Sustainable Transportation  
Conceptual Framework

This framework will continue to evolve as more is learned and understood about these topics; visit the Contacts page to contact someone if you have comments or suggestions for either framework.

Sustainability Background
Sustainability is a broad term that considers the environmental, social, and economic aspects of problems and their respective solutions.

- Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (Brundtland 1987)
- Physical, economic and social patterns of human development can affect sustainability at both a local and global level.
- Land use planning can play a role in improving the sustainability of communities, due to planning being related to how, where, and when human development occurs.
- Current transportation systems are heavily reliant on the burning of fossil fuels. This results in greenhouse gases, which have been linked to climate change as well as negative health impacts air pollution including smog and particulates.

Transportation History
There have been considerable changes in America’s transportation systems over the past two centuries.

- In the early 1800s, waterways provided the only practical option for long-distance travel, leading to America’s coastlines being populated first. Development spread into the country’s interior as railroads and roadways were built. By 1900, these roads and rails connected the coasts and allowed for growth throughout the country.
- In the early 1900s, cities were rapidly developing, which led to electric trolley lines being used for public transportation. The car was also invented during this time, and quickly went from being cost prohibitive to a popular and widely-used mode of transportation in cities. Airplanes were invented during this time, and used primarily for small-scale and regional transportation.
- Since the 1950s, the number of cars on the road has increased over five-fold. Air pollution became increasingly problematic, especially in urban centers. Air transportation became commonplace for transporting people and goods.

Wisconsin residents are driving substantially more than they did in the past.

- Between 1980 and 2005, mileage driven in Wisconsin increased at a rate nearly three times as fast as licensed drivers, five times as fast as population, and fifteen times as fast as road miles.
  - Gains in fuel efficiency during this time were offset by significant increases in driving and a trend toward more energy-intensive forms of transportation, such as personal vehicles.

Natural and social systems have been affected by the evolution of America’s transportation systems and increases in the commuter population.
Increasing populations of commuters and increased availability of personal vehicles has led to the rapid increase in the use of cars as personal transportation (31). This has in turn led to increases in the development of roads and highway systems. This rapid development and increase in personal transportation has altered environmental conditions, leading to land use changes and degradations in air and water quality (65, 66).

In the early years of transportation, the primary concern was development and convenience for getting people and goods from place to place. As negative environmental impacts of such an extensive transportation infrastructure along with increased travel time due to traffic have become evident, more and more people are recognizing the need for change.

**Transportation Issues**

No country in the world rivals America’s dependence on automobiles and highways; thus transportation policy plays a pivotal role in shaping land use. (Heidi Hoover)

- Once fossil-fuel dependent cars became commonplace, then our land use patterns changed to larger lots and lower densities.

America’s transportation systems are directly related to community design and land use planning.

- Suburban sprawl and inefficient land use planning make sustainable transportation difficult or impossible.
- Scattered development patterns lead to increased dependence on automobiles.

Lacking public transportation discourages civic involvement and may lead to a sense of discontent.

- Social capital consists of the networks and interactions that inspire trust and reciprocity among citizens.
  - Increased distance between living space and work space discourage civic involvement since time is split between communities.
- Older adults, minority groups, and low-income individuals are less likely to have access to personal vehicles, which often leaves them unable to access community amenities such as quality food and health care.
- As traffic increases, so does the noise level. This increases stress levels in city-dwellers and can cause more people to move out of the cities and into the country, increasing commute duration, traffic congestion, and pollution.

Increasing reliance on transportation systems, particularly personal vehicles, has had substantial consequences for the quality of the environment.

- Increased car use can cause increased air and water pollution (air pollution from emissions from cars and water pollution from runoff from driveways, parking lots and roads).
- Nearly 97 percent of greenhouse gas emissions from transportation come from the direct combustion of fossil fuels. Transportation is the largest end-use sector emitting CO₂, the most prevalent greenhouse gas.
- Transportation represents the fastest-growing source of greenhouse gas emissions in the United States, being responsible for 47 percent of the net increase in total U.S. emissions since 1990.
- Transportation is also the largest end-use source of carbon dioxide, which is the most abundant greenhouse gas. [http://www.epa.gov/otaq/climate/basicinfo.htm](http://www.epa.gov/otaq/climate/basicinfo.htm)
- In Wisconsin, about a quarter of all greenhouse gas emissions are a result of activities in the transportation sector. [http://dnr.wi.gov/climatechange/emissionsWI.htm](http://dnr.wi.gov/climatechange/emissionsWI.htm)
In the United States, vehicles use more gasoline each year than the entire U.S. oil industry produces. This gasoline is obtained from environmentally harmful practices and release greenhouse gasses when burned.

Huge tracts of land are cleared and locked-up to provide transportation corridors, removing these acres from constructive uses and natural habitat. As the corridors are widened and speed limits increase, it increases land development pressures and traffic congestion.

As homes and business spread outside of cities, they rapidly take away acreage previously used for farmland.

Meadows, wetlands and forests are lost along with farmland, greatly reducing wildlife habitat for fish and game, and endangered species. Further, fragmented habitats from roadways destroy corridors that animals use to travel from place to place.

Chemical gases and particles which are released by cars and trucks do eventually fall out of the air onto street surfaces and land. Vehicles often leak oil, gas, brake fluid, worn brake linings, windshield detergent, engine coolant and worn metal particles. Car tires leave a residue of zinc and other pollutants, as they wear. Road salt is added to the mix in the winter. Hard pavements, streets and parking lots often provide direct conduits to storm sewers, allowing these pollutants to wash directly into lakes and streams without any filtration.

Congested roadways and the emissions from transportation systems have resulted in public health and safety concerns.

Pollution from cars, trucks, busses, and other vehicles can lead to impaired lung development and function and increases in diseases such as asthma and lung cancer.

Women living near major roadways had higher rates of birth complications including low-weight births and pre-term babies.

Increases in the number of vehicles on the road lead to increases in accident-related deaths and injuries.

Studies have indicated that heavy traffic also leads to an increase in stress levels and possibly also raises the risk of heart attacks.

Commercial Transportation

Commercial transportation presents unique challenges for the development of sustainable transportation, because it requires the distribution of goods across the country.

For the time being, delivery trucks and semi-trucks are necessary for the distribution of goods across the country. These large vehicles typically have poor gas mileage and higher emissions than compact vehicles. However, there may be ways to decrease the negative impacts of these vehicles in the future through improvements in efficiency and different fuel sources.

Medium and heavy-duty trucks such as those used in commercial transportation contribute approximately 20% of the greenhouse gas emissions from transportation. Other means of commercial transportation such as airplanes, ships, and trains account for less than 20%. Fuel consumed in international travel by aircraft and marine sources is not counted in national greenhouse gas inventories, so the actual number is higher.

Aircraft can have some unique and complex effects on the atmosphere due to the release of emissions and water vapor at high altitude. Contrails affect the cloudiness of the earth's atmosphere, and therefore might affect atmospheric temperature and climate.

Sustainable Solutions
There are many options available today for improving the sustainability of our transportation systems. The “best” solutions likely vary by region, with different combinations of options working in under different scenarios.

- The green transportation hierarchy is the basic concept behind transportation reform groups all over the world. The hierarchy puts cyclists and pedestrians first, rewarding their low cost, space efficiency and low environmental impact. Single occupancy vehicles are last. Trucks are not last due to the vital commercial functions that they serve. http://www.transalt.org/files/newsroom/magazine/012Spring/09hierarchy.html

It is important that we take into consideration the entire lifecycle of various transportation options when weighing their respective pros and cons.

- It is important to take all aspects of production, use, and disposal into consideration when calculating the sustainability of transportation options. Some sustainable transportation options may require energy from heavily polluting sources, even though the option itself emits very small amounts of pollutants. Similarly, some options may emit fewer greenhouse gases during their usable life, but then have serious environmental implications for disposal.
- Estimates of greenhouse gas emissions from vehicle exhaust do not include additional "lifecycle" emissions related to transportation, such as the extraction and refining of fuel and the manufacture of vehicles, which are also a significant source of domestic and international GHG emissions. http://climate.dot.gov/about/transportations-role/overview.html

Improving the fuel efficiency of cars, buses, and other forms of transportation is something that we can start doing immediately to reduce new greenhouse gas emissions.

- Improving fuel efficiency will buy us time while improved alternative fuel source technologies are developed
- Improved fuel efficiency reduces greenhouse gas emissions and saves drivers money at the pump.

Driving behavior and vehicle maintenance can have substantial impacts on fuel efficiency.

- Instead of taking multiple short trips, link your trips together. This decreases the number of times you need to start your car on a cold engine, which creates more pollution.
- Don’t idle. Idling leads to more emissions than stopping the car, then starting it up again shortly after (while the engine is still warm).
- Speeding, rapid acceleration, and abrupt braking can decrease fuel efficiency by 33% at highway speeds.
- If your family owns more than one vehicle, choose the one with higher gas mileage whenever possible.
- By driving more slowly, you can increase fuel efficiency. Each five miles per hour over 60 miles per hour is like paying an additional 20 cents for gas. http://www.greendirectorymontana.com/articles/11_sustainable_driving_tips_save_$_313
  - If you drive a car with manual transmission, change gears at the right revs.
  - Use the lowest manufacturer-recommended octane gasoline
  - Travel during off-peak hours
  - Close windows when driving on the expressway to reduce drag
  - Take the shortest route with the best roads
- Practice proper vehicle maintenance
  - Keep your engine serviced and in good working order.
  - Regularly check and replace fuel filters.
  - Use high-quality oil.
  - Make sure tire pressure is where it should be. This increases the life of the tires and improves efficiency.
  - Don’t keep extraneous objects in your car. This adds weight and increases emissions.
Developments in alternative fuel source options may provide long term solutions to many of the problems that our reliance on transportation has caused.

- Several alternatives to traditional gasoline and diesel fuel are in existence today, each having its own set of advantages and drawbacks.
  - Biofuels
    - First Generation Biofuels
      - Biodiesel is made from plant oils, typically soybean. It can be used in any diesel engine with little to no modification of the engine. Biodiesel reduces most greenhouse gas emissions, but concerns include:
        - Increased nitrogen oxide emissions
        - Decreased fuel efficiency (depending on engine and fuel blend)
        - Negative impacts from extensive farming.
        - [http://www.globalstewards.org/biodiesel.htm](http://www.globalstewards.org/biodiesel.htm)
      - Corn grain ethanol reduces greenhouse gas emissions and comes from corn, a plentiful crop in the United States. Corn grain ethanol also comes with concerns, which include:
        - Decreased fuel efficiency by 30-40 percent (depending on fuel blend and engine).
        - Only a small portion of the plant is utilized.
        - Food shortages that can drive up price
        - Habitat destruction.
        - High cost
        - Increased smog in urban areas and negative environmental impacts from transporting the crops.
      - Ethanol can also be generated from sugarcane stalks or sugar beets. However, it comes with similar concerns to corn grain ethanol, including cost, food shortages, and habitat destruction.
    - Second Generation Biofuels
      - Second generation biofuels are biofuels created from the “leftovers” of crop and forest harvesting as well as non-food crops. This eliminates the food shortage issue of corn grain ethanol and uses the plant more efficiently.
        - There are still issues with land use and clearing land area for crops, which can destroy carbon-sequestering ecosystems.
      - Cellulose is found in all plant material and may be utilized to manufacture biofuels.
        - This advanced cellulosic biofuel can be derived from agricultural waste and fast-growing switchgrass.
        - Advanced cellulosic biofuels, like other forms, reduces greenhouse gas emissions.
        - Production is not limited to regions where corn can be produced, and it does not require the same excessive use of fertilizers, pesticides, and energy and water to grow as traditional crops.
        - The refining process for advanced cellulosic biofuels is more complex than that of corn grain ethanol, but the resulting product has a higher energy yield.
        - [http://www.seco.cpa.state.tx.us/re_ethanol_cellulosic.htm](http://www.seco.cpa.state.tx.us/re_ethanol_cellulosic.htm)
  - Third Generation Biofuels
While still a highly experimental process, researchers are looking into the possibility of converting oil produced from the growth of algae into biodiesel, and then using the carbohydrate content for ethanol.

- These fuels reduce greenhouse gas emissions, but growing the algae in high enough concentrations is complex and expensive.
- It is possible for algae to double in volume overnight under the right conditions.
- Algae production may also remove carbon from the atmosphere through photosynthesis.

http://www.popularmechanics.com/science/energy/biofuel/4213775

- Electric
  - Using battery power does not result in any tailpipe emissions, and they are 99% cleaner than gasoline-powered vehicles. However, concerns with battery power include:
    - Recharging from conventional energy sources often results in using energy that was generated from power plants that emit high levels of greenhouse gasses and pollutants.
      - Approximately 90% of Wisconsin’s generating capacity comes from power plants that burn fossil fuels.
      - Using solar energy to recharge the battery can eliminate this issue.
    - Limited range and time to recharge
    - Proper manufacturing and disposal of the batteries themselves can be problematic.


- Hybrid electric
  - Hybrid electric vehicles include an electric motor along with a combustion engine. This alleviates some of the concerns related to range and recharge time. However, hybrid electric vehicles still emit greenhouse gasses and have the same environmental concerns related to battery use.

- Hydrogen
  - Hydrogen fuel cell vehicles run off of energy generated from the reaction between hydrogen and oxygen, with water being the only byproduct. When pure hydrogen is used, the result is zero fossil fuel use and zero greenhouse gas emissions.
  - We are currently only capable of producing hydrogen through a process that requires fossil fuels, which results in the production of greenhouse gasses.
    - If we can develop a way to utilize solar energy to produce hydrogen, then there will be zero greenhouse gas emissions.
  - Fuel cell vehicles are at this point primarily prototypes, and therefore current costs are high.
  - Fuel cells do not need to be plugged in, but need to be refueled more frequently than traditional gasoline vehicles.


Well-designed public transportation systems can reduce our reliance on single-passenger vehicles and promote social capital and community identity and involvement.
In most of America, towns and cities are designed around convenience to cars as a mode of transportation. [http://www.ywalk.ca/downloads/PCVS_survey_results.pdf](http://www.ywalk.ca/downloads/PCVS_survey_results.pdf)

Increased use of public transportation results in fewer cars on the road and has the potential to greatly decrease emissions.

- Public transportation systems designed using sustainable technologies can even further reduce negative environmental impacts.

Improving the attractiveness of public transportation systems can improve the sustainability of transportation, especially in the winter months when walking and biking are less feasible.

- Currently, punctuality, frequency, and practicality of routes are major issues.

Improved public transportation systems would allow for more equality within communities by providing transportation to older adults, minority groups, and low-income individuals.

Access to public transit can expand job opportunities, increase worker satisfaction and productivity by lessening commute times, and cushion the effect of high gasoline costs on working families. [http://www.tc.gc.ca/eng/programs/environment-utsp-socialimplications-1013.htm](http://www.tc.gc.ca/eng/programs/environment-utsp-socialimplications-1013.htm)

Improving the attractiveness of public transportation in a community can improve the vitality of the city as well as affordability and environmental conditions.

- According to the American Automobile Association, the average annual cost of driving a car is $8,485. Of that amount $7,095 leaves the community in payments for finance charges, gasoline, insurance, etc.

- Transit costs the user far less (in Madison, an unlimited ride monthly bus pass is $55 – or $660 a year. That represents an annual savings of more than $7,500 over driving. That number does not including parking which can total more than $120 a month. [http://www.1kfriends.org/category/transportation/](http://www.1kfriends.org/category/transportation/)
  - Availability of bike lanes, bike parking, and distance between amenities impacts the attractiveness of using bicycles for transportation.

Well thought-out land use planning strategies can improve the safety and accessibility of communities.

- Safe neighborhoods where parents feel comfortable allowing children to play outside and walk or bike to school encourages social interaction, exercise, and independence.

- Genuinely walkable or bikeable communities provide adequate infrastructure including sidewalks, bike paths, and traffic calming measures, as well as attractive destinations such as shops and restaurants.
  - To encourage walking, destinations should be a reasonable 5-10 minute walk.
  - With destinations close by, car trips are shorter, resulting in fewer vehicle miles driven.
  - Ensuring both walkability and economic viability requires a high enough density of housing to support local businesses. However, high density does not imply that entire neighborhoods or communities need to be uniformly dense. Communities that provide higher average “blended densities” featuring a mix of land uses, nearby employment centers, vibrant streets, and nearby access to common green space can make considerable gains in reducing transportation related energy use. [http://www.uwsp.edu/cnr/landcenter/megatrends/docs/EnergyMegatrendswhite.pdf](http://www.uwsp.edu/cnr/landcenter/megatrends/docs/EnergyMegatrendswhite.pdf)

- Encouraging carpooling and providing park and ride lots can reduce greenhouse gas emissions by reducing the number of single-passenger vehicles on the road.

- Transit Oriented Development (TOD) is a strategy to create land use pattern that support mass-transit and reduce automobile miles traveled.
  - The focal point is the transit stop (bus, train, trolley, etc.) which is surrounded by relatively high levels residential and commercial development.

The present pattern of land use shapes the present demand for transportation, while transportation investment decisions shape the future patterns of land use.
Young people, parents, and schools must be involved in decisions regarding transportation in order for long-term change to take place.

- As the drivers and decision-makers of the future, young people must be involved in efforts to reduce the use of personal vehicles for transportation. This includes involvement in city planning and improving practicality and attractiveness of alternative means of transportation.
- Youth mobility is dependent upon the automobile, and children grow up associating cars with access to previously inaccessible places. Obtaining an automobile also has implications for parent-child relationships and relationships with peers. [http://www.ywalk.ca/downloads/PCVS_survey_results.pdf](http://www.ywalk.ca/downloads/PCVS_survey_results.pdf)
- Increases in the frequency with which parents drive students to school have led to serious consequences for children’s spatial skills and perceptions of the environment.
- Increased knowledge and engagement in environmental issues go hand-in-hand with education. Therefore, we cannot expect a change in transportation attitudes and behavior without an increase in environmental knowledge (not necessarily formal education).