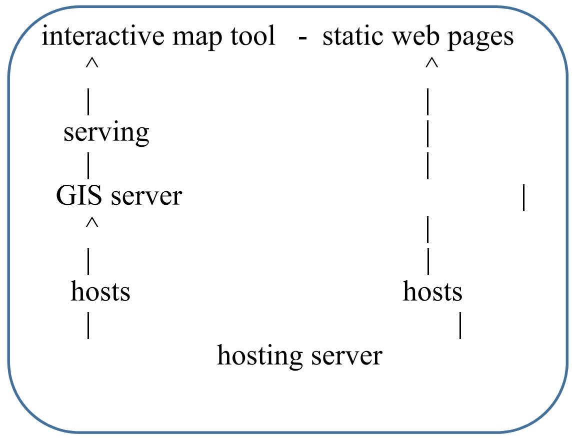


Figure 12. Architecture of the Web Application



- **Select layers for display**

About 40 data layers are organized in eight general folders for web display: Transit Routes, Rail Infrastructure, Community Profile, Safety, Livable Communities, Transit Equity, and Environmental Sustainability, and Potential High Adverse Impact Areas. Some folders also have sub-folders for easy organization and identification.

To view specific data layers in each folder, users can click the cross box next to the folder or sub-folder name, and check the box next to the data layer name. For example, to view the data layer of “Grade Crossing”, check the box next to “Rail Infrastructure” before checking the box next to “Grade Crossing”. Multiple data layers can be selected at the same time. Depending on the size of specific data layer(s) and internet connection speed, you may experience slow responses at times. By default, transit routes are shown in the main interface.

- **Specify an area of interest on the map**

To draw an Area of Interest, users have multiple choices - a point, multiple points, a straight line, a freehand line, polygon, or freehand polygon. Click on the button of the desired shape and hover the mouse cursor over the map. Users may also find instructions in a text box prompt if needed. The tool will automatically lead the user to the 3rd panel once an area is selected.

- **Select whether to add a buffering area**

As an optional step, users can choose to specify a buffer distance surrounding the specified area (e.g., 1000 feet, one mile, etc.). By default, a two-mile buffer will be added. Users can increase or decrease the buffer radius, or change the unit (e.g. mile, kilometer, etc.). Alternatively, users can also skip the buffering option, if the drawn shape is a polygon.

- **View summary data**

Summary statistics will be shown for the features/data layers that the user selects within the user-specified area, or the buffered area if a buffer is specified.

SECTION 7: RESULT DISTRIBUTION AND EVALUATION

Progressive results of the database development have been shared with transportation professionals and through conferences, workshops and stakeholder meetings. Journal articles for formal publication are currently being prepared.

7.1 Conference Presentations

- 2014 American Association of Collegiate Schools of Planning Conference. 2014. Platform Presentation. Presenter: Dr. Ning Ai.
- 2014 Railroad Environmental Conference. 2014. Platform presentation. Presenter: Dr. Ning Ai.2013 Rail Summit, Chicago, Illinois. October 25, 2013. Platform presentation. Presenter: Dr. Ning Ai.
- 2013 APTA Annual Meeting, Chicago, Illinois. September 29 – October 2, 2013. Poster presentation. Presenter: Marcella Bondie
- 2013 NURail Annual Meeting, Urbana-Champaign, Illinois. September 11-12, 2013. Session presentation and poster. Presenters: Steve Schlickman and Marcella Bondie.
- 2013 Transport Chicago, Chicago, Illinois. June 7, 2013. Platform presentation. Presenter: Marcella Bondie.
- 2013 Joint Rail Conference, Knoxville, Tennessee. April 16-18, 2013. Poster presentation. Presenter: Anthony Grande.

7.2 Webcast

- "Sustainability Metrics and Mapping Tool for Environmental Assessment of Rail Infrastructure in Illinois." Center for Urban Transportation Research (CUTR) Webcast Series, University of South Florida. (December 11, 2014). Presenter: Dr. Ning Ai

7.3 Graduate Student Educational Sessions

- NURail Annual Meeting 2015 – NURail Graduates in Action, June 4, 2015. Presenter: Marcella Bondie.
- NURail Annual Meeting 2013 – NURail Graduates in Action, April 16, 2013. Presenter: Anthony Grande.

7.4 Focus Group Meetings

The NURail-GIS project team organized a focus group meeting to solicit feedback on the initial development of the NURail-GIS web tool and Sustainability Metrics. The meeting was held at the Urban Transportation Center at the University of Illinois-Chicago on December 18, 2013. Attendees represented local and regional transportation and planning agencies, non-governmental organizations (NGOs), transportation consultants and academia. Meeting attendees include: Elizabeth Panella (CMAP), David Kralik (Metra), Liu Xiang (University of Illinois formerly), Greg Newmark (Center for Neighborhood Technology), Gina Trimarco (TranSystems), Janet O'Toole (URS), Robert Ginsburg, Sonali Tandon (Chicago Transit

Authority), Ning Ai (NURail-GIS), Marcella Bondie (NURail-GIS), Shuo Ma (NURail-GIS). Then a follow-up meeting was held in December 2013, with members of a Non-Government Organization, Center for Neighborhood Technology.

The NURail-GIS project team presented the web map and metrics, and facilitated a group discussion of the tools. Attendee comments and NURail-GIS project responses are summarized below.

- Marketing: Attendees indicated that adoption of the tool by a regulatory agency will be the most effective way of increasing its use. The FRA was suggested as a potentially interested partner, based on its rail planning mission and NEPA compliance responsibilities for freight and high-speed rail. In addition, attendees suggested that the Urban Transportation Center may wish to become the long-term web and data host of the NURail-GIS webtool, just as other databases and tools are updated annually by other university research centers.
    - *NURailGIS Response*: The NURail-GIS project team prepared a one-page brief, *Potential Applications of NURail Project "Environmental Impact Assessment of Rail Infrastructure in Illinois" to FRA's NEPA Implementing Procedures*. The brief was submitted to FRA for consideration. Long-term implementation of the NURail-GIS project is contingent upon funding.
- GIS Database and Web tool: Attendees strongly recommended an addition of an interactive drawing function that allows the user to specify a corridor or area for analysis, and generate a data summary report for the selected area. Some attendees suggested preparing printable thematic maps for use by the general public (e.g., map of "high potential adverse impact area").
    - *NURailGIS Response*: The NURail-GIS project team had another graduate student, Yin Shi, to assist with developing the drawing and reporting functions for the web tool.
- Refinement of Sustainability Metrics: Attendees suggested that separate metrics should be developed for transit, freight and commuter rail, to reflect variations in impacts. Attendees also noted that professionals and community members may be interested in different metrics. For example, transportation professionals may prefer a more limited set of metrics that closely align with NEPA requirements. Attendees suggested that project-specific issues such as noise might be best evaluated at a later stage of NEPA assessment, rather than incorporated into the web tool.
    - *NURailGIS Response*: The NURail-GIS Sustainability Metrics were revised to separate the metrics for freight and commuter rail. The NURail-GIS project team is currently focusing on more limited impact issues that have high interest for both professionals and community members, such as air emissions and public safety risks posed by derailments.
- *Integration of Sustainability Metrics*: Some attendees suggested the development of a weighted sustainability index score that would allow comparison between sites. However the weighted approach seemed to be controversial among meeting attendees.

- *NURailGIS Response*: The project team conducted a literature review of sustainability index score methodologies; an index may be included in future work. A "high hazard" GIS layer was considered. Current results reported here and online did not weigh the metrics.

7.5 Policy Brief

- Applications of UTC NURail Project on Environmental Impact Assessment of Rail Infrastructure in Illinois to FRA's NEPA Implementing Procedures. Submitted to Paul Nissenbaum, Associate Administrator for Railroad Policy and Development at Federal Railroad Administration. January 23, 2014.

7.6 Website Tracking

Google Analytics code has been inserted into the source code of each page of the NURail-GIS website. The NURail-GIS team will continue to monitor and evaluate the visitor rate.

7.7 Media at UIC Urban Transportation Center

The NURail-GIS project summary and progressive results, such as conference presentations and webinar recordings, have also been posted and continually updated at the web site of UIC Urban Transportation Center and social media, such as Facebook.

SECTION 8: SUMMARY AND RECOMMENDATIONS

The NURail-GIS Team has developed a comprehensive set of sustainability metrics for transit, commuter and freight rail, and an associated web tool that visualizes sustainability data at a community scale. There are several potential uses for the NURail-GIS database, Sustainability Metrics, and web interface. These tools can be used to help satisfy NEPA requirements for public involvement, such as by publishing the metrics generated during a project's NEPA evaluation. The mapping tool can also be used for public engagement campaigns, enabling the public to explore rail and environmental conditions in their community.

The NURail-GIS mapping tool and metrics could also be incorporated into the development and evaluation of State Rail Plans, which are required by PRIIA legislation. By specifying a single methodology and a list of key performance indicators, federal transportation professionals can more readily compare plans across state lines. Although the maps currently displays data for the State of Illinois or the Chicago metropolitan area, many of the datasets are available nationwide. If the mapping tool were adopted into the federal NEPA process, it would provide an agency-approved source for compliance documentation, as well as a pre-screening method to identify sensitive or high-risk areas. This could facilitate project prioritization, and improve the efficiency of consultants and agency staff who prepare and evaluate NEPA documents.

Finally, the NURail-GIS metrics can further the objectives of DOT's *Strategic Plan.* By encouraging or mandating that rail companies complete the metrics evaluation on a yearly basis and report the results to DOT, an industry-wide database can be developed. These data can be used to quantify the beneficial impacts of rail, identify areas for improvement, and suggest new programmatic directions for DOT. Publishing the data would also further DOT's research programs.

Potential next steps for the NURail-GIS project include refining the air emissions model, adding risk and LCA modeling functions, adding benchmarking data for the sustainability metrics, and refining the web interface. Evaluation of economic impacts may be another potential research area for NURail-GIS. Transportation cost-benefit analysis (CBA) typically estimates the monetary value of several cost-benefit categories (Litman, 2009). Cost-benefit estimates have also been prepared with the goal of comparing transport modal options (Black et al., 1996; DeCorla-Souza & Jensen Fisher, 1994). Full cost accounting of transportation has been performed since at least the mid-1970s in the U.S. and Europe (Keeler & Small, 1975; Kågeson, 1993; Levinson et al., 1997; Banfi, 2000; Community of European Railway and Infrastructure Companies, 2004; Cevero & Guerra, 2011). Incorporation of additional models and metrics into NURail-GIS would allow transportation professionals and communities to have a fuller understanding of rail's economic, environmental, and social impacts.

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