Context Dependent Pavement Life Cycle Analysis

INVESTIGATING PAVEMENT EMISSIONS

There are over 35 million kilometers of paved roads across the world. Since they appear static and passive, it is commonly believed that their environmental impact derives solely from their construction processes and the extraction and production of their materials.

Upon closer inspection, however, there are many ways in which the design of a pavement affects its emissions during its use phase, or operational life. CSHub research provides stakeholders with an understanding of these different factors and their influence on a pavement's emissions.

PVI IS THE PRIMARY SOURCE OF USE PHASE EMISSIONS

- **Researchers analyzed the main factors that impact pavement use phase emissions.** Their analysis did not include the influence of pavement albedo, which refers to the surface reflectivity of a pavement. **The factors they studied were:**
  1. **Carbonation**: the process by which CO_2 in the air binds itself to the cement found within the pavement. While carbonation lowers net emissions, it accounts for only a small portion of use phase environmental impacts.
  2. **Lighting**: the energy required to light roads over their use phase is an additional environmental impact. Emissions from lighting depend upon adjacent land use, roadway classification, and surface material.
  3. **Pavement Vehicle Interaction (PVI)**: the structural and surface qualities of a pavement that cause excess fuel consumption in vehicles. Researchers found that PVI induced emissions were by far the most significant use phase environmental impact **(See Figure 1)**.

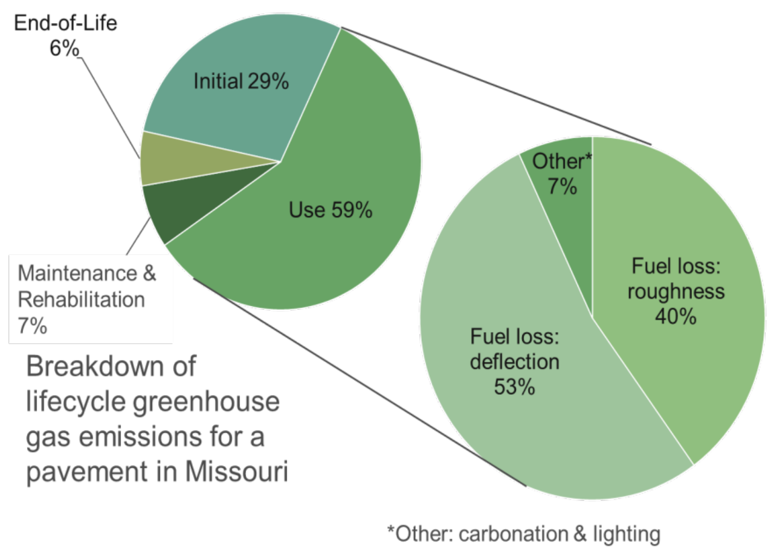

Figure 1. Lifecycle greenhouse gas emissions for a pavement in Missouri.

PVI INDUCED EMISSIONS HAVE TWO MAIN SOURCES

1. **Pavement roughness**
   - Roughness refers to the irregularities in the surface of the pavement.
   - Roughness causes dissipation in the shock absorbers of a vehicle's suspension system which, in turn, increases fuel consumption.
   - Since passenger vehicles prioritize ride comfort, they tend to have dampened suspension systems that allow considerable dissipation to occur. This dissipation

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leads to greater fuel consumption and makes passenger vehicles more prone to roughness induced PVI.
- To measure pavement roughness, the vertical travel of the suspension system over a given distance is used. This measurement is called the International Roughness Index (IRI) and uses units of inches/mile or m/km.

2. **Pavement Deflection**
   - Deflection occurs when the structure of a pavement deforms mildly under the weight of a vehicle.
   - This indentation in the pavement increases fuel consumption by creating a slight slope that the vehicle must travel up as it continues forward.
   - Since deflection depends on the weight of the vehicle, it has a greater influence on larger vehicles, primarily trucks.

PVI INDUCED EMISSONS DEPEND UPON TRAFFIC, DESIGN AND CLIMATE

- To examine how PVI induced emissions vary by context, CSHub researchers looked at several scenarios with a range of different climates and traffic levels **(See Table 1)**.
- Their research found that PVI induced emissions depended primarily on **three contextual factors:**
  - **Traffic**
    - Pavements with the most traffic had the greatest amount of use phase impacts across all climate zones. In the case of interstates, use phase impacts outweighed those of initial construction **(See Table 1)**.
    - For pavements with less traffic, much of their emissions derived from materials extraction and initial construction.
    - Since less trafficked roads saw more truck travel, their main PVI impact came from deflection.
    - Interstate highways saw greater passenger vehicle traffic and, as a result, pavement roughness contributed more to use phase impacts than deflection.
  - **Pavement Design**
    - On local and state highways with asphalt pavements, use phase emissions represented a greater proportion of total emissions than on those with concrete pavements **(See Table 1).**
    - The use phase of concrete pavements under similar traffic conditions contributed a smaller proportion of total emissions due to more emissions generated during initial construction.
  - **Climate**
    - In freeze zones, asphalt and concrete pavements had high stiffness which led to low deflection PVI impacts. However, both materials also deteriorated more quickly which caused higher roughness impacts **(See Table 1)**.
    - In no-freeze zones, asphalt pavements had a higher proportion of deflection impacts due to their tendency to deform in warmer temperatures.

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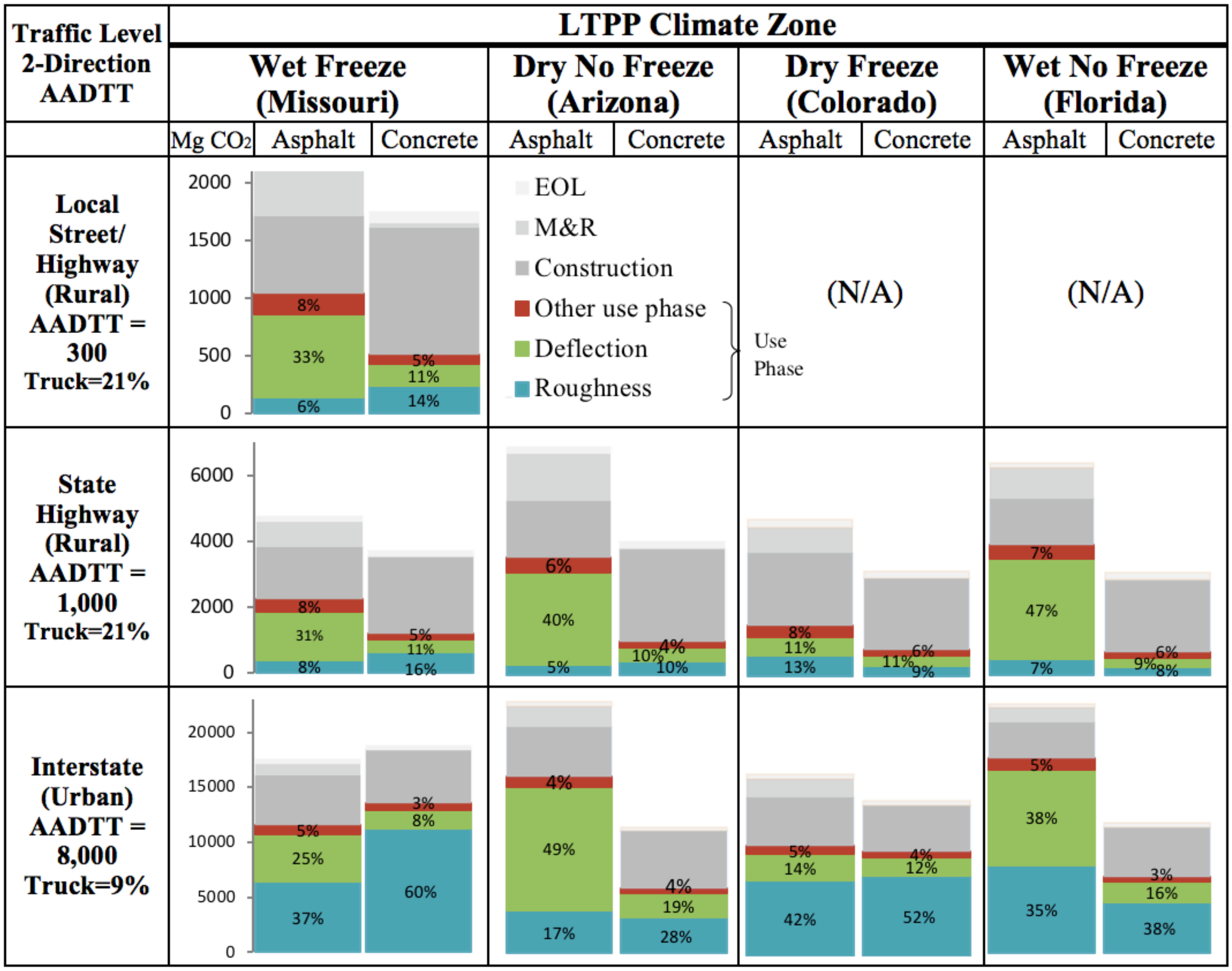

Table 1. A breakdown of the life cycle emissions of the nine different scenarios studied. AADTT refers to average annual daily truck traffic.

References: Xin, X., Akbarian, M., Gregory, J., Kirchain, R.; "Role of the Use Phase and Pavement-Vehicle Interaction in Comparative Pavement Life Cycle Assessment as a Function of Context," *Journal of Cleaner Production*, Volume 230, 2019.

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