3. Planning considerations

A wide variety of issues must be considered as the Iowa Department of Transportation (DOT) plans the future transportation system. While several far-reaching subjects are identified in this chapter, these planning considerations do not represent an exhaustive list, and new issues are likely to arise over the life of the Plan. This chapter will cover the following planning topics. Many of these themes recur in the strategies identified in Chapter 5.

- Economic vitality
- Energy
- Environmental justice
- Environmental mitigation
- Land use and livability
- Maintenance and preservation
- Management and operations
- Safety
- Security
- Technology

3.1 Economic vitality

One consideration critical to the transportation planning process is economic vitality. Throughout Iowa's history, economic growth has occurred along thoroughfares of all forms, from rivers to railroads to highways. While the relationship between transportation improvements and economic growth seems rather straightforward, many professionals and academics would argue it is not yet fully understood. Regardless, it is critical that the potential economic impacts of transportation projects are considered during the planning process.

The impact of each mode on Iowa's economy is covered in Chapter 4. Within the Iowa DOT, the importance of this consideration is manifested in a number of ways. For example, the Five-Year Program identifies several transportation policies, the first of which is to promote a safe transportation system that addresses user needs and maximizes economic and social benefits for Iowans. As part of the programming process, economic development impacts are considered as candidate projects are identified and evaluated. In addition, the Revitalize Iowa's Sound Economy (RISE) Program has funded more than 770 transportation projects and provided more than $405 million in assistance to support the creation and retention of nearly 83,000 jobs over the program's 30-year existence.

Another example of an effort related to economic vitality is the freight network optimization project, which was a joint effort with the Iowa Economic Development Authority (IEDA) completed in 2016. The goal of this project was to effectively identify and prioritize investment opportunities for an optimized public and private freight network to lower transportation costs for Iowa's businesses and to promote business growth in Iowa. The optimization strategy will assist in improving the effectiveness and performance of the multimodal freight transportation network. It is expected that, over time, the optimization strategy will lower or stabilize transportation costs for Iowa businesses, make Iowa's transportation system a more valuable and efficient asset in economic development, and enhance freight mobility. These examples are just a few illustrations of the value that the Iowa DOT has placed on economic vitality.

3.2 Energy

Energy issues are another important consideration in transportation planning. Areas where energy and transportation overlap include the cost and availability of fuel, the production and movement of different types of fuel, and the impact of alternative fuel vehicles on transportation.

Iowa Energy Plan

The Iowa Energy Plan[1] was developed in 2016. The plan is a joint initiative between the Iowa DOT and IEDA. Iowa's energy plan is a means to set state priorities and provide strategic guidance for decision-making while working to encourage energy, economic, and environmental benefits through goals and recommendations. It includes an assessment of current and future energy supply and demand, examines existing energy policies and programs, and identifies emerging energy challenges and opportunities. The plan synthesizes the existing state energy goals and strategies that are beneficial for the state, and outlines new objectives and strategies to position Iowa for the future.

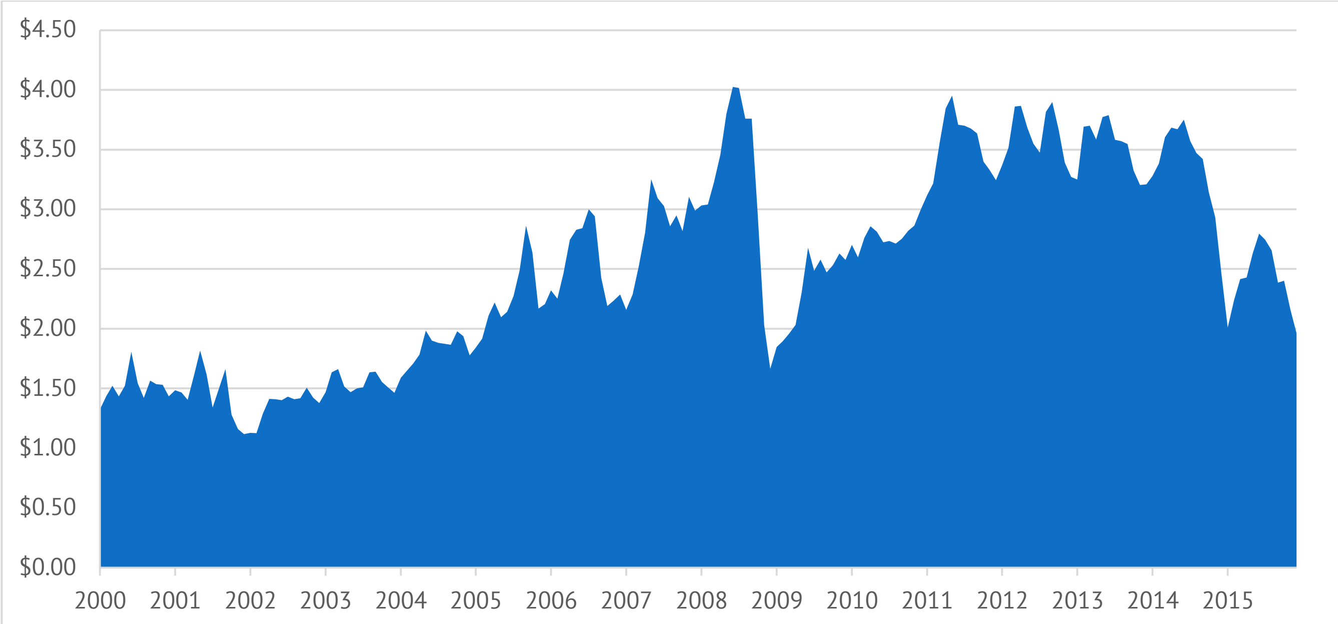
The plan was built on four foundational pillars, one of which is transportation and infrastructure. The other three are economic development and energy careers, Iowa's energy resources, and energy efficiency and conservation. Several strategies derived from the energy plan have been included in the action plan in Chapter 5.

Fuel supply and cost

Both the supply and cost of fuel can directly affect many facets of the transportation industry. For example, when the cost of fuel fluctuates noticeably, driving behavior can change and create an immediate impact on the transportation system through variations in number of miles driven and changes in mode of travel. Such changes in behavior can also have more far-reaching impacts, as notable increases or decreases in travel can affect transportation-related revenues such as those derived from fuel taxes. Figure 3.1 shows the average monthly price for gasoline in the Midwest from 2000-2015. The lowest price during that time was $1.12 per gallon in December 2001, the highest price was $4.03 per gallon in June 2008, and the average during the 15-year time period was $2.51.

[1] http://www.iowaenergyplan.org/

Figure 3.1: Midwest retail average monthly gasoline price per gallon for all grades, all formulations, 2000-2015



Source: U.S. Energy Information Administration

The fuel market can also affect transportation construction costs. In recent years, many state transportation departments have experienced unprecedented construction cost increases. The escalation of global fuel prices is one of several factors that has contributed to higher bid prices. As construction cost inflation continues, the buying power for all revenue sources decreases. In fact, cost inflation can even negate the impacts of increased revenue, as was the case with the Road Use Tax Fund (RUTF) in recent years. An example of this was shown in the TIME-21 Funding Analysis, which noted that even with a 2.9 percent annual increase in RUTF revenue in fiscal year (FY) 2008, construction cost inflation resulted in an 11.0 percent decrease in buying power compared with FY 2007.

In addition to construction costs, the supply and cost of fuel also affect the operational costs associated with maintaining Iowa's expansive and aging public roadway system. If coupled with extreme weather, such as abnormal winter storms, the impacts of high fuel costs are compounded. Increased unit costs for fuel reduces funding available for maintenance, resulting in further deterioration of the system and loss of useful life.

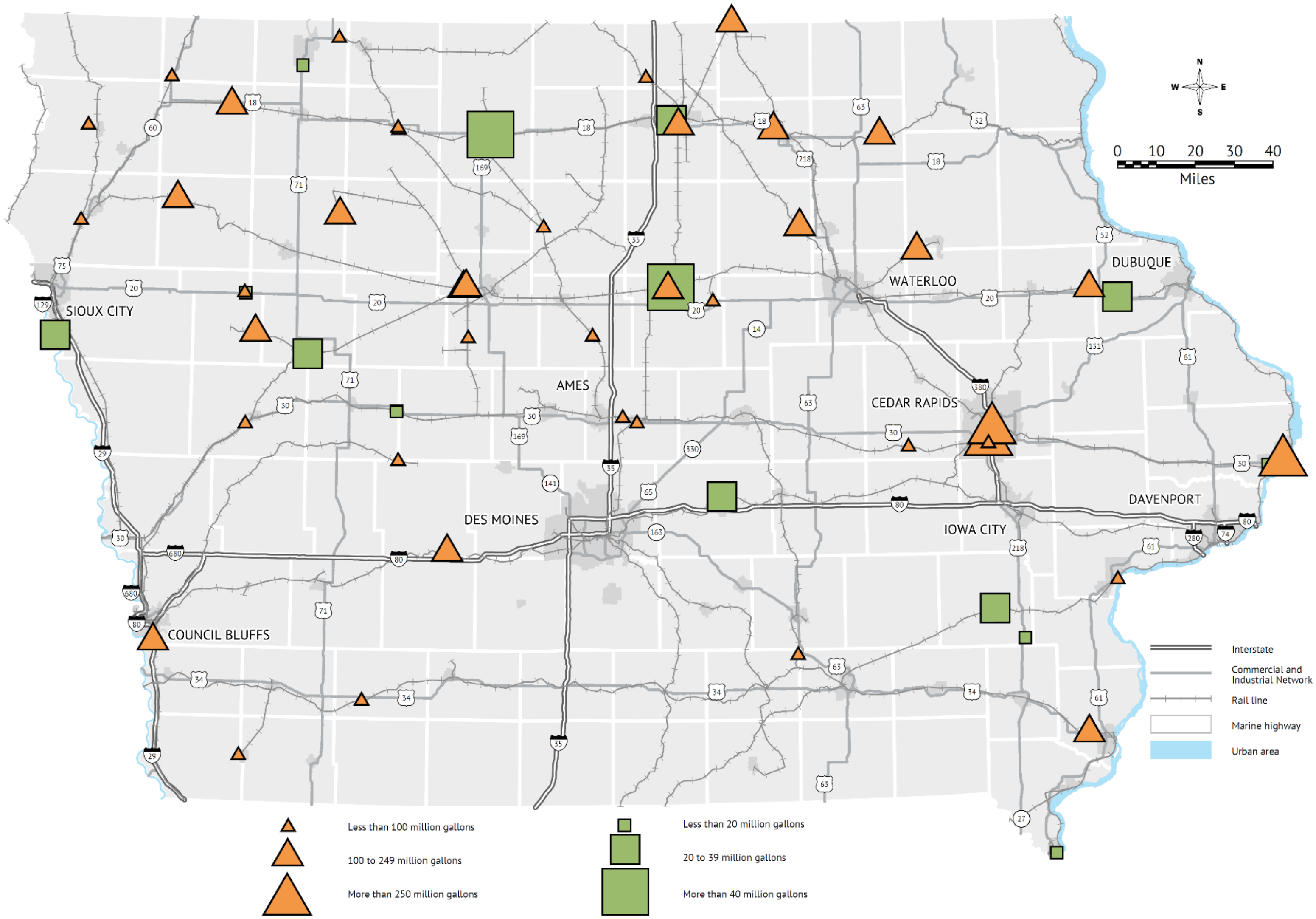
Energy production and movement

Biofuels and wind energy industries

Iowa has emerged as a national leader in both the biofuels and wind energy industries, resulting in physical and financial impacts. An example of these impacts is increased large truck traffic during the construction of a biofuels plant, with traffic remaining relatively high after construction to support plant operations. Increased rail traffic is also common on the lines that service these plants. This traffic growth leads to accelerated infrastructure deterioration and increased maintenance costs. Figure 3.2 provides a map of Iowa's biodiesel and ethanol plants along with their production capacity.

Ethanol and biodiesel fuels have become significant value-added products for Iowa's agricultural economy over the past few decades. Iowa produced 28 percent of the nation's fuel ethanol in 2014, the most of any state. Nationally, 70 percent of all ethanol produced is transported by rail.

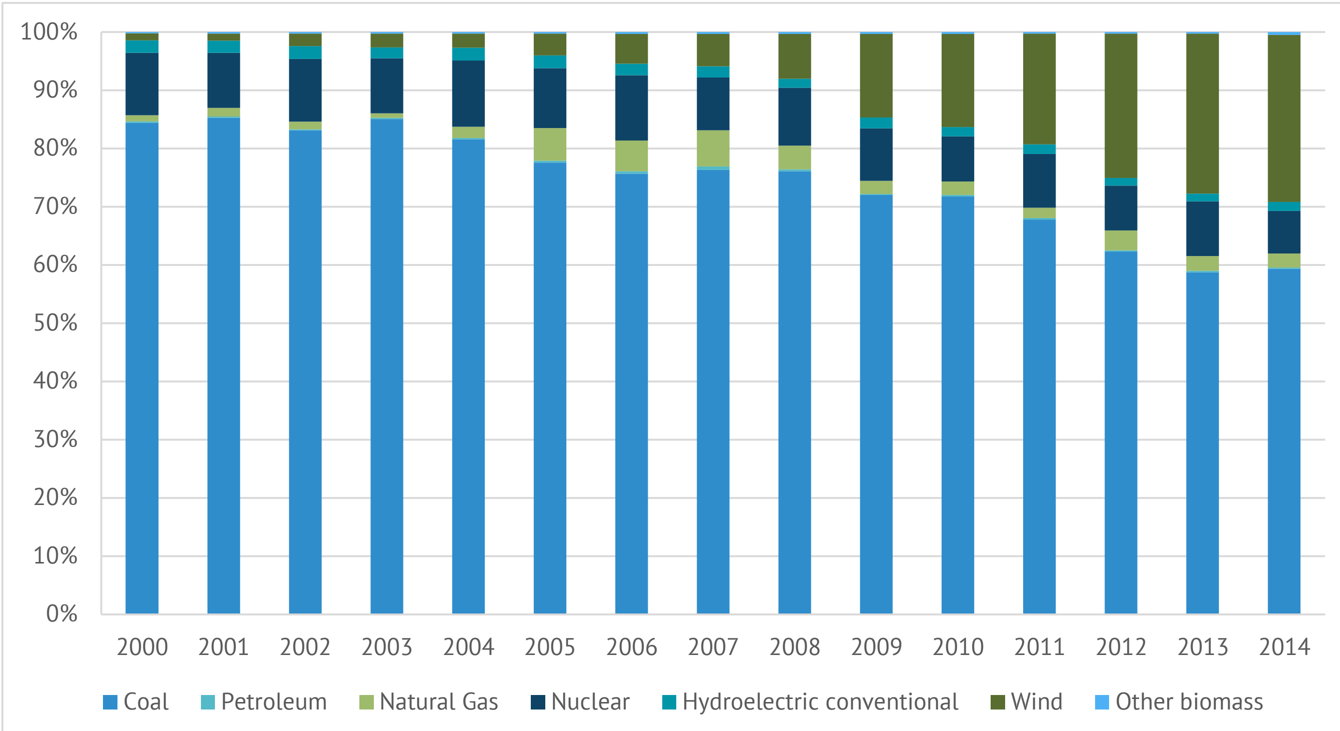
Figure 3.2: Iowa biodiesel and ethanol plants and annual production capacity



Source: Iowa DOT

Iowa has also become a leader in wind energy, and has a higher percentage of its power generated by wind than any other state. Figure 3.3 shows trends in Iowa's energy production since 2000. There are 15 manufacturing facilities in Iowa that produce parts for the wind industry, including a turbine manufacturer, two blade manufactures, and a tower manufacturer. The movements of the raw materials to make these components, the finished products, and the construction equipment to install the turbines has a significant impact on Iowa's transportation system. This requires coordination across modes and planning for the movement of oversize/overweight loads. If the transportation infrastructure supporting these movements deteriorates, costs to move the materials and products associated with these industries will increase. If this happens, the state could lose its competitive edge in these growing economies.

Figure 3.3: Iowa utility generation by source, 2000-2014



Source: U.S. Department of Energy

Crude oil movements

Energy production in the United States has been growing significantly since the turn of the century. One of the largest growing sectors, and perhaps the one with the largest impact on the national freight network, is hydraulic fracturing of rock or "fracking." This process allows for the recovery of deep sources of gas and petroleum products. Fracking has resulted in large amounts of gas and oil being extracted, particularly from the Bakken Shale formation region of North Dakota, Montana, and parts of Canada. This can have major transportation impacts, including increased freight traffic (product being shipped from the region and materials used for fracking being shipped to the region) and the potential for lower fuel prices.

Much of the freight movement to and from the Bakken region is by rail due to the fact production has increased at a rate that exceeds the capacity of the nation's pipelines. Of all the oil produced in the Bakken region, roughly 63 percent is shipped by rail with a portion of that traveling through Iowa. Since 2008, oil shipments carried by two Class I railroads in Iowa have increased by nearly three million tons. There were two billion gallons of crude oil shipped on Iowa railways in 2014. Destinations include oil refineries on the East and Gulf coasts. In 2016, construction began on a pipeline to transport Bakken oil through South Dakota and Iowa to Illinois, which may affect the amount of crude oil shipped on Iowa rail lines.

Iowa DOT completed the *Iowa Crude Oil and Biofuels Rail Transportation Study*[2] in 2016. The study considered both the physical characteristics (i.e., people, facilities, environment) in the vicinity of the crude oil and biofuels rail routes, as well as the insight of representatives from all sides of this industry. The study recommended improvement strategies in the areas of prevention, preparedness, response, and recovery.

Alternative fuel vehicles

In addition to the use of ethanol to make E85 and other fuel blends, and the use of biodiesel, additional fuel sources are becoming common options for alternative fuel vehicles. The use of natural gas as a transportation fuel is being explored and adopted by some trucking and railroad companies. When used as transportation fuel, natural gas comes in the form of either compressed natural gas (CNG) or liquefied natural gas. The use of natural gas as a fuel in the trucking industry has increased substantially in the past several years. Despite the lower cost of diesel fuel in recent years, the price of natural gas has remained even lower, and future projections show prices remaining steady. Typically, trucking companies will add CNG vehicles to their fleets allowing for greater diversification and the ability to switch between diesel and natural gas for higher-mileage routes depending on the lower-cost option.

[2] http://www.iowadot.gov/iowarail/safety/crudeoilbiofuels.htm

Electric vehicles have also become increasingly popular. Hybrid electric vehicles are powered by a combination of an internal combustion engine and an electric motor that uses stored battery energy. These vehicles do not receive energy from plugged charging; typically, the battery is charged by either regenerative braking or by the internal combustion engine. Plug-in hybrid electric vehicles can be powered through plug-in sources, and may or may not have an internal combustion engine for charging and/or operating.

The growth in alternative fuel vehicles has several implications for transportation planning. They provide air quality benefits by aiding in the reduction of greenhouse gases. While many of these technologies require a higher up-front investment, the fuel sources tend to be a lower-cost option over the life of the vehicle. Some of these fuel sources require retrofitting equipment or providing new infrastructure, such as storage tanks for CNG and charging stations for electric vehicles. If alternative fuel vehicles continue to grow in popularity, they will also have significant implications for traditional transportation revenue sources, such as the fuel tax.

3.3 Environmental justice

On Feb. 11, 1994, Executive Order (E.O.) 12898 was signed into law by President Clinton and required “each federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States.” It is through E.O. 12898 that the policies set forth in the Civil Rights Act of 1964 and Title VI of the National Environmental Policy Act of 1969 are clarified and enforced. While federal regulations do not specifically require environmental justice (EJ) to be considered in the development and content of a long-range statewide transportation plan, the Iowa DOT believes that the importance of this issue warrants inclusion in the Plan.

EJ defined

According to the U.S. Environmental Protection Agency, EJ is defined as:

> "The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people, including racial, ethnic, or socioeconomic group should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies."

EJ is the term used to describe the uneven environmental and social hardships that disadvantaged groups bear. EJ is a broad and multifaceted social welfare issue with the goal of improving the disparate or unequal impacts of growth and development, such as crime, hazardous waste sites, and pollution. It also aims to ensure equitable access to physical and social opportunities, such as clean air and water, education, food, jobs, and transportation.

EJ and transportation planning

Within the realm of transportation, consideration of EJ is important given that impacts of transportation can be both beneficial (e.g., improved access and mobility) and burdensome (e.g., increased noise and congestion). Because of the diverse and potentially uneven transportation impacts, it is important that EJ be included throughout the transportation planning process, including short- and long-range planning and public participation outreach efforts. Specifically, by identifying the transportation patterns of socially disadvantaged groups (e.g., minority and low-income) and involving them in the public participation process, the needs of these groups can be determined and assessed to guide transportation investment and ensure impacts are distributed as evenly as possible.

Americans with Disabilities Act (ADA) of 1990 compliance

Another issue closely tied to EJ under the umbrella of civil rights is that of compliance with ADA. Title II of this legislation emphasizes the accessibility of infrastructure within the public right of way. Title II also requires the Iowa DOT to develop a transition plan to bring facilities into compliance with ADA. As a result, a transition plan was developed identifying specific steps the Iowa DOT will take to achieve ADA compliance for pedestrian facilities. These steps are:

1. Identify physical obstacles limiting the accessibility of programs or activities to individuals with disabilities.
2. Describe in detail the methods that will be used to make facilities accessible.
3. Develop a schedule for achieving compliance.
4. Identify the Iowa DOT's ADA coordinator who will be responsible for ADA compliance.
5. Develop a grievance procedure to review complaints.
6. Initiate public involvement and provide community awareness.

The first four steps are the minimum requirements for a transition plan as set forth by 28 CFR 35.150. The remaining steps are additional requirements for achieving ADA compliance as set forth by Title II. In addition to the above steps, the Iowa DOT will track and report on their progress. To ensure ongoing compliance with ADA requirements, the Iowa DOT will perform periodic reviews of the plan and update as necessary.

3.4 Environmental mitigation

National Environmental Policy Act (NEPA)

NEPA defines the process used by decision-makers to make informed decisions on proposed federal actions, which includes federally funded Iowa DOT actions. NEPA requires the examination and avoidance of potential impacts to the social and natural environment when considering approval of proposed transportation projects. The NEPA process is an approach to balanced transportation decision-making that takes into account the potential impacts on the human and natural environment and the public's need for safe and efficient transportation. For recipients of federal funds, this means that before proceeding with final design, right of way acquisition, and construction, the project sponsor must first disclose any environmental consequences and evaluate alternatives that would avoid or lessen the project's impacts. In addition to evaluating the potential environmental effects, transportation needs of the public must also be taken into account when reaching a decision that is in the best overall public interest.

The U.S. DOT adopted the policy of managing the NEPA project development and decision-making process as an "umbrella," under which all applicable environmental laws, EOs, and regulations are considered and addressed prior to the final project decision and document approval. Conclusion of the NEPA process results in a decision that addresses multiple concerns and requirements, including many individual regulations under the NEPA umbrella.

Levels of environmental analysis

Transportation projects vary in type, size, complexity, and potential to affect the environment. Transportation project effects can range from minor to significant impacts on the natural and human environment. To account for the variability of project impacts, three basic "classes of action"[4] are allowed, which determine how compliance with NEPA is carried out and documented. This decision-making process is shown in Figure 3.4.

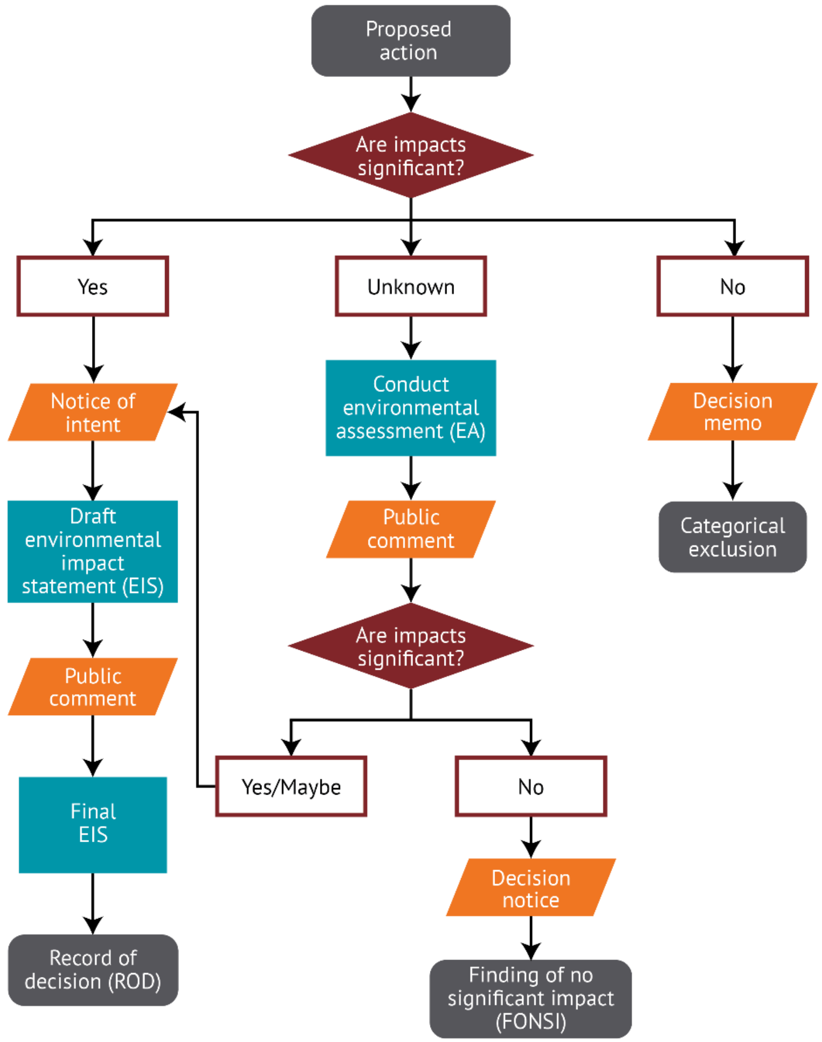
[4] https://www.environment.fhwa.dot.gov/projdev/pd4document.asp

- An environmental impact statement (EIS) is prepared for projects where it is known the action will have a significant effect on the environment.
- An environmental assessment (EA) is prepared for actions for which the significance of the environmental impact is not clearly established. Should environmental analysis and interagency review during the EA process find a project to have no significant impacts on the quality of the environment, a finding of no significant impact (FONSI) is issued. If significant issues are found, an EIS is prepared.
- Categorical exclusions are issued for actions that are not individually or cumulatively significantly affecting the environment.

Linking planning and NEPA

When possible, it is important to create an early linkage between planning and NEPA to discuss developing early analysis and preliminary decision-making that can be incorporated into the project-level NEPA process. The Federal Highway Administration (FHWA) defines the Planning and Environment Linkages (PEL) program as: "a collaborative and integrated approach to transportation decision-making that 1) considers environmental, community, and economic goals early in the transportation planning process; and 2) uses the information, analysis, and products developed during planning to inform the environmental review process." This helps provide a solid foundation of information for the environmental review process, and enables early analysis, public input, and decisions to help streamline the environmental review decision-making process. PEL activities at the Iowa DOT are discussed further in Chapter 5.

Figure 3.4: NEPA document decision process



Source: U.S. Environmental Protection Agency

Environmental mitigation

Environmental mitigation proceeds differently at the planning and project development levels. At the broad, long-range planning level, it is primarily achieved through the inclusion of environmental resource inventories in the planning process and a comparison of transportation planning inputs and outputs to any environmentally sensitive resources. This is done to determine possible conflicts or benefits. Types of efforts typically conducted during this process include the development of inventories of environmentally sensitive resources, consultation with agencies at various levels of government that are responsible for environmental resources and oversight, and discussion of mitigation activities at the policy and strategy level.

The project development level involves the NEPA process outlined previously. Depending on the type of project and its potential environmental impacts, it may require a detailed environmental review. Should there be potential for major environmental impacts, mitigation measures will likely be required. Mitigation occurs in the following sequenced approach.

- Avoid the impact altogether by not taking a certain action or parts of an action.
- Minimize impacts by limiting the degree or magnitude of the action and its implementation.
- Rectify the impact by repairing, rehabilitating, or restoring the affected environment.
- Reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action.
- Compensate for the impact by replacing or providing substitute resources or environments.

Some example mitigation activities may include:

- Replace impacted wetlands at a minimum of 1:1 or 1:1.5 ratio.
- Replacement of parkland at 1:1 ratio or equivalent usage ratio.
- Avoid parking and/or storing construction equipment in the vicinity of potential groundwater contamination.
- Preserve trees along watercourses to protect aquatic life and prevent streambank erosion.
- Construct noise and/or visual barriers.
- Physically move the impacted resource while maintaining the structural integrity and historic qualities.
- Document the historical nature of a structure prior to demolition.

The mitigation activities highlighted above have the potential to be very costly. However, these expenses should be considered as a cost of doing business, and should be reflected in the overall project cost estimates. Ultimately, the planning and coordination described in this section involves approaching a project area as one functioning ecosystem, which has the potential to be impacted by any planned activity.

Air quality and climate change

Two issues closely tied to the subject of environmental mitigation, air quality and climate change, have received a considerable amount of attention in recent years. The Iowa DOT has been monitoring a number of recent air quality developments, particularly those related to the National Ambient Air Quality Standards (NAAQS) for particulate matter and ozone. The NAAQS for particulate matter were last adjusted in 2013, and the NAAQS for ozone was most recently lowered in 2015. Iowa continues to remain in attainment for both these criteria air pollutants. A nonattainment status would result in additional transportation planning and programming requirements for the state.

As Iowa prepares for the possibility of increasing air quality regulation, the state is also preparing for the effects of a changing climate. These impacts, particularly extreme weather events, would not only affect the state in areas such as agriculture and public health, but could also result in serious implications for Iowa's transportation infrastructure. According to Climate Change Impacts on Iowa, a 2010 report by the Iowa Climate Change Impacts Committee, the 2008 flooding in Iowa accounted for $660 million in infrastructure losses. Resiliency has become increasingly important at all levels of planning, from designing projects to withstand extreme weather events to having plans in place for responding to emergency weather situations. Smaller-scale efforts are underway as well. As Iowa expects to continue to receive higher levels of precipitation than in the past, some areas of the state have already started implementing elements of "green" infrastructure to improve managing stormwater runoff, by using permeable pavements, bioswales, rain gardens, and more.

Iowa's changing climate and air quality levels have the potential to affect the state's current transportation infrastructure and future project decisions greatly, and it is vital these issues are considered during the planning process.

3.5 Land use and livability

The 2015 federal surface transportation reauthorization bill, Fixing America's Surface Transportation (FAST) Act, continued to emphasize the need to consider land use and quality of life as one of the bill's 10 transportation planning factors. This planning factor, which states: "Protect and enhance the environment, promote energy conservation, improve quality of life, and promote consistency between transportation improvements and state and local planned growth and economic development patterns," has been used to guide the following discussion on planning for transportation, land use, and livability in Iowa.

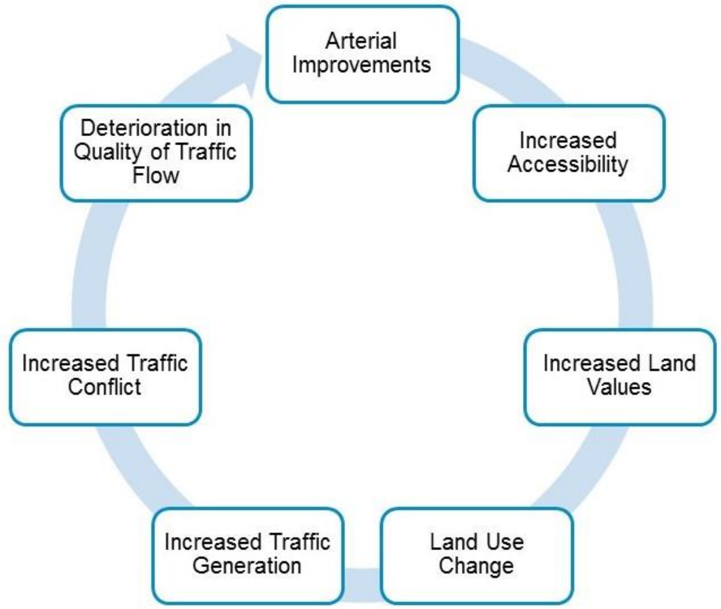
Land use

Land use can be defined as the human management of land. In land-use planning, areas are often classified to accommodate a variety of uses, such as residential, commercial, industrial, agricultural, and more. Coordinating land use and transportation planning is essential in creating more sustainable, vibrant, and well-connected communities. Several recent planning initiatives involving concepts such as new urbanism, smart growth, complete streets, and transit-oriented development are only achievable when cooperation between the transportation and land-use sectors takes place. In addition to creating healthier, safer, and more efficient communities, sensible land-use decisions are essential to Iowa's economy, where urban expansion can permanently destroy valuable farmland.

The linkage between transportation and land use is also demonstrated through access management, which is the management of vehicular access points to adjacent land parcels. Managing access points increases safety and efficiency for travelers. Common access management techniques include providing larger spaces between driveways and side streets; increasing the distance between access points and traffic signals; safe turning lanes; median treatments; and right of way management.

While policies, principles, and strategies for integrating transportation and land use can be established on the state level, the most visible coordination takes place on the local level. Figure 3.5 illustrates the cyclical nature between land use and transportation, and shows the need to be continuously mindful of present and future land-use needs when making transportation investment decisions.

Figure 3.5: Transportation and land use cycle



Source: FHWA

Livability

In June 2009, the U.S. DOT, in partnership with the U.S. Department of Housing and Urban Development and the Environmental Protection Agency, announced a new interagency effort, the Partnership for Sustainable Communities (PSC). This partnership, which aims to "improve access to affordable housing, provide more transportation options, and lower transportation costs while protecting the environment in communities nationwide," is founded on livability principles, including providing more transportation choices; promoting equitable, affordable housing; enhancing economic competitiveness; supporting existing communities; coordinating policies and leveraging investment; and valuing communities and neighborhoods. The PSC's 2015 priorities were:

1. Using PSC agency resources to advance Ladders of Opportunity for every American and every community.
2. Helping communities adapt to a changing climate, while mitigating future disaster losses.
3. Supporting implementation of community-based development priorities.

In the transportation planning process, livability is an important consideration in maintaining a community's quality of life. A livable community has a well-connected transportation network with many transportation choices and better facilities, which in turn provides access to quality jobs, housing, schools, and other amenities.

Enhancing livability in Iowa through transportation can be achieved by investing in multiple transportation modes, maintaining roadway infrastructure, expanding bicycle and pedestrian facilities, utilizing new technologies, and coordinating new investments with surrounding communities. As Iowa's population grows, it is important to strengthen communities through valuing and supporting the existing transportation network.

3.6 Maintenance and preservation

Routine maintenance refers to the daily functions and activities that provide for an acceptable level of service on the transportation system. Typical highway activities, for example, may address maintenance needs related to potholes, pavement markings, roadway shoulders, snow removal, traffic signs, and signals. Maintenance activities usually address immediate system needs, but they do not address underlying infrastructure deterioration due to time and usage.

In contrast to routine maintenance, preservation strategies appreciably extend the useful life of infrastructure. Preservation strives to use cost-effective and well-timed strategies, such as a surface treatment, to extend the life of system components. Safety and user expectations are important considerations in selecting a specific preservation strategy. Preservation strategies for all modes include a wide variety of improvement categories with specific corrective actions that must be matched to the current age and condition of the candidate component.

In recent years, especially in light of limited funding and increasing costs, the efficient management of Iowa's existing transportation system has been identified as the priority investment path. Iowa's citizens have overwhelmingly expressed their support of this stewardship philosophy and keeping the existing system in a state of good repair before pursuing expansion needs. Some expansion of the existing system is needed, but it will only occur when and where careful planning efforts have identified the need to do so. Yet even with minimal expansion, funding limitations will make maintaining and preserving the existing system at an acceptable level a challenge.

Beyond roadways: maintaining and preserving a multimodal system

It is important to note that maintenance and preservation of the transportation system is more than just highways and the maintenance of those highways. All modes of transportation have critical maintenance and preservation needs. In addition to including all modes, maintenance and preservation also addresses more than the infrastructure components of these modes. The transportation system involves the services and support functions keeping it operational. Examples of these functions include air traffic control, construction materials testing, driver's license renewal, highway patrol duties, intelligent transportation systems (ITS), lock and dam operation, planning support, transit fleet dispatching, and weight-restriction enforcement. Iowa has a comprehensive transportation system that involves many functions and roles that keep it operational.

Asset management

As defined by the American Association of State Highway and Transportation Officials' (AASHTO) Subcommittee on Asset Management, "transportation asset management is a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively through their life cycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision-making based upon quality information and well defined objectives." Given the challenges posed by issues such as aging infrastructure and escalating construction and operating costs, tools such as asset management are increasingly valuable when seeking to balance funding realities with public needs and expectations.

According to FHWA, an effective asset management program can:

- Track system condition, needs, and performance.
- Clearly identify costs for maintaining and preserving existing assets.
- Clearly identify public expectations and desires.
- Directly compare needs to available funding, including operating and maintenance costs.
- Define asset conditions so decisions can be made on how best to manage and maintain assets.
- Determine when to undertake action on an asset, such as preservation, rehabilitation, reconstruction, capacity enhancement, or replacement.

Asset management provides insights and tools to help transportation professionals make wise investments that result in improved service and greater cost-effectiveness. Within the context of transportation planning and programming, asset management can positively influence every phase of the process. This influence is illustrated in Table 3.1.

Table 3.1: Influence of asset management on planning and programming

Common practice	Asset management best practice
Transportation options considered in the long-range plan reflect primarily the choices included in the current transportation program.	The long-range plan identifies transportation options broadly in terms of potential modes and intermodal linkages, types of investments, and program or funding alternatives.
Methods, formulas, and criteria to prioritize projects reflect a historical evolution of engineering, financial, and political factors.	Methods, formulas, and criteria to prioritize projects reflect stated policy objectives, performance measures, and targets.
Projects are evaluated largely in terms of initial cost and judgment as to potential benefit.	Projects are evaluated in terms of realistic estimates of lifecycle costs, benefits, and performance impacts.
Programming is based mainly on intuitive judgment.	Programming is based to the degree possible on objective information, supported by sound analytical procedures.
Management systems and condition surveys are used as engineering or research tools, but are not applied to program building or budgeting.	Information from condition surveys and management systems directly informs the process that builds the recommended program and budget.
Management systems are used only to rank the condition of assets; needs are programmed based on "worst first."	Management systems guide the programming of projects based on valid engineering and economic criteria.

Source: AASHTO

The Iowa DOT has begun an effort to develop and implement asset management strategies. The Iowa DOT believes asset management is necessary to continue providing a high level of service for infrastructure users while balancing maintenance and improvement costs of Iowa's transportation system. The Moving Ahead for Progress in the 21st Century (MAP-21) Act and the FAST Act include the requirement for states to develop transportation asset management (TAM) plans. While rulemaking was not finalized for these requirements until 2016, a steering committee was formed in 2014 to oversee the development of the Iowa DOT's first TAM plan. The initial TAM plan was finalized in fall 2016. In addition to TAM plan development, the Iowa DOT established a highway TAM governance structure, which was a need identified during the TAM plan development. A team was assembled to design a process and governance structure for highway program development with the objectives listed below. While this effort was developed independently of the ongoing MAP-21/FAST Act rulemaking process, much of the team's work aligns with the procedures that need to be formalized for the establishment of performance targets.

- Add transparency to the programming process, align associated tools and plans, and incorporate appropriate stakeholders.
- Define roles and responsibilities of the associated stakeholders.
- Create a process that is adaptable over time as technology, initiatives, and priorities change.
- Oversee the incorporation of risk management into the prioritization process. Provide input to critical plan development efforts, including the TAM plan and state transportation plan.

- Propose performance targets, propose funding levels to achieve those performance targets, and coordinate the associated monitoring and reporting.

Efforts related to TAM governance are discussed further in the programming discussion in Chapter 7. There have also been other parallel efforts pertinent to the development of the TAM plan.

- A committee was formed, including staff from Iowa's city and county governments, called the Iowa Transportation Asset Management (ITAM) group. This group has met on a periodic basis to discuss approaches to harmonize Iowa DOT and local TAM efforts and work together to improve the TAM process in Iowa.
- Pavement management has received a renewed focus. Although Iowa DOT has had pavement management tools for some time, there is work underway to improve pavement models and broaden their use.
- Likewise, for bridge management, there are efforts underway to improve bridge management system models to better forecast deterioration and use that information to select treatment strategies, as well as to forecast network condition under various funding scenarios.

Several asset management strategies derived from the TAM plan are included in the action plan in Chapter 5.

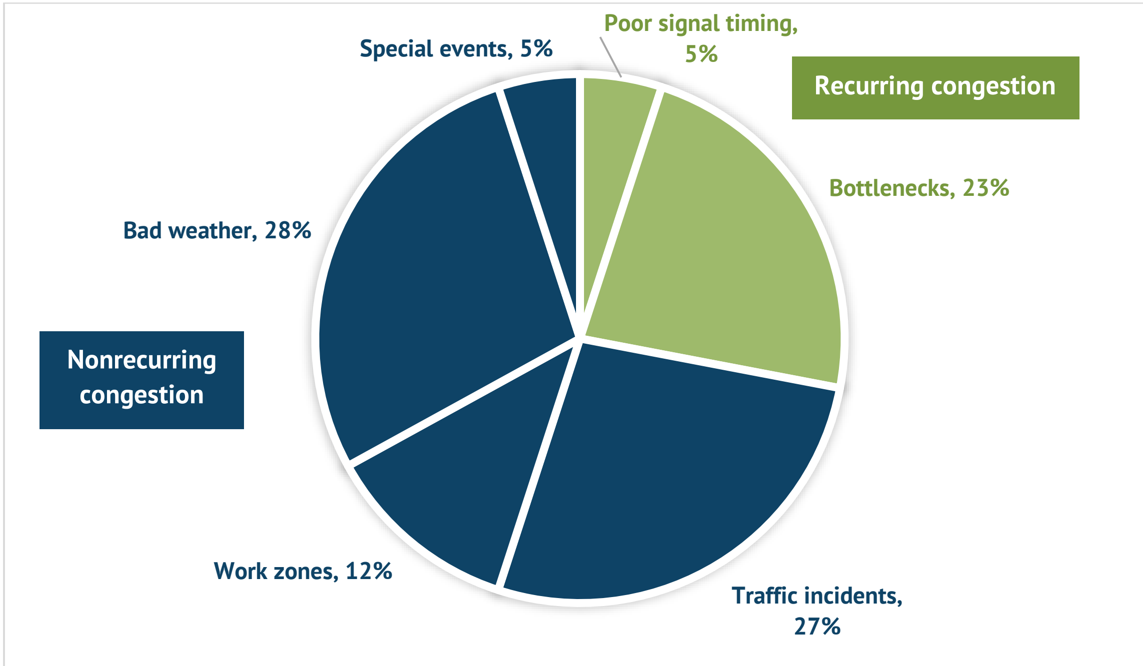
3.7 Management and operations

Traffic on Iowa's roadways has steadily grown over time, which has also increased the potential for crashes and congestion. Optimizing performance of the system is critical to keep traffic flowing in a safe and efficient manner. This is embodied in the strategic approach of transportation systems management and operations (TSMO). The aim of TSMO is to proactively manage and fine-tune the performance of the state's transportation system, particularly by managing or mitigating congestion and incidents. This includes current Iowa DOT strategies such as monitoring the system through traffic cameras and speed sensors, quickly deploying response resources to incidents, and providing traveler information through platforms like Iowa 511. TSMO also includes efforts to prepare for and adapt to changing technology, such as connected vehicles and highly automated vehicles.

Mobility challenges occur on Iowa's roadways every day. Recurring congestion, due to issues like poor signal timing or bottlenecks, accounts for a portion of this issue. However, in Iowa the most significant of these challenges are temporary disruptions that take away part of the roadway from use, known as nonrecurring congestion. Primary causes of this type of congestion include bad weather, traffic incidents, and work zones, as shown in Figure 3.6.

In Iowa, about 72 percent of the congestion and delay experienced by the traveling public is nonrecurring congestion. Nonrecurring congestion can happen anywhere in the state at any time, and the impact of congestion goes well beyond a traffic event. In calendar year 2015, there was an average of approximately 1,400 traffic incidents on state roadways per month, with an average duration of approximately 60 minutes for blocked lanes. Each minute a lane is blocked can lead to 4 to 5 minutes of delay, and for each minute that a primary incident continues, the likelihood of a secondary crash increases by 2.8 percent. The U.S. DOT estimates that secondary crashes represent more than 20 percent of all crashes and are often more deadly than the primary incident. Fewer incidents and quicker clearance of incidents help to reduce congestion, allowing the transportation system to operate more safely and efficiently.

Figure 3.6: Sources of congestion in Iowa, 2013-2015



Source: Iowa DOT

Cost-effective TSMO strategies are used to improve service by "taking back" the transportation system capacity lost to congestion without necessarily adding lanes. TSMO is important because it deals directly with the root causes of congestion, offers the potential to improve safety and efficiency, and can help to maximize existing infrastructure capacity through cost-effective strategies. Ultimately, this improves the safety and mobility of the transportation system and helps Iowans travel to their destinations safely, efficiently, and conveniently.

TSMO planning

There has been a significant TSMO planning effort at the Iowa DOT over the past several years. This has included the development of the overall TSMO plan, which has three levels: strategic, program, and service layer.

TSMO Strategic Plan

The TSMO Strategic Plan highlights Iowa's challenges, makes the case for TSMO, and describes the vision, mission, goals, and strategic objectives for TSMO. It focuses on the benefits of a comprehensive approach to TSMO to support Iowa DOT's vision, and provides a strategic direction for Iowa DOT's TSMO program and integration.

TSMO Program Plan

The TSMO Program Plan is a companion to the Strategic Plan, which provides the structure for a comprehensive TSMO program. The Program Plan outlines the programmatic objectives, strategies, processes, procedures, and resources needed to deliver the vision and goals of the Strategic Plan. The Program Plan covers the following areas.

- **Program objectives**: Provides specific programmatic objectives supporting the strategic goals and objectives.
- **TSMO integration with current plans and programs**: Highlights how TSMO principles support current Iowa DOT plans and programs, and how they can be integrated across the Iowa DOT from the earliest stages of planning and project development.
- **Leadership and organization**: Identifies how the Iowa DOT can adopt effective practices to improve TSMO capabilities and inform future organizational culture.
- **Business processes and resources**: Provides a detailed investigation into a variety of departmental TSMO activities.
- **Performance management and decision support assessment**: Provides a snapshot of ongoing performance measurement activities and highlights the need for improved decision support to make better TSMO-based decisions.
- **Five-Year TSMO Program**: The program includes three components: 1) a tool that leverages the original Interstate Condition Evaluation (ICE) methodology to reflect traffic operations criteria (ICE-OPS); 2) a five-year list of activities that deliver TSMO strategic goals and objectives; and 3) a five-year budget plan.

The program plan has served as the basis of the operations analysis and strategies discussed in Chapter 5. This includes using the ICE-OPS tool to evaluate interstate corridors from an operations perspective, and the incorporation of a number of strategies identified in the Program Plan.

Service layer plans

There will be eight service layer plans that will provide more detailed recommendations and actions for each of the service areas. Table 3.2 defines each service layer. Each service layer plan will outline opportunities and challenges associated with that area; describe existing services, activities, and projects; assess related existing conditions; identify service gaps; provide actionable recommendations; develop performance measures and an evaluation process; and provide a five-year service layer cost estimate.

Table 3.2: TSMO service layers

Service layer	Definition
Traffic management center (TMC)	The round-the-clock hub of traffic coordination and management activities throughout the state.
ITS and communications	Fixed and mobile traffic sensors, non-enforcement traffic cameras, dynamic message signs, highway advisory radio transmitters, and supporting communications infrastructure.
Traveler information	Traveler information tools that communicate planned and prevailing traffic conditions, such as Iowa 511 and various social media.
Traffic incident management	The coordination of Iowa DOT and its partners' response to routine highway traffic incidents.
Emergency transportation operations	The coordination of Iowa DOT and its partners' response to large scale incidents (not necessarily highway-related), such as flooding, tornadoes, epidemics, etc.
Work zone management	The planning and deployment of various strategies to maintain traffic flow and safety through highway work zones.
Active transportation and demand management	Innovative strategies to maximize available capacity of roadways, such as ramp metering, variable speed limits, lane control signing, active signal control, and time-of-day shoulder use.
Connected and autonomous vehicle	While still an emerging technology, this service layers considers the challenges and opportunities of vehicle-to-vehicle and vehicle-to-infrastructure connectivity and autonomous vehicles to improve vehicle safety and efficiency.

Source: Iowa DOT

Office of Traffic Operations

The Office of Traffic Operations was formed in 2013, partially to help consolidate staff working in areas of TSMO across the department. In addition to overseeing the department's TSMO efforts, some of the office's key duties include:

- Management of the day-to-day traffic operations on the highway system through the 24-hour statewide traffic management center (TMC).
- Management of the emergency transportation operations (ETO) response efforts on behalf of the Iowa DOT.
- Management and maintenance of the 511 Travel Information System.
- Deployment and maintenance of ITS on the highway system.
- Development and maintenance of a coordinated, comprehensive statewide traffic incident management (TIM) response plan.
- Traffic critical projects planning and deployment.
- Traffic incident and emergency management, including federal Emergency Relief program, statewide/regional TIM planning, state and local agency coordination, emergency management, and major incident after-action reviews.

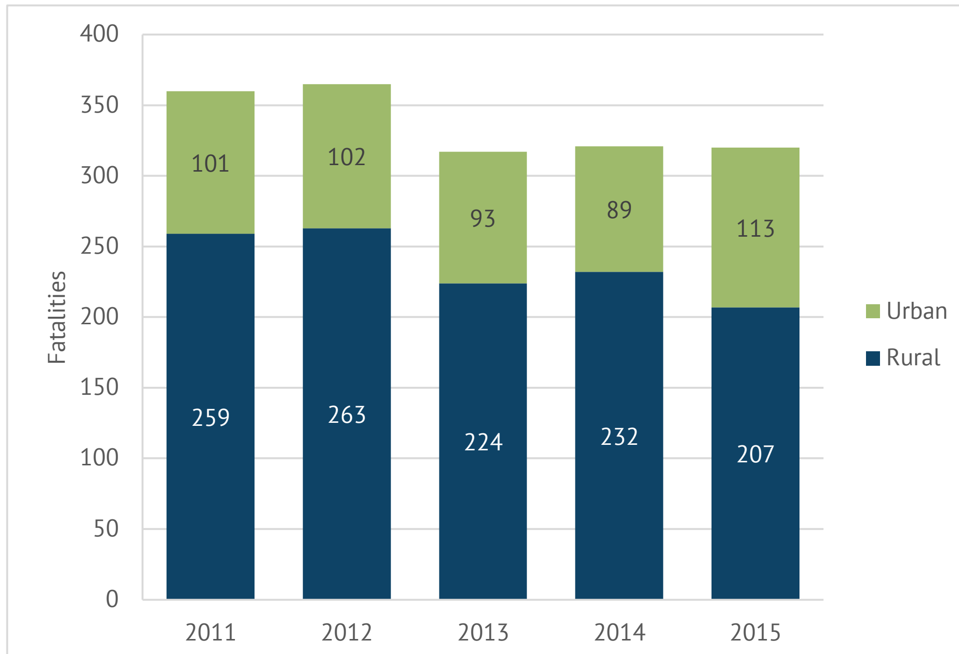
3.8 Safety

Safety is a foundational consideration in this Plan. The department emphasizes safety in all efforts, including enforcement, education, engineering, and emergency response. Safety is most often thought of in terms of the highway mode, but each modal area is an important part of an interrelated transportation system. The overriding goal for all aspects of transportation safety is to reduce injuries and fatalities, thereby reducing personal and economic losses experienced by families, employers, and communities, and improving Iowa's quality of life. Educating users, designing safer facilities, and joining with partners in collaborative efforts can achieve this.

Safety trends

Between 2011 and 2015, there were 1,683 fatalities on Iowa roadways. During this five-year period, there was an 11 percent overall decrease in the number of fatalities, from 360 in 2011 to 320 in 2015 (see Figure 3.7). The most significant annual decrease occurred between 2012 and 2013, which had a 13 percent decrease in fatalities. Although the rural population continues to decline in Iowa, roadway fatalities in rural areas continue to represent a disproportionate number of Iowa's fatalities as compared to urban areas. On average, 70 percent of Iowa fatalities occurred in rural areas during this period, while 30 percent occurred in urban areas. Unfortunately, preliminary numbers for 2016 show a marked increase in Iowa crash fatalities. This trend also occurred at the national level.

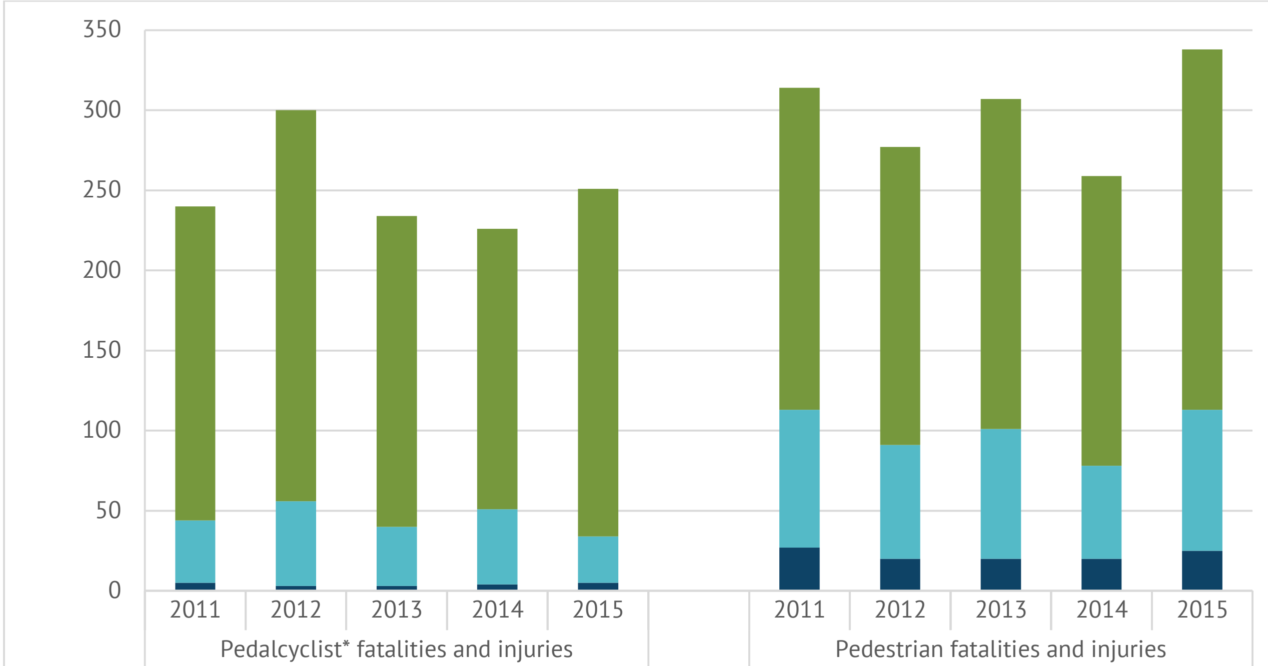
Figure 3.7: Annual crash fatalities, divided into rural and urban crashes, 2011-2015



Source: Iowa DOT

Injury and fatality crashes involving pedestrians or pedalcyclists (defined as a bicycle, tricycle, unicycle, pedal car; a two-wheeled, nonmotorized cycle or a vehicle that has three or four wheels but is propelled by pedal power) have increased during the past five years (see Figure 3.8). Preliminary numbers for 2016 indicate that the increase in severe crashes has continued, prompting efforts for additional study and implementation of measures to help decrease the number of nonmotorized fatalities.

Figure 3.8: Pedalcyclist and pedestrian fatalities and injuries, 2011-2015



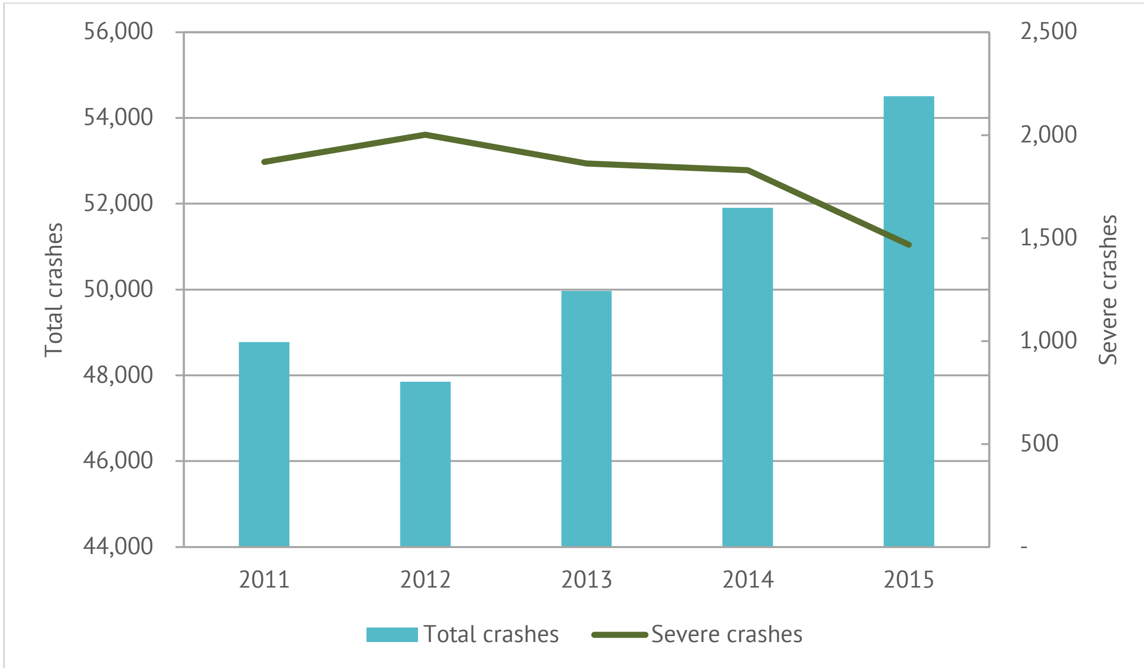
	Pedalcyclist* fatalities and injuries					Pedestrian fatalities and injuries				
	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Minor	196	244	194	175	217	201	186	206	181	225
Major	39	53	37	47	29	86	71	81	58	88
Fatal	5	3	3	4	5	27	20	20	20	25

**Pedalcyclist (bicycle, tricycle, unicycle, pedal car) – a two-wheeled, nonmotorized cycle or a vehicle that has three or four wheels but is propelled by pedal power.*

Source: Iowa DOT

In Iowa, the total number of crashes increased between 2011 and 2015, as shown in Figure 3.9. Although there was a steady increase in the total number of motor vehicle crashes, the total number of severe crashes (fatal and major injury crashes combined) declined during this period. It is also important to note that vehicle-miles traveled (VMT) for the state has increased during this the same period (reference Figure 4.8).

Figure 3.9: Total crashes and severe crashes in Iowa, 2011-2015



Source: Iowa DOT

Federal legislation

The current federal surface transportation reauthorization legislation, the FAST Act, continued many comprehensive approaches to highway safety that started with previous reauthorization legislation. One key provision that has been continued under the FAST Act legislation is the Highway Safety Improvement Program (HSIP), which was created "to achieve a significant reduction in traffic fatalities and serious injuries on public roads."

The Fast Act continues the mandated state Strategic Highway Safety Plan (SHSP) and requires each state's transportation department to lead diverse road safety disciplines, such as engineering, education, enforcement, and emergency response services, in collaborating to develop their state's plan. Proposed strategies are required to address safety needs of all public roads, include projects or strategies that are regularly evaluated, and to be reported annually to the U.S. DOT secretary.

Iowa's SHSP

According to the U.S. DOT, a SHSP "is a statewide coordinated safety plan that provides a comprehensive framework for reducing highway fatalities and serious injuries on all public roads." The purpose of the SHSP is to identify and establish statewide goals, objectives, and key emphasis areas to address areas of greatest need to make roadways safer. The HSIP requires state transportation departments develop an SHSP that:

- Includes consultation from a variety of stakeholders during the development process.
- Analyzes and makes effective use of crash data.
- Addresses the Four E's (engineering, enforcement, education, and emergency services) plus management and operation.
- Considers the safety needs of all public roads.
- Describes a program of projects or strategies to reduce or eliminate safety hazards.
- Is implemented and evaluated.

In 2017, Iowa's traffic safety community finalized an update to Iowa's SHSP, which was previously adopted in 2013.

SHSP emphasis areas

The main objective for developing the SHSP is to identify severe crash types and characteristics (known as safety emphasis areas) that present the best opportunity to reduce severe and fatal injuries. Iowa's SHSP advisory team initially focused on 22 emphasis areas suggested by the AASHTO Strategic Highway Safety Plan Guide. Through research, crash data analysis, and concurrence among the SHSP Advisory Team, 10 emphasis areas were selected to be further analyzed in Iowa's 2017 SHSP. The 10 emphasis areas were divided into the categories of behavioral or roadway/infrastructure-related. The 10 emphasis areas are listed below.

- Lane departures
- Local roads
- Speed-related
- Unprotected persons
- Younger drivers
- Roadside collisions
- Intersections
- Impaired driving
- Older drivers
- Motorcycles

SHSP vision and goals

During each SHSP update, the advisory team and stakeholders are tasked with creating a long-term vision and short-term goal for Iowa's SHSP. Since the adoption of the 2013 SHSP, Iowa has continued to align itself with the national vision to eliminate traffic fatalities on all public roads. In order to do this, the Zero Fatalities campaign was developed in 2014 in a partnership between the Iowa DOT, the Iowa Department of Public Safety, and the Iowa Department of Public Health. The vision of Zero Fatalities and the strategies associated with it have been continued in Iowa's 2017 SHSP update, and several of these strategies have been incorporated into the action plan in Chapter 5. While the partner agencies realize that zero fatalities is a lofty vision for the state, messaging strategies focus on the fact that zero is the only acceptable goal for individuals when it comes to their loved ones. Therefore, it should be the only goal for the state.

Local and district road safety plans

The Iowa DOT recognized the need to take proactive steps for addressing crashes on its rural roadways. Using Minnesota's Local Road Safety plans as a model, the Iowa DOT began developing county specific local load safety plans (LRSP) in 2015. The LRSPs analyze the types of crashes occurring on the road system and use risk assessment to identify proactive improvements to mitigate crashes. The result of an LRSP is a prioritized list of safety projects for the county that proactively address the safety performance of the roadway. Similar to Iowa's SHSP, the LRSPs address how improved safety can be implemented at the county level. This is done with the understanding that in order to make the roadways safer, more than just engineering improvements need to be made. The Iowa DOT's district road safety plans will parallel the efforts of the county LRSPs for the primary system.

Modal safety

As was previously mentioned, safety is most often thought of in terms of the highway mode, yet it is an important component of each mode in the transportation arena. The following provides a brief overview of safety considerations for each mode.

Aviation safety

System planning and aviation programs strive to maintain infrastructure and services promoting safety in Iowa's air transportation system. Services specific to safety include a statewide network of aviation weather systems, a runway marking program, and windsocks for airports. While the Federal Aviation Administration certifies pilots, commercial airports, and aircraft, Iowa assumes responsibility for certifying that public-use airports meet minimum safety standards. The state also sponsors education safety programs geared toward pilots, aircraft mechanics, airport operators, and aerial applicators.

Bicycle and pedestrian safety

Bicycle and pedestrian facilities interplay with highway and local street systems, and include both shared and separated facilities. Iowa has incorporated many safety strategies and programs to protect those using bicycle and pedestrian facilities. These strategies and programs include the distribution of Transportation Alternatives Program (TAP) funding across MPOs and RPAs, where it is primarily used for bicycle/pedestrian projects; federal and state recreational trails programs; complete streets design; safety compliance; AASHTO design guidelines; facility compliance; optimization of signal design; and support for bicycle helmet use.

Public transit safety

Safety is integrated throughout public transit, including planning, design, operations, maintenance, employee training, technology development, and implementation of the Federal Transit Administration's drug and alcohol testing programs. Intelligent technology systems, such as in-vehicle cameras and radio communications, are incorporated when possible to enhance safety.

Rail safety

Iowa's rail system includes both commercial freight and passenger rail. Due to the large number of rail and highway intersections, rail crossing safety is critical. Several rail crossing safety programs are administered by the Iowa DOT, including the federal-aid Highway-Railroad Crossing Safety Program, the Grade Crossing Surface Repair Program, and Iowa's Highway Railroad Grade Crossing Safety Program. Safety programs support projects such as grade separations, track maintenance, and signal upgrades. The Iowa DOT also cooperates with implementation of the National Rail Safety Action Plan and supports Operation Lifesaver, which is a nonprofit education and awareness program dedicated to ending highway-rail collisions.

Multidisciplinary safety approach

To maximize safety improvement efforts, the Iowa DOT has partnered with other public and private agencies to develop a multidisciplinary approach. Solutions to safety concerns can often be achieved by including input from law enforcement, emergency response, tow companies, firefighters, transit agencies, and many others. This multidisciplinary approach is promoted by FHWA and other national organizations. The Iowa DOT also partners with several state agencies to promote safety efforts, such as the Governor's Traffic Safety Bureau, Iowa Department of Public Safety, Iowa Department of Education, and Iowa Department of Natural Resources.

One unique way the multidisciplinary safety approach has been incorporated in planning efforts across the state is through the development of multidisciplinary safety teams (MDSTs). These groups meet to discuss safety issues for their region and are composed of individuals from various backgrounds, professions, and agencies. Some examples of MDST activities include road safety audits, crash analysis workshops, and local media and marketing campaigns. Currently there are nine MDST groups across the state.

3.9 Security

Security is an important consideration in the transportation planning process, and it has received heightened attention since the terrorist attacks of Sept. 11, 2001. Security should not be thought of only in terms of criminal or terrorist attacks, but also vulnerability to natural and manmade incidents, such as floods, tornadoes, and hazardous materials spills. In Iowa, recent flooding and winter weather events have dramatically affected both rural and urban transportation systems, requiring adjustments to response policies and procedures. All modes of transportation are vulnerable to disruption due to natural or manmade incidents. The Iowa DOT partners with agencies at all levels of government, as well as private firms, to implement security initiatives.

National response framework

The U.S. Department of Homeland Security issued the second edition of the National Response Framework (NRF) in May 2013. The NRF outlines key principles, roles, and frameworks that enable all response partners to prepare for and initiate a national response to emergencies and disasters. Iowa complies with the principles outlined in the NRF, which include:

- **Engaged partnership:** Those leading emergency response efforts must communicate and support engagement with the whole community through shared goals and aligning capabilities to ensure nobody is overwhelmed in times of crises.
- **Tiered response:** Incidents must be managed at the lowest possible jurisdictional level and supported by additional capabilities when needed.
- **Scalable, flexible, and adaptable operational capabilities:** As incidents change in size, scope, and complexity, response efforts must also adapt to meet dynamic requirements.
- **Unity of effort through unified command:** Effective unified command is essential to response efforts and requires clear understanding of the roles and responsibilities of each organization that will participate.
- **Readiness to act:** All partners must be in a state of readiness to act, but must also balance this with an understanding of risk.

National Incident Management System (NIMS)

The NIMS is a support document to the NRF and outlines standard command and management features that apply to response activities. This system enables all levels of government and private partners to provide a consistent nationwide structure to work together to prepare for, prevent, respond to, recover from, and mitigate the effect of incidents. The NIMS covers all incidents from daily occurrences to those of the highest national level. Iowa incorporates features of the NIMS into its incident management programs. Iowa developed its Emergency Transportation Operations (ETO) Plan in 2013 to guide statewide, multijurisdictional response to large-scale incidents and natural disasters. The Iowa ETO Plan follows a standardized, all-hazards approach to incident management consistent with the NIMS.

Iowa DOT's security and emergency response efforts

The Office of Traffic Operations is responsible for overseeing the Iowa DOT's security and emergency response efforts. Many of the office's core functions related to managing and operating the system are a key part of these efforts. In particular, this includes several ITS components. Iowa has a 511 traveler information system in operation, which has important applications for both emergency operations and homeland security concerns. The 511 system is a nationwide program that is administered and funded at the state level and provides callers, website visitors, and app users with free access to real-time, route-specific travel conditions, weather conditions, incidents, congestion, and construction information. Live feeds from the Iowa DOT's network of traffic cameras are available to the public. Dynamic message signs are also part of roadway safety and security ITS applications. The Iowa DOT has placed large electronic signs on interstates and primary highways for congestion mitigation, traffic management, and emergency diversion efforts. This system is operated remotely from the Iowa DOT.

The Iowa DOT partners and coordinates security-response efforts with a variety of entities, including local agencies (e.g., county sheriff and city police departments), which provide critical local enforcement services. Private companies (e.g., rail lines, trucking companies, emergency medical services, towing firms) also play a critical role in transportation security. This is especially true where the Iowa DOT has little jurisdictional authority. Other important partners include local urban and rural planning agencies, the Iowa Governor's Traffic Safety Bureau, and the Iowa Department of Homeland Security.

Security will continue to be a key consideration in the Iowa DOT's efforts. A proactive approach and coordination with many public and private partners will continue to be keys to success.

3.10 Technology

Technology is rapidly changing in the field of transportation. These changes will affect more than just mode choice and auto ownership; the impacts will likely affect how we utilize increasing amounts of data and how the future economy will function. Although experts disagree with how quickly some innovations will be adopted, it is clear technology will continually be integrated into the transportation system and will change the way people travel. Despite quickly changing technology, concerns and barriers still exist related to the cost, safety, security, privacy, and regulation of these new technologies. As the ways people travel and goods are transported continues to change, the Iowa DOT will continue to adapt to those changes and help ensure Iowa has a safe and reliable transportation system. The Iowa DOT is also taking a leadership role in the technological arena through some current initiatives and strategies, which are discussed in Chapter 5.

Transportation options

Many recent developments in technology are already influencing how people travel. Transportation network companies, such as Uber, Lyft, and others, connect passengers with drivers who provide the transportation in their own vehicles, typically through a website or mobile app. Shared transportation services are emerging that enable travelers to utilize vehicles they do not own on a limited, on-demand basis, typically by paying online or at a kiosk. Bike-sharing programs exist in some Iowa communities, and car-sharing programs are becoming more common nationwide. Transportation subscription services are also emerging, which enable consumers to pay a fee allowing them access to multiple modes of transportation. While many of these types of services are primarily applicable in urban areas, they are beginning to change the way people choose to travel, and may have significant effects on future planning across modes.

Automated and connected vehicles

Automated vehicles (AV) and connected vehicles (CV) have been rapidly developing and are likely the most anticipated form of technological advancement in the transportation industry. Although both AV and CV technologies are often talked about synonymously, the two emerging technologies have several differences. AV use a combination of light detection and ranging (LIDAR), global positioning systems (GPS), optical cameras, and processing power to analyze the roadway and make decisions for the driver. Recent tests of AV have demonstrated the feasibility of this technology. The most famous example of AV technology is likely the Google self-driving car, which was developed in 2010.

CV use wireless communication in various forms such as vehicle to vehicle (V2V), vehicle to pedestrian (V2P), and vehicle to infrastructure (V2I) to inform the driver of changing conditions of the roadway via sensors. These communications are collectively called V2X and are intended to improve the safety and operation capacity of roadways. The sensor technology necessary for handling such dynamic and complex problem solving is becoming more commonplace and is expected to not only advance CV technology, but also result in large amounts of data gathering.

One of the biggest attractions of AV and CV technology is the potential to eliminate driver error. This would have substantial improvements to transportation safety, as the vast majority of crashes are at least partially caused by driver error. By eliminating human error, future AV and CV technology could result in substantial reductions in the number of vehicle crashes and the number crash injuries and fatalities. Not only could this technology reduce the amount of human suffering, but it could also reduce the amount of economic loss from property damage and physical injury.

Levels of automation

Automation in vehicles exists at varying levels of complexity. Because of this, the U.S. DOT's National Highway Traffic Safety Administration has defined the following five levels of automation.

- No automation (Level 0): The driver is in complete and sole control of the primary vehicle controls at all times.
- Function-specific automation (Level 1): Automation involves one of more specific control functions (e.g., electronic stability control or precharged brakes).
- Combined function automation (Level 2): Automation of at least two or more control functions designed to work in unison, relieving the driver of control of those functions (e.g., adaptive cruise control in combination with lane centering).
- Limited self-driving automation (Level 3): At this level of automation, the driver is not expected to constantly monitor the roadway. The vehicle monitors roadway and environmental conditions and controls the vehicle accordingly. The driver is expected to be available for occasional control during certain conditions with a sufficient level of transition time to regain control of the vehicle. The Google car is an example of limited self-driving automation.
- Full self-driving automation (Level 4): The vehicle is designed to perform all safety critical driving functions and monitor roadway conditions for an entire trip and would not necessarily need a human driver for trips.

Potential impacts

Emerging trends and technologies will likely have a range of benefits that apply to the field of transportation and beyond. Specifically, the advancement of AV and CV technologies has the potential to increase the safety performance of roadways along with the operational capacity. It is believed this technology would result in numerous benefits such as fewer traffic incidents, increased reliability, reduced congestion, and more efficient use of the roadway system. Efficiency of operation coupled with clean energy technology could have substantial benefits to the environment. CV and AV may have significant effects for commercial industries, as they should help reduce costs and increase reliability and efficiency. In addition, full automation would potentially help provide a solution to the increasing truck driver shortage in the country.

The prospect of V2V and V2I presents a very unique opportunity for large amounts of data to be gathered. Conceptually, the predicted use of this information is still very hard to understand; however, the hope is this large amount of data could rapidly advance the field of transportation and the use of transportation systems. For example, real-time information about the temporal and geographic distribution of trips could lead to better modeling and forecasting. Utilizing this data could also improve maintenance and operational capacity of transportation systems. Drivers could benefit by having real-time information to help them avoid congestion or be able to locate destinations and services easily. Private industry could potentially utilize this information to improve logistics and supply chain management.

In addition to the many potential benefits of these trends and technology, there will be many other implications, some of which may be negative, that are yet unknown. It will be necessary to explore potential impacts to the rest of the transportation system, the economy, and land uses. With trends related to shared services and transportation network companies affecting how people choose to travel, and the potential for CV and AV technology to change the behavior of both travelers and vehicles, these technologies may have wide-ranging implications for land use and development.

Examples of impacts could include changes in areas such as patterns of vehicle ownership, the amount of parking needed by cities and individual households, the distance people live from work, and many others. Traffic forecasting methods will need to be adapted based on AV being part of the freight and passenger vehicle fleets. The potential impacts of technology and changing travel patterns lead to some types of projects being considered higher risk, in the sense that they may become less necessary or need to be re-evaluated. Examples of these types of projects include:

- High-dollar investments.
- Purchasing right of way.
- Highway capacity expansion.
- Roadside infrastructure (e.g., dynamic message signs, overhead sign trusses).

Technology changes may have significant implications at not only the planning level, but at the project development level. Major projects take from several years to multiple decades to design and build, and the changing nature of transportation may require adaptation and scope refinement not just before, but also during the project development process. Strategies related to adapting to changing technology are included in the action plan in chapter 5.