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Senior Project Proposal

Advisor: Ms. Olender
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AI Usage in Infrastructure Maintenance

Question:

How can AI-driven predictive maintenance models be applied to extend the lifespan of aging bridges in Manhattan, and how do these approaches compare to traditional inspection and schedule-based maintenance methods in terms of cost efficiency, safety, and failure prevention?

Statement of Purpose:

The purpose of this research is to investigate how AI-driven predictive maintenance models can be used to extend the lifespan of aging and congested vehicle bridges in Manhattan and to compare their effectiveness with traditional inspection- and schedule-based maintenance methods. This study aims to evaluate whether predictive maintenance systems, which rely on structural health monitoring data and machine learning algorithms, can identify potential failures earlier and more accurately than conventional approaches. By analyzing cost, safety outcomes, and failure prevention capabilities, this research seeks to determine whether AI-based maintenance strategies offer a more efficient and reliable alternative to existing bridge maintenance practices or whether they are best used as a complement to traditional methods.

Background:

My interest in this topic emerged from an earlier attempt to research the use of artificial intelligence in maintenance across a different range of engineering systems, specifically renewable energy. That initial project was intended to examine how AI could be applied to improve maintenance efficiency in structures such as wind farms, but due to the difficulty of finding reliable sources as well as personal reasons, it fell through. However, this experience introduced me to the concept of predictive maintenance and clarified the importance of narrowing research questions to allow for deeper analysis.

Through coursework in school, summer programs, and independent study in engineering, applied mathematics, and data analysis, I became interested in how predictive models can be used to anticipate system degradation and reduce failure risk. In particular, I want to compare AI-driven approaches with traditional maintenance strategies, such as scheduled inspections and reactive repairs, which remain the standard for most civil infrastructure. This comparison will highlight both the potential advantages of predictive maintenance and the practical challenges involved in implementing it at scale.

Manhattan’s bridges offer a well-defined and relevant case study for continuing this investigation in a more focused way. These structures are aging, subject to heavy daily use, and critical to the city’s transportation network, making maintenance decisions vital for city life to flow. By examining how AI-based predictive maintenance models compare to conventional bridge maintenance methods in terms of cost efficiency, safety, and lifespan extension, this research allows me to build on my initial interests while applying them within a clearly defined and manageable scope of the city I grew up in.

Prior Research:

Bridges have long been studied to ensure they remain safe for public use, especially in cities with heavy traffic and aging infrastructure. In the United States, bridge maintenance has traditionally relied on regular visual inspections guided by federal standards such as the *Bridge Inspector’s Reference Manual* published by the Federal Highway Administration. These inspections are typically conducted every two years and focus on identifying visible signs of deterioration, including cracking, corrosion, and joint damage. While this approach has been effective in preventing major failures, several sources note that it can be limited in its ability to detect early or hidden forms of structural damage.

To address these limitations, researchers have explored the use of structural health monitoring systems that collect data from sensors placed on bridges. These systems measure factors such as vibration, strain, temperature, and traffic loads, providing a more continuous picture of how a bridge behaves over time. According to FHWA and other engineering studies, this type of monitoring can help engineers better understand long-term wear patterns, and also produces large amounts of data that can be difficult to interpret using traditional analysis methods.

More recent research has begun to investigate how artificial intelligence and machine learning can be used to analyze structural health monitoring data. Predictive maintenance models use past inspection records along with real-time sensor data to estimate when maintenance may be needed. Studies suggest that these models could help identify problems earlier than traditional inspection schedules and allow maintenance to be planned more efficiently. However, much of this research is still developing and often focuses on controlled studies or newly installed systems rather than older bridges in dense urban environments.

There is also ongoing discussion about how cost-effective predictive maintenance actually is when compared to traditional inspection-based maintenance. Government reports on bridge preservation emphasize the importance of preventive maintenance but do not yet fully incorporate AI-driven predictive models into standard practice. This suggests that while predictive maintenance shows promise, more research is needed to understand how it can be realistically applied alongside existing maintenance methods, particularly for older bridges like those found in Manhattan.

Significance:

With the usage of AI and automated systems growing every day, it has adapted to be used in many different fields, including infrastructure and maintenance. This research question is worth considering because aging bridge infrastructure is a growing problem in both New York City and the United States as a whole. According to the American Society of Civil Engineers, over 40% of U.S. bridges are more than 50 years old, and repairing structurally deficient bridges nationwide would require tens of billions of dollars in funding. In Manhattan, bridges support extremely high daily traffic volumes, meaning that maintenance failures or emergency repairs can cause major safety risks and economic disruption. These statistics highlight the importance of finding maintenance strategies that are not only safe but also cost-efficient and sustainable over time.

The Senior Project Committee should allow this research because it examines a real-world engineering challenge using a focused and realistic approach. Rather than attempting to design a new AI system, this project compares existing maintenance practices—such as inspection-based and scheduled maintenance outlined by the Federal Highway Administration—with emerging AI-driven predictive maintenance models discussed in recent research. Through this comparison, I hope to learn whether predictive maintenance has the potential to improve decision-making for bridge upkeep, or whether it is better understood as a tool that supports traditional methods rather than replaces them. This research adds to existing knowledge by synthesizing technical, economic, and practical considerations instead of evaluating AI purely from a theoretical standpoint.

This project brings a new perspective by focusing specifically on Manhattan's bridges, which operate under conditions that are not always addressed in broader infrastructure studies, such as high traffic density, aging construction, and limited maintenance windows. The final presentation may be useful to students, educators, and members of the general public who are interested in how artificial intelligence is being applied to public infrastructure. It could also be shared with local transportation agencies, engineering programs, or student research forums as an example of how emerging technologies can be evaluated critically before being adopted. Overall, this research aims to encourage informed discussion about how data-driven tools might play a role in managing aging infrastructure responsibly.

Description:

To complete this project, I will rely on a combination of internet-based research, observational learning, and exploratory modeling. Internet research will include reviewing government publications, academic journals, and technical reports related to bridge maintenance, structural health monitoring, and AI-driven predictive maintenance. These sources will help establish a foundational understanding of both traditional and emerging maintenance strategies.

In addition, I hope to gain insight through observations in professional environments, potentially through an internship related to engineering, infrastructure, or data analysis. Observing how maintenance decisions are made in real-world settings will allow me to better understand the practical constraints that are not always captured in academic research. I may also experiment with creating simple predictive models using publicly available data to better understand how AI maintenance systems function in theory. The final product of this research will be a written analysis that synthesizes these approaches.

Final Product:

The final product for this project will be a formal research paper that examines how AI-driven predictive maintenance models compare to traditional inspection- and schedule-based maintenance methods for bridges in Manhattan. This paper will reflect my effort to answer the research question by integrating research findings, observational insights, and theoretical modeling. The paper will be distinct from my final presentation and will aim to clearly explain both the potential benefits and limitations of predictive maintenance in a real-world infrastructure context.

Methodology:

The research process will begin by refining the research question and reviewing foundational literature on bridge maintenance, structural health monitoring, and predictive maintenance models. This initial phase will involve collecting and annotating academic articles, government reports, and technical documents to establish an understanding of existing maintenance practices and emerging AI-based approaches.

Next, I intend to pursue an internship or work-based learning opportunity related to engineering, infrastructure management, or data analysis. Through this experience, I hope to gain firsthand exposure to how maintenance systems operate in practice and how data is used to inform decision-making. If available, I will observe workflows, tools, and decision processes related to maintenance and asset management. These observations will help ground my research in real-world conditions and clarify the gap between theory and implementation.

Alongside this, I may attempt to develop basic predictive models using publicly available infrastructure or maintenance datasets. While these models will not replicate real-world systems, they will help me understand the inputs, assumptions, and limitations of AI-based maintenance approaches. Throughout the three-month research period, I will continuously refine my findings, compare traditional and predictive maintenance methods, and synthesize this information into a structured research paper that addresses the research question.

Problems:

One major challenge in answering this research question is that AI-driven predictive maintenance is still relatively new in the field of civil infrastructure. As a result, there are limited real-world implementations, especially for older bridges in dense urban environments like Manhattan. This makes it difficult to obtain concrete data that directly compares AI-based maintenance systems with traditional methods. Many existing studies rely on simulations, pilot programs, or theoretical models rather than long-term operational results.

To address this issue, I plan to rely on a combination of case studies, government reports, and exploratory modeling rather than attempting to draw definitive conclusions. If access to detailed data or internship opportunities is limited, I will adjust the scope of the project to focus more on feasibility, challenges, and potential future applications rather than performance outcomes. By clearly acknowledging these limitations, I hope to present a balanced and realistic analysis of predictive maintenance in infrastructure rather than overstating its current capabilities.

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