Sustainability Assessment for Transport Infrastructure

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INTRODUCTION

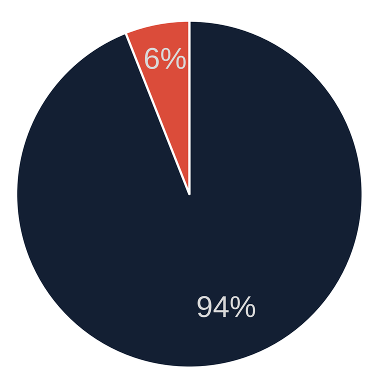
Modern pavement networks have grown parallelly throughout the 20th century with the advent of the motor car. After 1960, big scale highways were developed to ensure faster transit and bypass small cities, enabling long distance freight and passenger land transport. Currently the US has approximately 6.43 million kilometres of highways within its borders.

Modern Materials and Technologies

Concrete and Asphalt are competing construction methods and materials.

Asphalt is a flexible pavement, whereas concrete is considered rigid. Due to their intrinsic material behavior the design philosophy is different for each type. Asphalts use many, low cost layers while concrete relies on a surface slab to provide most structural capacity.

Figure 1: Percentage mile share for each construction method



Sustainability Considerations

Both approaches use different materials, quantities equipment, maintenance schedules, logistic chains, etc. There is a lack of standard comparison in the literature for both materials on a unitary scale, understandably so due to complexity in posing comparable project metrics and competing stakeholder interests.

AIM

First Order Sustainability Assessment

We focused on developing a first order analysis on both types of pavements, considering the following rough depiction of the highest impact stages

Construction → Operation → Maintenance

Comparability

These processes have to be analyzed and scaled, in a manner that allows scalability to a per-unit metric.

Design Assumptions

We propose obtaining values for our comparison pavement stretch:

Project Length	Traffic	Lifetime
1km	2600 v.p.d.	25 Years
Hauling Distance	**Width**	**Maintenance**
16 km	7.5m	At 5% and 50% of LT

(Detailed assumptions available in the full report)

METHOD

Input Equivalent Designs

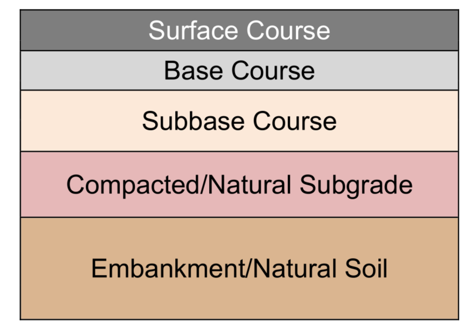


Figure 2: Layer Configuration

A standard structural design is composed of several layers that will withstand passing traffic. A decision on the *material* at each layer and the respective *depths* required result from a structural analysis for Y years.

When performing this comparison is agreeing to when two competing designs are actually equivalent. Pavement performance is traditionally addressed through the Pavement Serviceability Index (PSI)

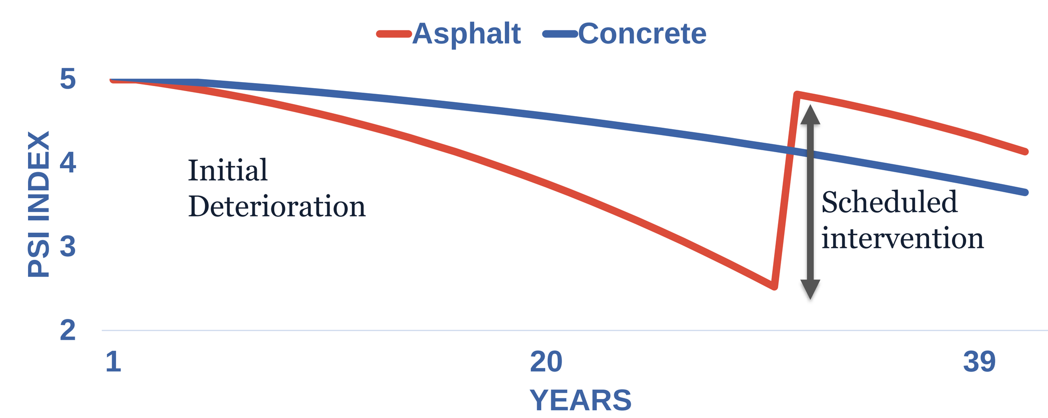


Figure 3: Qualitative sketch of pavement serviceability in time. Here asphalt receives a major maintenance revamp on year 30.

Activities Considered

Roadway Design: Planning | Material | Shoulders | Wearing course | Subbase

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Material Production: Input Materials | Transportation | Processing

↓

Construction: Transport | Excavation | Compaction | Placement

↓

Maintenance: Crack Sealing | Patching | Micro-surfacing | Milling | Reclaim

↓

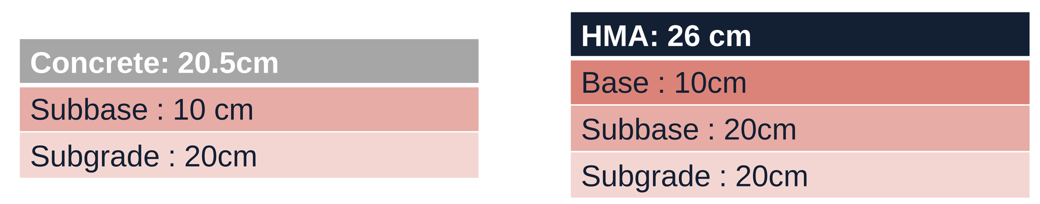
Operation: Heavy Traffic | Light Traffic

Traffic Analysis

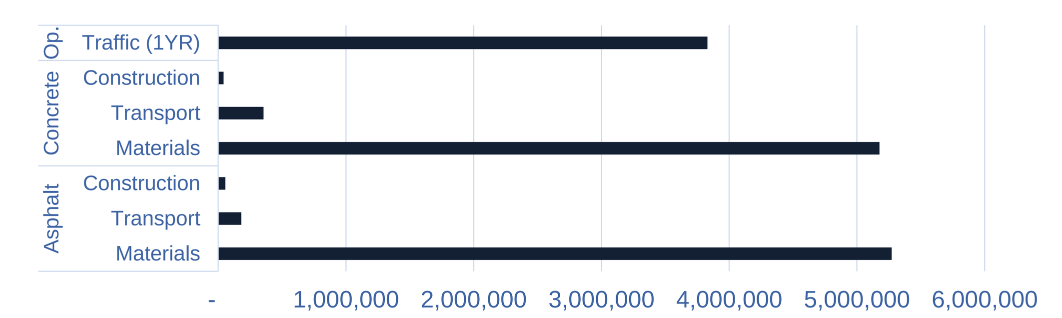
Traffic data and emissions where obtained through the software EPAMoves, which provides emissions and energy use values for 13 different vehicle categories. The values can then be aggregated for the lifetime of the project, which consider a yearly growth in traffic of 2.5%.

RESULTS

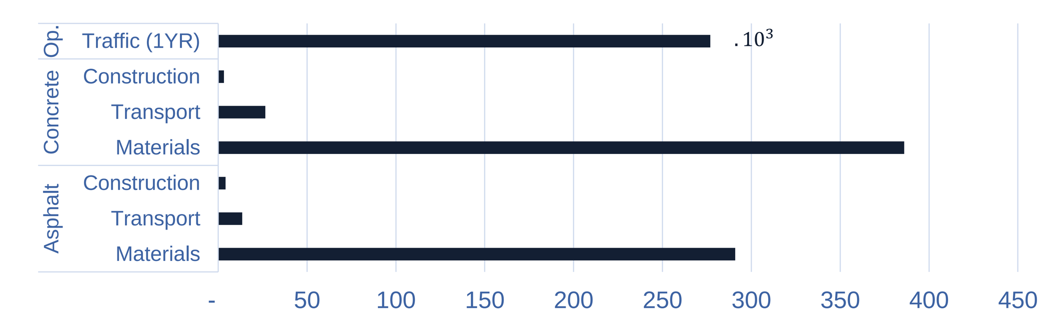
Competing Designs for 25 Year Lifetime



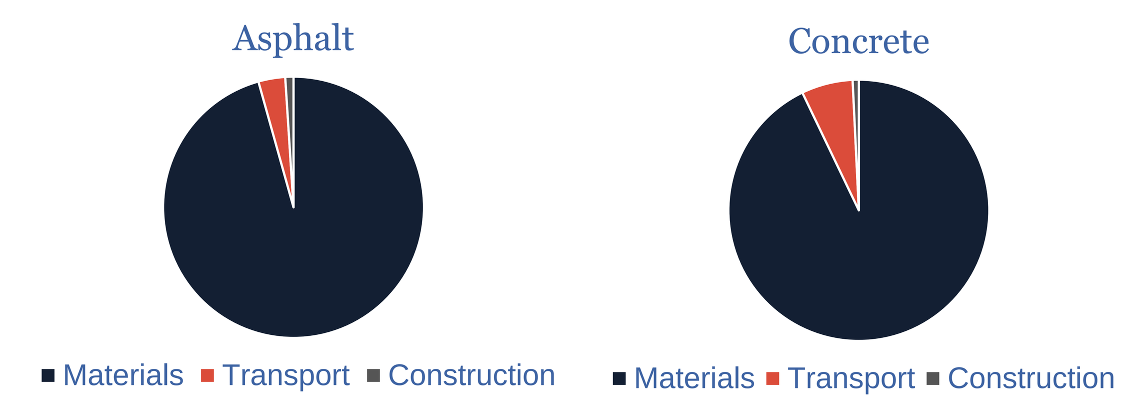
Energy Consumption [MJ/KM]



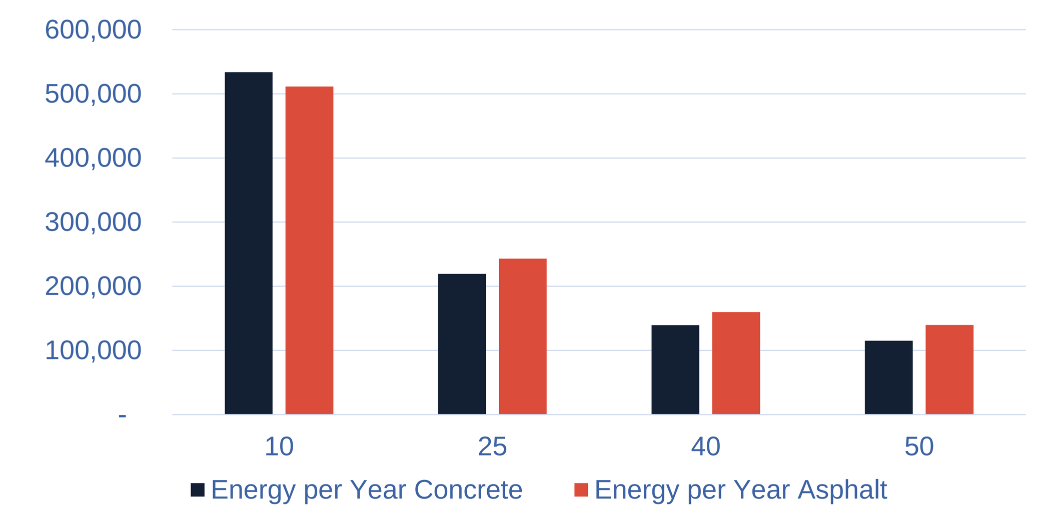
CO2 Emissions [Kg/KM]



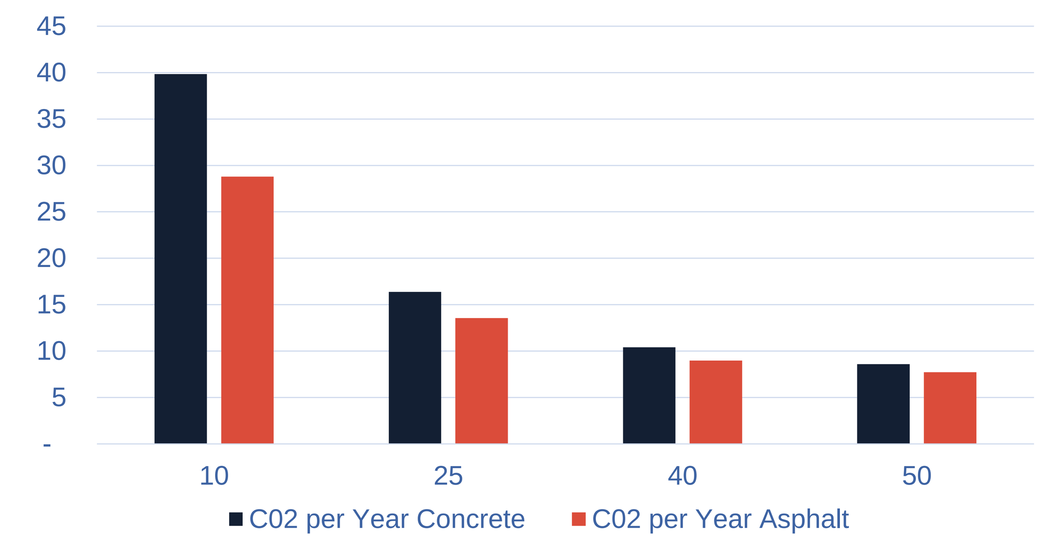
Energy Contribution by Sector



Per Lifetime Year Energy Use [MJ/KM]



Per Lifetime Year Co2 Emissions [Kg/KM]



DISCUSSION

The problem discussed is highly nonlinear and involves engineering judgement at many stages (Materials gradation, maintenance schedules, design methodology), therefore the results are far from definite. In this project we aimed to obtain some overarching conclusions on both construction types sustainability parameters.

Recycling strategies exist for both materials, with varying degrees of implementation. This is omitted in this study due to varying industry standards on the percentage recyclability of each material. But the incorporation of this in a full Life Cycle Analysis as well as an economic assessment would be following steps in this project.

EPAMoves software is very detailed, allows for much more computing specifics than shown in this project.

CONCLUSIONS

A first order analysis reveals asphalt pavements are more energy intensive construction process, whereas concrete provides more emissions overall, for standard industry design lifetimes.

Transport emission parameters were found to be of equal magnitude at a transport distance of about 100 miles.

A major, perhaps expected conclusion is that the operation phase by far exceeds in emissions, and energy usage the infrastructure construction. While traffic occurs constantly over the design life, infrastructure impacts are incurred at the year zero and then fairly distributed in the lifetime.

When considering the emissions and energy consumption per life year of design we observe a "structural economy of scale" from using concrete in pavement construction.

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