Chapter 9. Analysis of System Alternatives

An alternatives analysis is a useful tool in examining scenarios that could take place, understanding their potential impact on the system, and identifying recommendations or solutions that could be considered by the Colorado Department of Transportation (CDOT) to address these scenarios. There is a broad range of topics that may impact the Colorado aviation system in the future, and several have been identified as key topics worth consideration as part of the 2020 Colorado Aviation System Plan (CASP). The following aviation- and non-aviation-related topics were identified for further evaluation through discussions with CDOT Division of Aeronautics and members of the Project Advisory Committee (PAC):

- Aviation-Related Alternatives
  - General Aviation (GA) Fleet-Mix Changes/Electric Aircraft
  - Urban Air Mobility (UAM)/Unmanned Aerial Systems (UAS) Growth
  - Change in Commercial Air Service/Regional Airline Fleet Changes
  - Supersonic Air Travel
- Non-Aviation-Related Alternatives
  - Population Changes
  - Transportation Changes
  - Economic Changes

Each aviation- and non-aviation-related alternative section below is organized with a brief introduction, followed by its impact on the system relative to four overarching categories: infrastructure, funding, workforce, and environmental. Several alternatives have multiple components that are presented such as transportation changes; however, the impacts for the alternatives are combined for purposes of the analysis. The alternatives analysis can be used by CDOT to inform decision-making as it relates to each potential alternative and its impact on the airport system and its future needs.

9.1. Aviation-Related Influences

Many of the aviation-related influences listed below are already starting to be realized at the state and national levels. Advances in technology are being experienced more rapidly than modernizations in policy and regulations, which has the aviation industry struggling to keep up with the vast and significant changes.

9.1.1. GA Fleet-Mix Changes/Electric Aircraft

The FAA Aerospace Forecast Fiscal Years 2019-2039 projects industry-wide declines in piston aircraft to occur over the next 20 years. Fixed-wing piston aircraft comprise the largest segment of the GA aircraft fleet. Forecasts over 20 years anticipate this fleet to decline at -0.9 percent annually, whereas the turbojet sector is anticipated to grow at 2.2 percent annually. The FAA speculates that the shrinkage in number of fixed-wing piston aircraft is influenced by rising ownership costs, an aging fleet, and pilot demographics, which show increases in some pilot certificate categories such as air transport pilots (ATP) to address the commercial pilot shortage, but a large decline in the number of active GA

pilots. Additionally, funding and advancements in technology are supporting the development of electric aircraft, which could further transform the future aircraft fleet mix. This includes all electric and hybrid electric, and even turboelectric technology. There is also retrofitting of aircraft to transition from operating with fossil fuels to electric.

Electric aircraft represent the leading-edge of aviation technology driven by the world's growing concern for carbon emissions related to air travel. Electric aircraft applications range from small two-seater aircraft designed exclusively for pilot training to full-sized passenger planes developed for long-haul routes. Current challenges affecting electric aircraft include limited battery capacity, need for more efficient thermoregulation systems and technologies, and limited existing charging infrastructure for aircraft at airports. These challenges may well be the limiting factors in the electric aircraft revolution, but its many benefits and applications for commercial and military aviation have led to significant investments by the federal government and other public institutions, as well as tremendous private investment.

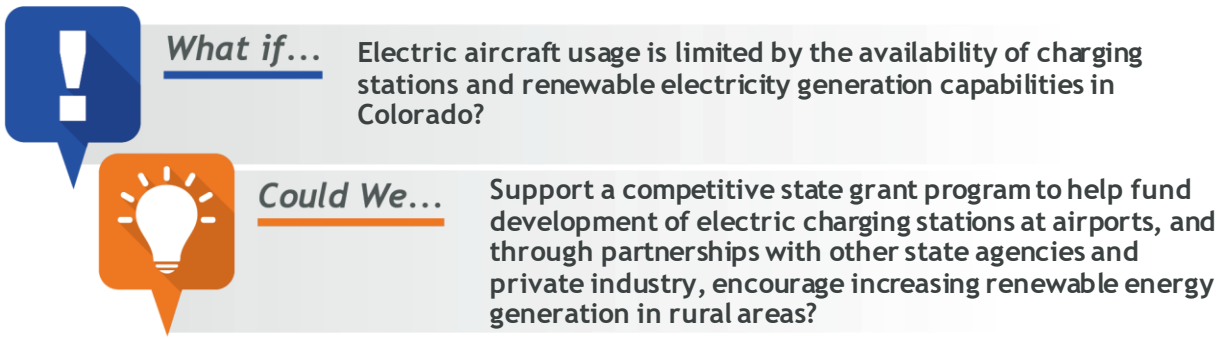
Electric aircraft offer reduced costs as electricity is significantly cheaper than fuel in Colorado, as it is generally nationwide. Electricity generated in Colorado is protected from the market volatility of oil given the current high reliance on coal, including noteworthy increases in renewables to generate electricity in the state. Electric aircraft also present new opportunities for smaller airports as they can be operated on shorter runways and are lighter weight, reducing runway strength requirements. Additionally, their reduced noise generation may allow them to be flown in urbanized areas where noise pollution traditionally has been a concern.

While the focus of this analysis is on electric aircraft, it is important to note that hydrogen-powered aircraft are also under development and in the testing phase. ZeroAvia's hydrogen fuel cell system has zero emissions and would result in 75 percent lower fuel and maintenance costs with fixed-wing, 10- to 20-seat aircraft.[1] The National Aeronautics and Space Administration (NASA) is supporting research for development of all electric aircraft "using a liquid hydrogen fuel cell propulsion system," which would increase efficiency and maintain zero emissions.[2] While hydrogen-powered aircraft are still in testing, electric aircraft are being manufactured and operated on a limited basis today, primarily for training purposes, but there are already orders for use in small regional/commuter airline service.

[1] ZeroAvia. "Our Mission." 2019. https://www.zeroavia.com/
[2] Quailan Homann. "Aviation." 2019. http://www.fchea.org/in-transition/2019/11/25/aviation

9.1.1.1. *Infrastructure*

Although a reduction in costs associated with increasing electric aircraft operations could increase mobility across the state, the availability of electric vehicle charging stations significantly limits what facilities electric aircraft can access today. The availability of electric charging stations directly influences the usage and accessibility of electric aircraft across the state. To promote electric aircraft usage, charging stations would need to be built at a variety of airports; this comes with its own challenges. Currently, the industry does not have a single standard for universal charging plug-ins for aircraft, resulting in a literal disconnect between charging facilities and the different types of electric aircraft. Until this equipment is standardized, it may not be financially feasible for airports to install charging stations that only serve specific types of electric aircraft. Additionally, growth in electric aircraft ownership could put substantial strain on current electricity supplies at airports and across Colorado. Rising costs to support the additional electrical capacity and continued demands for more electricity could outweigh the benefits of providing charging stations at remote airports. Electric capacity conditions were not analyzed; however, it is possible that additional electrical generation may be needed. In order to maintain the reduced environmental impacts of electric aircraft, the electricity should be generated by renewable energy sources. Many of these sources are not available to remote communities.

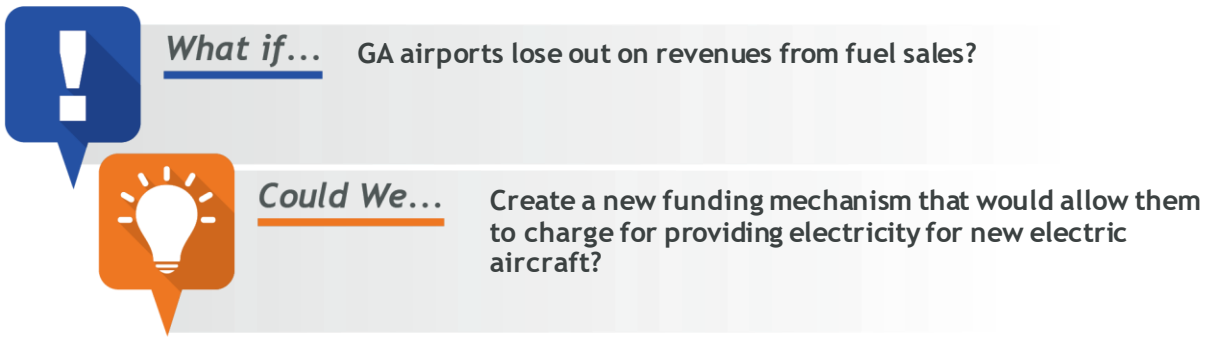


9.1.1.2. *Funding*

Traditional fueling facilities generate revenue that can be used to fund airport capital projects, operating costs, and other needs. They also generate revenue that CDOT Division of Aeronautics utilizes to provide funding, support, and capital investments to airports. According to CDOT Division of Aeronautics' analysis of the potential impact of electric aircraft on fuel taxes that support the system, the transition of GA aircraft to electric power would have a minimal impact of less than one percent in total revenue. The largest impact to state funding would be the transition of large commercial aircraft to electric propulsion or some other power supply, which is not anticipated in the foreseeable future.

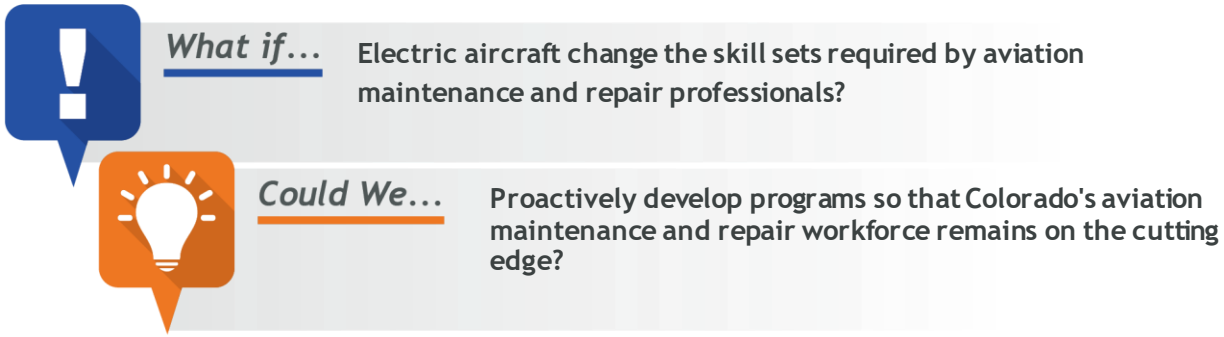
For individual airports, the loss of fuel sales would need to be made up in some way as these sales are a primary driver of revenues for many GA airports. According to the *Airport Cooperative Research*

Program (ACRP) Report 16: Guidebook for Managing Small Airports, fuel sales were noted as the primary source of revenue for GA airports.[3]



9.1.1.3. *Workforce*

The electric aircraft industry is projected to become a commercially viable reality at some time, likely starting with regional/commuter service using small aircraft. As the technology continues to progress and these aircraft come to fruition, aviation professionals may need to acquire new skills to develop, manufacture, and maintain these aircraft. Integrating electric aircraft into current training curriculums for aircraft maintenance and repair could provide established and new aviation professionals with the skill set and knowledge required to support this aircraft engine technology.

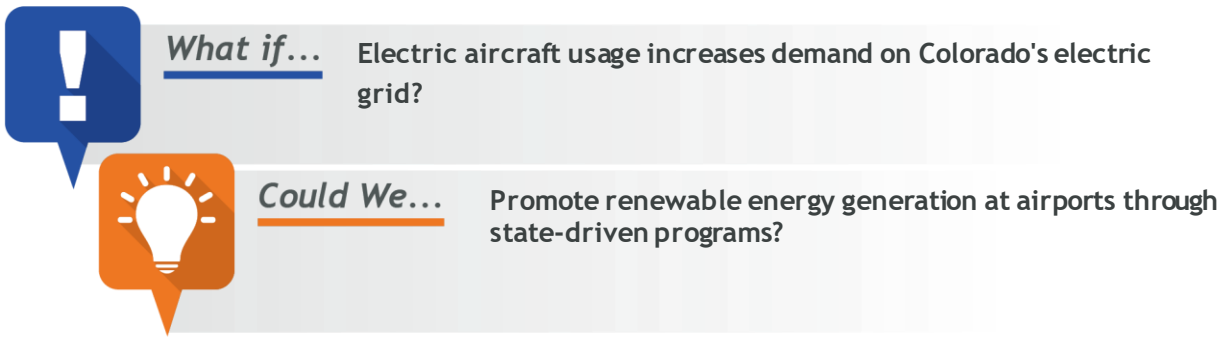


9.1.1.4. *Environmental*

One of the key advantages of electric aircraft is the reduced environmental impact in comparison to traditional aircraft. In terms of emissions, electric aircraft have zero emissions during operation compared to fossil fuels, which contribute a large percentage to global greenhouse gases (GhG). However, the production of electric energy does have associated emissions that are not factored into the operation. The concept of "wheel to well" considers the energy consumed and GhG from the creation of the energy "at the well" until it is consumed "by the wheel." The production of electricity produces around 25 percent of the global GhG emissions and 27.5 percent of the U.S.' emissions.[4]

[3] ACRP Report 16: Guidebook for Managing Small Airports. http://www.trb.org/Publications/Blurbs/162145.aspx
[4] United States Environmental Protection Agency (EPA). "Sources of Greenhouse Gas Emissions." 2018

Utilizing renewable energy sources to accommodate electric aircraft demand would further reduce aircraft and airport environmental impacts.



9.1.1.5. *Conclusion*

The FAA's forecasts for the GA fleet over the next 20 years projects the decline of fixed-wing piston aircraft and rises in turbine, experimental, and light sport aircraft. GA pilots and GA airports may further transform the GA fleet towards the incorporation of electric aircraft and other alternatives due to their reduced costs for fuel and maintenance, ability to operate on smaller runways, and minimal noise impacts to the surrounding communities compared to current aircraft. Fleet-wide transitions to electric aircraft could result in decreased prices for air travel and other aviation-related services to the consumer due to the reduced operational costs for electric aircraft. Environmentally, the electrification of aircraft would reduce operational GhG emissions in comparison to traditional aircraft. To further decrease their environmental impact, airports may seek the integration of renewable energies to reduce GhG emissions produced from electricity generation.

9.1.2. UAM/UAS Growth

Urban air mobility (UAM) has emerged in response to the issues and costs associated with growing congestion of ground transportation networks in cities and the opportunities afforded by the evolution of technology related to unmanned aerial vehicles (UAV). UAM focuses on delivering passenger travel and cargo/delivery services by using specialized electric vertical takeoff and landing (eVTOL) aircraft and highly-automated (unmanned) aircraft designed to safely navigate in the low-altitude airspace above high-density areas.

Exploration and development of UAM has been gaining traction as market opportunities continue to be identified that would benefit from initial implementation across major cities. This has been likened to current use of rotorcraft in major markets such as New York to transport passengers by air instead of by ground. There are many potential opportunities for UAM ranging from "last mile" parcel delivery through the use of small unmanned aircraft to air metro applications similar to today's public transportation options. UAM faces key regulatory, infrastructure, and technological challenges, but the industry is optimistic that some form of implementation could be viable within the next 10 years.

UAM is expected to impact both ground and air travel but given the likely seating configuration of four to five seats per vehicle, UAM is unlikely to have a significant impact on the reduction of vehicle miles traveled (VMT) on highways. UAM are not expected to replace current regional/commuter airline

service, at least based on current research and technology. UAM are also not expected to replace long-distance automobile trips. The focus is more on short-haul markets, especially in major metropolitan areas.

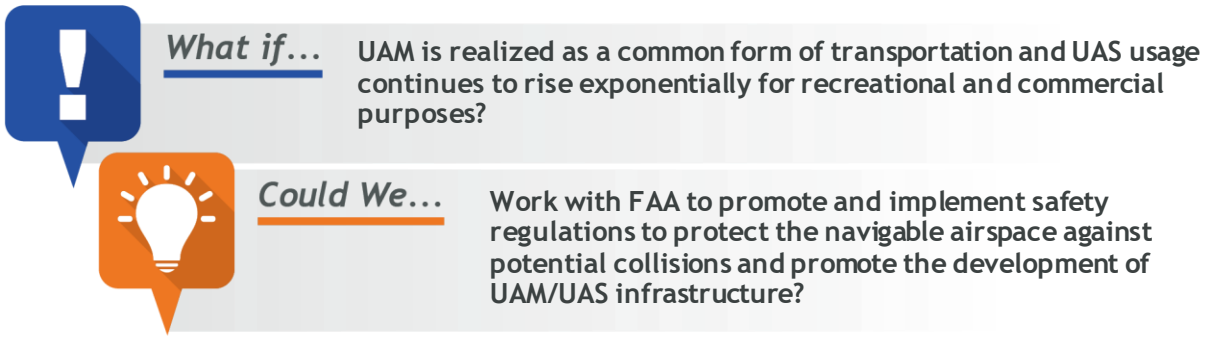
Unmanned aircraft systems (UAS) rely on UAV technology and provide an array of uses for commercial, government, educational, and recreational purposes. As UAV usage became more prolific and emerged into a popular market, at least in the small UAS market, it was important to think of UAV technology as more than just the individual aircraft—it is a system that encompasses a variety of factors that contribute to UAV usage.

UAS has already been implemented for a wide array of applications across many sectors. Some applications include delivering real-time footage to inform public safety crews during emergency situations, completing data-gathering efforts that are deemed dangerous or potentially life-threatening, and aerial agricultural spraying for crop maintenance. Since UAS and UAV have been in use for many years, several policy and procedural developments are established to support safe and responsible UAS/UAV usage. However, this technology can be optimized through infrastructure development, strategic investments, proper workforce training, and policy implementation.

Industries, potential users, regulatory agencies, and others will have to consider new challenges and opportunities for UAM and UAM applications as the technology transitions from conceptualization to widespread implementation.

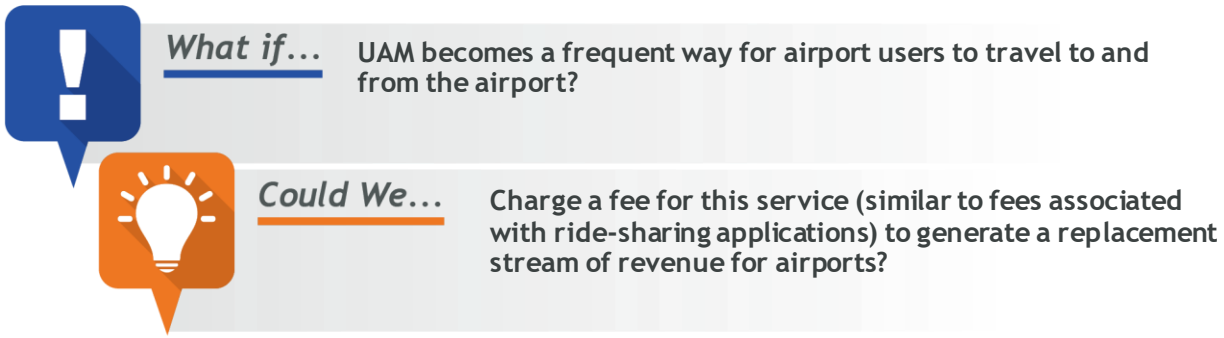
9.1.2.1. *Infrastructure*

A fully-functional and integrated UAM network is needed as implementation moves forward. This network encompasses both airspace and infrastructure on the ground to support the operation and maintenance of UAM. The most significant challenge of integration is the protection of current navigable airspace for the existing system. Further, regulations to mitigate potential land use and height control issues that result from UAM and UAS operation need to be considered. UAM and UAS operations are likely to be different than traditional aircraft activity experienced today and will require additional regulation to support successful integration on the national, regional, and local levels.



9.1.2.2. *Funding*

Integration of UAM aircraft into Colorado's existing transportation system could transform the way people travel around cities. Airports serve as important nodes in connecting travelers to their destinations and have the potential to evolve into hubs for future UAM networks. Similar to unforeseen challenges that have arisen as a result of Transportation Network Companies (TNC) like Uber and Lyft, airport users utilizing UAM to connect to airports could cause a decline in long- and short-term parking revenue and customer facility charges (CFCs) collected by rental car facilities. Passengers that currently park at airports or rent cars may no longer need these services as a result of utilizing UAM.



9.1.2.3. *Workforce*

New educational requirements for aviation professionals will be required as UAM and UAS are further incorporated into aviation networks and systems. As an emerging technology, the UAM industry is still in the research and development phase. As it progresses closer to becoming a commercially viable transportation option, it will require a whole new sector of aviation professionals to pilot and maintain these new aircraft, develop and supervise monitoring systems, and complete other skills/jobs critical to UAM operations. An initial operator, Uber Elevate, has laid out a flight plan to start operations in 2023 and has indicated that its fleet will include a fifth seat for a pilot "until autonomous flight is proven out."[5] The actual timing of unmanned UAM has not been put forth as it is highly dependent on regulatory approvals through testing and passenger acceptance. As UAS continue to develop and begin to be flown as part of or in tandem with UAM vehicles, more advanced remote pilot certifications may be required in the future. To support a new sector of aviation professionals well-equipped to enter these markets, current educational programs should incorporate best practices regarding these industries as soon as possible.

Of note, CDOT is working with the Colorado Workforce Development Council to develop an industry-led sector partnership to address the shortage of truck drivers. This may serve as a model for existing and potential ongoing aviation workforce shortages.

[5] Jerry Siebenmark. "Uber Elevate Summit Lays Out 2023 Flight Plan." 2019.

What if... Existing educational programs in Colorado could integrate UAM operations knowledge into their courses?

Could We... Train a new sector of aviation professionals that have the expertise to develop, maintain, and pilot UAM technologies?

9.1.2.4. *Environmental*

Environmental conversations surrounding UAM and UAS trend toward mitigating environmental impacts from the expected high usage and potentially low altitudes these aircraft are expected to operate within. UAM's intended use is to relieve ground transportation congestion utilizing eVTOL to reduce overall GhG emissions. UAS has been used to advance environmental efforts from monitoring illegal deforestation, measuring GhG levels, and tracking soil erosion.

The full environmental impacts of UAM remain unclear since it is still largely in research and development. NASA presented a market study presentation about UAM in November 2018, which cited potential environmental impacts such as noise pollution, light pollution, wildlife strikes, and battery waste.[6] Similarly, Smithsonian America published a study that analyzed GhG emissions from UAS for parcel delivery in comparison to diesel-powered trucks and vans. The study found that while electric-powered UAS could reduce energy use and GhG emissions, traditional trucks and vans would be more efficient and cleaner than non-electric UAS.[7] Additionally, the EPA cited that buildings contributed 12 percent of the US' GhG emissions in 2017.[8] The construction and maintenance of new UAM and UAS infrastructure would increase aviation's environmental footprint.

What if... Increasing demands for UAM result in growing needs for new UAM infrastructure?

Could We... Reduce UAM environmental impacts by incorporating LEED standards into new infrastructure?

[6] NASA. "Urban Air Mobility (UAM Market Study." 2019
[7] Constantine Samaras; Joshuah Stolatoff. "Is Drone Delivery Good for the Environment?" 2018
[8] United States Environmental Protection Agency (EPA). "Sources of Greenhouse Gas Emissions." 2018

9.1.2.5. *Conclusion*

Continued proliferation of UAS usage and development coupled with the realization of UAM transportation could impact aviation operations throughout Colorado. UAM applications may increase mobility to airports with limited ground transportation infrastructure or utilize airports as a major transit node. Ease in obtaining a Remote Pilot Certification and sustained popularity in recreational and commercial uses indicates UAS usage will continue to grow as users find new ways to use drones to complete numerous applications. To mitigate environmental impacts of implementing UAM and increasing UAS usage, it will be important to utilize alternative fuel and/or electrified aircraft/vehicles and consider the need for LEED standard infrastructure.

9.1.3. Change in Commercial Air Service/Regional Airline Fleet Changes

In the last five years, growth in commercial air service has been supported by very positive underlying factors including:

- Expansion in U.S. gross domestic product (GDP)
- Low unemployment rates
- Greater worldwide consumer buying power
- Relatively low fuel prices
- Low interest rates
- Careful deployment of capacity by airlines to match consumer demand in different markets

Overall, the airline industry has remained profitable, but as a global enterprise the industry is vulnerable to unanticipated disruption brought about by regional conflicts, climate change, or pandemics (such as COVID-19 which is addressed in a separate analysis due to the timing of the pandemic and the progress of the 2020 CASP). This section discusses some of the air service developments where change is already occurring and could be a factor in the next decade, including:

- Growth at Denver International (DEN), Aspen-Pitkin County (ASE), Durango-La Plata County (DRO), and Montrose Regional (MTJ); and challenges at the smallest airports
- Retirement of a generation of turboprops and regional jets; replacement aircraft either small narrow body jets or new turboprops with fewer than 12 seats
- Essential Air Service (EAS) program remains an uncertainty

Each of these trends is described first followed by a discussion of potential impacts to the Colorado system of airports. **Section 9.2.2** presents non-aviation developments that are likely to influence commercial air service such as use of self-driving cars, high-speed rail, or other technologies such as hyperloops.

9.1.3.1. *Growth of Colorado's Air Service Market*

Colorado commercial service airports were integral to the state's economic expansion since the recession of 2008. For Colorado this expansion was fueled not only by positive underlying economic factors, but also by significant population and employment growth particularly on the Front Range, by increased demand for travel to vacation destinations on the Western Slope, and by effective air service initiatives at Western Slope destination airports. **Table 9.1** shows growth of 6.6 million enplanements

at DEN. Other Colorado airports have also grown, notably ASE, DRO, Grand Junction Regional (GJT), and MTJ.

Over the 10-year period, concentration of capacity and passengers at DEN increased from 92 percent of state enplanements in 2008 to 94 percent in 2018. DEN's share of capacity as measured by available seat miles (ASMs) is even greater, growing from 95 percent to 96 percent. These trends are likely to continue in the near-term as DEN moves ahead with its gate expansion and terminal projects. In 2020, United Airlines signed a lease to add 24 gates, 12 on Concourse A and another 12 on Concourse B, with plans to increase daily departures from 500 to 700 by 2025. United's additions to service in 2020 include several smaller markets such as:

- Riverton, WY
- Sheraton, WY
- Dodge City, KS
- Salina, KS
- Panama City, FL
- Nassau, Bahamas
- Santa Maria, CA

In addition to United's growth at DEN which includes service and facility expansions, Southwest Airlines is building a $100 million maintenance facility at DEN and has plans for 16 new gates on Concourse C to facilitate additional service growth. In 2020 Southwest added new service to Des Moines and Hayden/Steamboat Springs. Beyond United and Southwest at DEN, there is new Frontier service to Newark, and Norwegian service to Rome.[9] GJT also has new United service from GJT to Chicago O'Hare and new Allegiant service to Phoenix-Mesa Gateway.

[9] Denver International Airport, new service announcements through June 2020.

Table 9.1. Growth in Enplanements and Available Seat Miles (ASMs) at Colorado Airports

City	Airport Name	FAA ID	Enplanements			Available Seat Miles (ASMs) (000's)		
			2008	2018	Annual Growth	2008	2018	Annual Growth
Alamosa	San Luis Valley Regional	ALS	7,161	6,798	-0.5%	3,288	1,712	-6.3%
Aspen	Aspen-Pitkin County	ASE	213,381	285,472	3.0%	81,377	237,254	11.3%
Colorado Springs	Colorado Springs Municipal	COS	997,348	883,776	-1.2%	720,406	691,394	-0.4%
Cortez	Cortez Municipal	CEZ	8,401	8,089	-0.4%	4,766	2,806	-5.2%
Denver	Denver International	DEN	24,287,939	30,849,992	2.4%	29,091,617	37,469,762	2.6%
Durango	Durango-La Plata County	DRO	134,386	189,771	3.5%	57,582	101,504	5.8%
Eagle	Eagle County Regional	EGE	212,832	174,369	-2.0%	262,303	229,850	-1.3%
Fort Collins/Loveland	Northern Colorado Regional	FNL	31,094	3,288	N/A*	22,156	N/A	N/A
Grand Junction	Grand Junction Regional	GJT	212,588	239,063	1.2%	98,370	128,577	2.7%
Gunnison	Gunnison-Crested Butte Regional	GUC	36,035	38,213	0.6%	20,377	23,229	1.3%
Hayden	Yampa Valley	HDN	136,600	103,410	-2.7%	119,924	108,103	-1.0%
Montrose	Montrose Regional	MTJ	85,868	134,106	4.6%	58,452	116,992	7.2%
Pueblo	Pueblo Memorial	PUB	4,345	10,500	9.2%	2,115	6,508	11.9%
Telluride	Telluride Regional	TEX	13,325	19,109	3.7%	6,027	898	-17.3%
	All Airports		**26,381,303**	**32,945,956**	**2.2%**	**30,548,760**	**39,118,589**	**2.5%**
	All Airports (less Denver)		**2,093,364**	**2,095,964**	**0.0%**	**1,459,151**	**1,650,845**	**1.2%**
	Percent Denver		**92%**	**94%**		**95%**	**96%**	

**Note: FNL doesn't have 10-year annual growth rate due to the airport's inconsistent air service availability between 2008-2018.*

Sources: FAA Enplanement Data; Bureau of Transportation Statistics T-100 Segment data, 2019

As noted in **Chapter 7**, the regional airline industry did not recover from the 2008 recession as well as the network airlines.

Table 9.2 shows an overall growth in Colorado of passenger enplanements of 2.2 percent annually; however, regional enplanements remained essentially flat. Total aircraft departures have declined less than 1 percent per year overall, but regional departures have declined annually by 2.5 percent.

Table 9.2. Regional Airline Share of Colorado

Colorado	2008	2018	Compound Annual Growth Rate (CAGR)
Regional Enplanements	5,306,234	5,410,924	0.2%
Total Enplanements	26,381,303	32,945,956	2.2%
Percent Regional Enplanements	**20%**	**16%**	
Regional Departures	156,621	121,927	-2.5%
Total Departures	348,365	316,846	-0.9%
Percent Regional Departures	**45%**	**38%**	

Sources: Regional Airline Association; FAA Enplanement Data, 2019

Two divergent trends with relevance for Colorado's small commercial service airports are emerging. The first is retirement of turboprop aircraft and early-generation 50-75 seat regional jets. For the larger markets, small narrow body aircraft are replacing regional jets (100+ seats), often with fewer daily departures. For the smallest markets the trend is reversed: many cities have either lost service or are served by aircraft with fewer than 12 seats.

Currently, three cities in Colorado participate in the EAS program: Alamosa, Cortez, and Pueblo. Boutique Air is the EAS carrier for Alamosa and Cortez and SkyWest provides EAS service to Pueblo. Since 2010, several legislative changes to the program have limited eligibility for subsidies, although Alamosa and Pueblo are among 110 communities that were granted waivers from new eligibility requirements.[10] In 2019, the GAO interviewed many EAS stakeholders to identify the benefits, challenges, and potential reforms for the program. Challenges reported by users and airlines include difficulty recruiting pilots, right-sizing the aircraft to the market, and providing service within the subsidy caps.

For Colorado EAS points, subsidies have grown substantially as shown in

[10] GAO-20-74, Effects of Changes to Air Service Program, and Stakeholders Views on Benefits, Challenges, and Potential Reforms, December 2019.

Table 9.3. However, as has been the case for at least a decade, continuation of EAS service in Colorado will ultimately depend on local support, the availability of eligibility waivers for Alamosa and Pueblo, and decisions by Congress and the U.S. Department of Transportation.

Table 9.3. EAS Colorado Contracts

Airport	2009	2019	EAS Carrier	
			Previous	Current
Alamosa	$1,853,475	$2,891,307	Great Lakes	Boutique
Cortez	$1,297,562	$3,579,705	Great Lakes	Boutique
Pueblo	$1,057,128	$2,548,067	Great Lakes	SkyWest

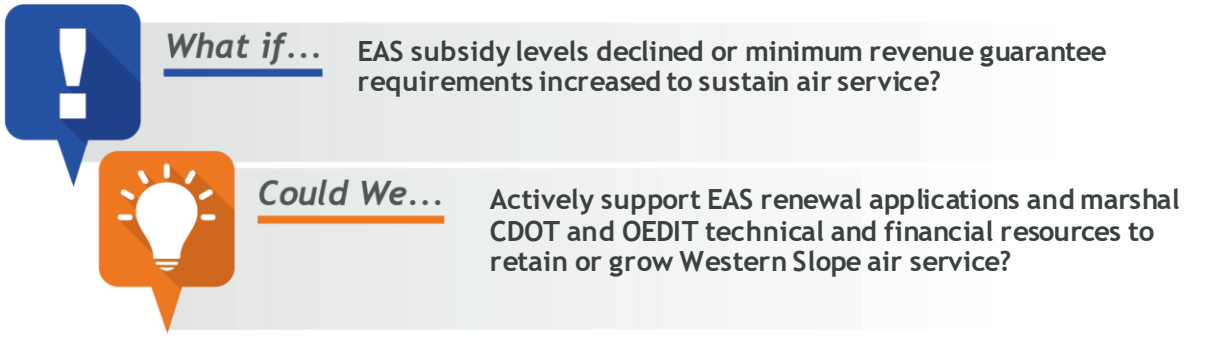
Source: Regional Airline Association, 2019

9.1.3.2. *Infrastructure*

With DEN dominating air service in Colorado, smaller commercial service airports remain heavily dependent on regional air carriers, destination travelers, good winter sports conditions, or EAS subsidies to retain or grow air service.

9.1.3.3. *Funding*

To continue EAS subsidies, both Alamosa and Pueblo received eligibility waivers. Contract renewals are imminent and will depend on decisions by the federal government. Growth in air service at Western Slope airports has come in large part through the efforts of local communities, the Colorado Flights Alliance, the winter sports resorts, and the tourism industry. Air service development programs have been primarily grassroots efforts.

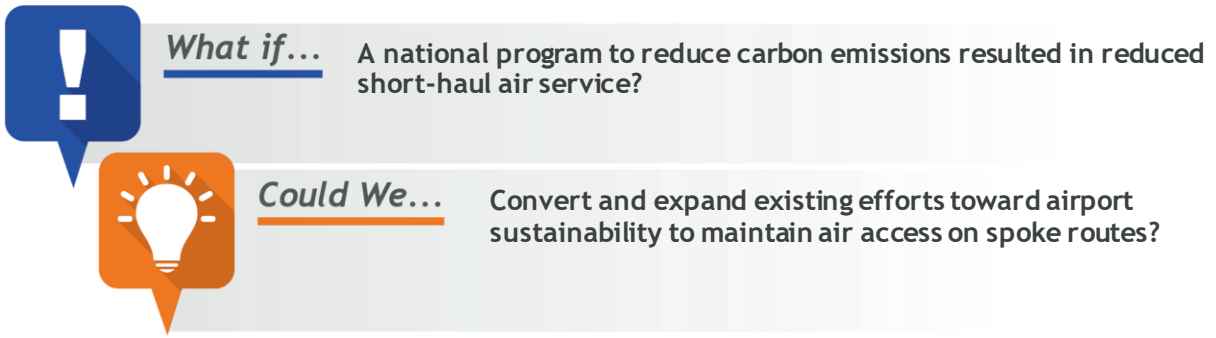


9.1.3.4. *Workforce*

The regional air service markets are facing shortages of pilots and certified aviation technicians. The pilot shortage has been somewhat alleviated through increased wages and other incentives. However, there is likely to remain disparity in pay scales between pilots who fly for regional airlines and those who fly for the majors. This difference exists because employment in a regional airline is generally a natural first step in a career path for pilots who aspire to fly for one of the major flag carriers. Licensed aircraft mechanics remain in short supply.

9.1.3.5. *Environment*

According to the Center for Climate and Energy Solutions, U.S. aircraft are responsible for 3 percent of carbon emissions in the U.S. Approximately 25 percent of CO_2 emissions occur when an aircraft is taking off or landing. Some climate change proponents are in favor of minimizing short-haul flying to reduce emissions. For Colorado, a policy to reduce short-haul flying will also reduce air access for some more remote communities.



9.1.3.6. *Conclusions*

Airports in Colorado serve different functions. As an international hub airport DEN has participated in a dynamic market for air travel and enjoys the strong presence of United, Southwest, and Frontier airlines as well as most other U.S. airlines. Colorado Springs (COS) provides access to the southern Front Range region and serves an extensive military community around Peterson Air Force Base and numerous other U.S. Air Force and Army installations situated within an hour's drive. Commercial service airports on the Western Slope support growing business communities in this part of the state in

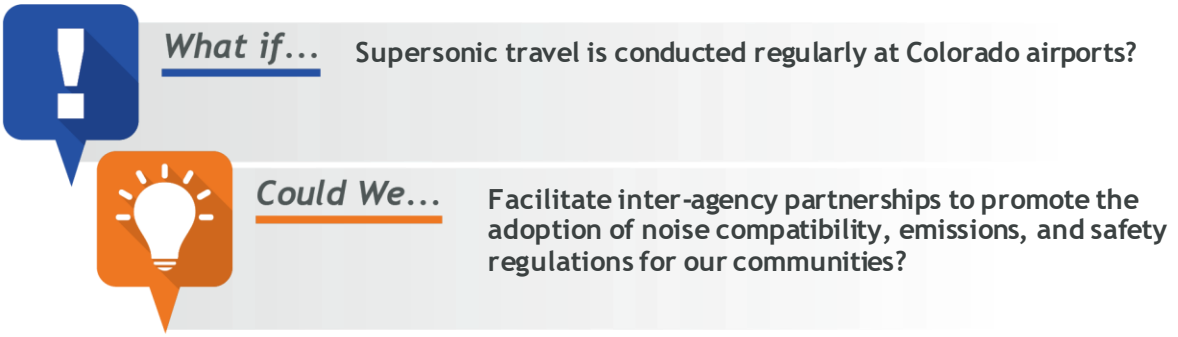
addition to an avid winter sports and tourist population. EAS communities ensure that there is basic air access to Cortez, Alamosa, and Pueblo. The commercial air service industry is highly sensitive to economic conditions as a large portion of air passengers are traveling for personal reasons. In the last decade, growth of air service has occurred in the largest or most profitable markets. Airlines can move their assets to the markets where risk is the lowest and return is the greatest, making it essential that airports monitor their air service to evaluate potential impacts.

9.1.4. Supersonic Travel

Supersonic air travel is garnering renewed interest as companies construct a modernized Supersonic Transport (SST) aircraft. Development of new engines and new airframe designs and the availability of lighter composite materials may help address some of the historical issues posed by previous SST aircraft. The FAA is ushering this new age of supersonic air travel by initiating two rulemaking activities that would establish noise certification standards for supersonic aircraft and refine guidelines for obtaining flight authorization for testing in the U.S. Congress has also sparked the recent push for supersonic air travel through Section 181 of the FAA Reauthorization Act of 2018. Section 181 stipulates that the FAA administrator support development of regulations, standards, and policies that would permit the certification of safe and efficient operation of civil supersonic aircraft at the federal and international level. Currently, the FAA has been working in partnership with the International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP) as operations of supersonic aircraft are anticipated to be utilized for international air travel. Their collaborative partnership is intended to develop international standards for noise and emissions applicable to supersonic aircraft and their engines.

9.1.4.1. *Infrastructure*

A key financial advantage for airports is that these types of aircraft will not require construction of specialized airside facilities to accommodate them. Regulating noise and emissions of SSTs to lessen impacts to surrounding communities or those beneath SST flight paths is a concern. At present, a sonic boom will result every time an aircraft achieves supersonic speeds. Existing noise mitigation regulations pertaining to supersonic airplanes and sonic boom are expressly communicated in the FAA's 14 Code of Federal Regulations (CFR) 91.817 through 14 CFR 91.821. These regulations may change with the new rulemaking activity initiated by the FAA that will set the noise certification standards and determine noise-level requirements appropriate to supersonic aircraft. In similar fashion, emissions certification and safety regulations will need to be established before operations of civil supersonic aircraft can be realized in Colorado.



9.1.4.2. *Funding*

The importance of continued advancements in developing a civil SST in the U.S. was made clear with the passing of the FAA Reauthorization Act of 2018. Section 181 of the Act specifically outlined the FAA administrator's responsibility to lead the industry in achieving safe and efficient civil supersonic aircraft. To support this action, 2021 Federal budget proposals for NASA included an increased aeronautics research budget to $819 million, of which supersonic aircraft is a chief program. Specific to SST funding in Colorado, Denver-based Boom Supersonic acquired a $100 million investment in 2019 with 30 pre-orders for their Mach 2.2 airliner, Overture. As more manufacturers follow suit, Colorado could attract other companies which support future SST operations and manufacturing if the industry becomes economically viable. It may be important for the state to leverage their advantage as a top aeronautics industry destination and drive SST companies to locate and/or relocate to Colorado.

What if... Supersonic travel becomes a commercially-viable option domestically and internationally?

Could We... Develop competitive grant opportunities that create an attractive environment for supersonic travel providers to conduct operations at Colorado airports?

9.1.4.3. *Workforce*

Today, Colorado SST companies such as Boom Supersonic are leading the way in research and development of quieter, more fuel-efficient supersonic aircraft. The industry relies heavily upon innovative engineering and manufacturing professionals to produce commercially-viable SST aircraft. Aviation engineering and manufacturing subsections of the workforce are in high demand to solve the current challenges plaguing the SST industry: fuel inefficiencies, sonic boom generation, and aircraft design safety.[11] In the near term, these professionals are tasked with developing and testing aircraft components capable of utilizing different alternative fuels, creating less drag, and diminishing the impacts of sonic boom. If SST becomes realized, the industry may require staff with specialized knowledge to maintain SST aircraft components and technology, pilots capable of operating the new fleet, and additional manufacturing professionals to produce SST components. At the moment, the industry is still within the research and developmental stages of producing commercially-viable aircraft and the specific demands and desired skills for future aviation professionals once SST become realized are largely unknown.

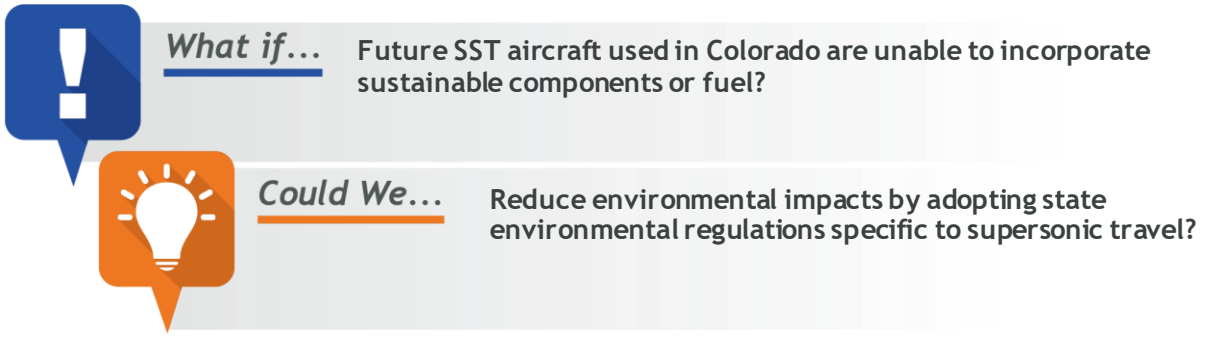
What if... Supersonic travel requires new skill sets for aviation professionals?

Could We... Integrate supersonic pilot, development, and maintenance training to prepare the workforce for this emerging technology?

[11] Mark Matousek. "Aviation Companies are Plotting the Return of Supersonic Flight – and They Think Their Jets Will be Better than the Concorde." 2018

9.1.4.4. *Environmental*

One of the major disadvantages that supersonic travel poses is its negative impact on the environment. The International Council on Clean Transportation (ICCT) published a paper on the environmental impacts of SST and estimated supersonic aircraft burn five to seven times more fuel per passenger to achieve supersonic speeds than conventional jets. ICCT estimates the global SST fleet could produce 96 million metric tons of CO_2 per year, which equates to the combined CO_2 emissions of American, Delta, and Southwest Airlines or 20 percent of the aviation industry's global carbon budget.[12] Additionally, noise impacts of SST aircraft is a major point of concern for communities near airports and underneath the flightpaths. To reduce these potential environmental impacts, supersonic aircraft developers are researching alternatives to make aircraft carbon neutral, use alternative fuels, and quiet enough to be flown over land without negatively impacting people below.



9.1.4.5. *Conclusion*

Increasing federal and private funding is kickstarting development of supersonic aircraft that could become economically and commercially viable. The FAA is conducting two rule-making activities which would energize the testing and certification of supersonic aircraft in the U.S. SST companies are currently researching and testing methodologies in modernizing aircraft to be quieter, more fuel-efficient, and potentially reduce the environmental impacts which plague the industry. Overall, due to these factors promoting civil supersonic development, SST may return sooner than anticipated.

9.2. Non-Aviation-Related Influences

The following sections discuss non-aviation-related influences paired with actionable ideas to stay in front of the ever-changing aviation industry.

9.2.1. Population Changes

Colorado is anticipating 8.7 million residents in the state by 2050, marking an era of unprecedented growth. The Western Slope region is estimated to experience the highest share of population growth in the same period and comprises seven of the 10 fastest-growing counties according to the Colorado State Demography Office, which anticipates over 67 percent growth in population over the next 30 years. Northern Colorado, which includes Greeley and Fort Collins, is projected to see a 107 percent

[12] Dan Rutherford, Ph.D. Grandon Graver, Ph.D. Chen Chen. "Noise and Climate Impacts of an Unconstrained Commercial Supersonic Network." 2019

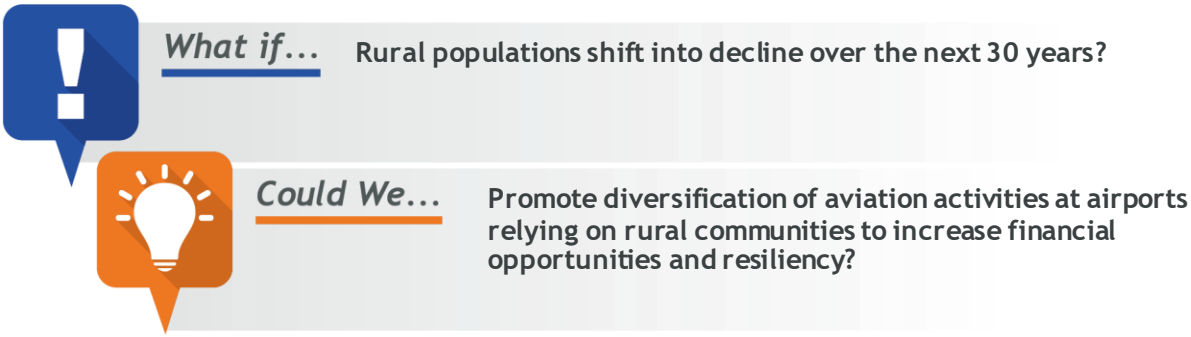
population boom and is followed by Colorado Springs, which will experience a significant growth at 60 percent by 2050. The Denver and Boulder metropolitan region, currently home to nearly 3.2 million residents, is anticipating a 45 percent increase in population resulting in more than 1.3 million additional residents. Most of the significant population growth is anticipated to settle in urban areas, while some rural communities may experience limited growth or decline.

9.2.1.1. *Infrastructure*

Communities in urbanized areas of Colorado's Western Slope (e.g., Grand Junction, Montrose, Delta, etc.) are anticipated to see a growth of almost 66 percent through 2050 according to the Colorado State Demography Office. Urban Northern Colorado (Fort Collins, Greeley-Weld Country, etc.) communities are also projected to double in size over the same period. Airports within these regions may experience rising aviation demand as the population size grows. Airports may need to work closely with CDOT to identify timing and completion of projects that align with the needs of anticipated airport users in the future.

9.2.1.2. *Funding*

Although much of Colorado's urban populations are anticipated to see substantial growth over the next 30 years, the Colorado State Demography Office projects rural areas to see very little growth or even decline in the future. Current trends in the state reveal new Colorado populations are more likely to settle in urbanized areas than in rural communities. Per the findings in **Chapter 6. Existing System Performance**, all system airports but one (Gunnison-Crested Butte Regional [GUC]) serve a remote or rural community and contribute to a portion of the system's aviation demand. Smaller GA airports whose aviation demand is derived solely from rural communities may experience a serious decline in activity. Loss in population could result in lowered demand for aviation services at these airports and influence their revenue and funding opportunities.



9.2.1.3. *Workforce*

Rising aviation demand stemming from growing populations may outpace airports' abilities to develop and expand services in response. Without a growing number of aviation professionals, expansion of services may be inhibited, and the additional population can cause negative strains on services and facilities that cannot meet demand. Fortunately, Colorado is anticipated to attract a large labor force with its growing population. According to the findings in **Chapter 7. Forecasts of Aviation Demand**, employment in Colorado is outpacing the national average and is expected to continue through 2038. In addition to a growing labor force in Colorado, the transportation and warehousing industry (which includes the aviation industry) is projected to see a modest 0.9 percent increase in employment over the next 20 years. Increasing access to aviation-related education programs and training may leverage new population into entering the aviation workforce and supporting new demand.

9.2.1.4. *Environmental*

Projected population booms in Colorado's Western Slope and Northern Colorado could outpace the facilities and services currently provided at airports in these regions. To properly accommodate demand, airports may need to construct larger facilities, add new or more frequent routes, and expand other services. In response, airports will increase their environmental footprint to serve growing demand. Similarly, declining populations in rural communities could put undue burden on airports in these regions. For instance, airports experiencing a prolonged drop in airport activity would incur higher operating costs and increased negative environmental impacts to maintain overbuilt facilities. Incorporating sustainable design into new and existing structure could mitigate both the financial and environmental costs associated with population changes.

9.2.1.5. *Conclusion*

The Colorado State Demography Office projects statewide population in Colorado is predicted to grow exponentially over the course of the next 30 years; however, increased populations are not anticipated to be shared equally across the state's regions. Regions that may experience the fastest growth will remain in urbanized metropolitan areas, with population growth in the Western Slope and Northern Colorado regions. Denver's and Colorado Springs's metropolitan areas are projected to see substantial rises in population through 2050 though not nearly as quickly as the Western Slope and Northern Colorado regions. During this same period of rapid population growth, rural communities are projected to experience stagnant populations, minimal growth, or decline.

9.2.2. Transportation Changes

This section explores emerging transportation technologies that could potentially impact aviation demand in Colorado. Technologies such as self-driving cars, hyperloops, high-speed rail, and smart applications are likely to transform an individual's trip from door to destination. These emerging technologies could affect demand for air service, use of parking and rental car facilities, traditional airport revenue streams, ground access, and basic land use at airports. Given the long planning and financing lead times to make significant changes to airport infrastructure and address funding challenges, airports and CDOT should be monitoring the changes and how they may impact airport facilities and land use programs.

9.2.2.1. *Transportation Network Companies (TNCs)*

The unexpected emergence and rapid adoption of app-based ride services, referred to as TNCs (Uber, Lyft, etc.) is testament to just how fast new transport modes can capture market share. When these companies and their unique business model emerged in 2012, the category of ride sharing was lightly regulated and TNCs could simply rely on independent drivers and vehicles to support their services. Using mobile apps to connect riders with drivers, TNCs offered fast, low-cost service, and easy payment for door-to-door service. In the case of airports, TNCs became a popular alternative to parking a car at the airport or renting a car. By 2016, TNCs had operating agreements at about 60 airports and by 2019, were authorized to operate at most large hubs as well as many other commercial service airports.

As use of TNCs grows, airport operators faced key issues including:

- Establishing trip fees and permit conditions
- Managing curb congestion and enforcing permit compliance
- Supervising and managing staging areas (location, dwell times, capacity)
- Balancing changes in mode shares (reassigning curbs, hold lots, and fees)
- Ensuring safety of passengers using the services (driver background checks/training and wayfinding)
- Conducting program audits and trip reporting[13]

Early evaluation of the impacts of TNCs on airport revenues by the ACRP has produced a mixed picture in terms of the timing and extent of the impacts.[14] In most cities, TNCs have captured market share from taxis and limos. However, if the airport assesses ground transportation fees on TNCs, these fees for the most part have replaced lost taxi and limo fees. When TNCs replace private vehicle trips, many airports are adding new airport 'per trip' fees that didn't exist before. Less clear are the long-term impacts of TNCs on parking and rental car revenues since expanding demand for air travel has occurred simultaneously with high adoption rates for use of TNCs. TNCs are causing industry-wide disruptions for rental car agencies and subsequently generation of airports' major sources of revenue. These include fees paid by the rental car companies for counter space and their operations, as well as CFCs paid by those that rent cars. Higher percentages of travelers, and especially business travelers, are turning to TNCs for transportation instead of rental car agencies.[15] Additionally, airport users are now less likely to utilize short- and long-term parking facilities in favor of TNCs to provide transportation to and from airports. A TNC modeling study found that parking revenues could drop 3-5 percent as a result of TNC user growth.[16] Losses in parking and CFC revenues could diminish airports' abilities to develop in the future if TNCs continue to divert users from these airport services.

9.2.2.2. *High-Speed Rail*

High-speed rail development opportunities in Colorado would promote regional connectivity and key transportation nodes such as airport and highway connections. Several feasibility studies have been

[13] Ricondo, Craig Leiner and RSG, Thomas Adler. ACRP Report 215, "Transportation Network Companies (TNCs): Impacts to Airport Revenues and Operations." 2019.
[14] Ibid.
[15] Ray Mundy. "Current Trends in Airport Ground Transportation." 2019.
[16] Walker Consultants. "Airport Parking, TNC's and Airport Business." 2018

completed in recent years to assess opportunities related to the provision of high-speed rail across Colorado, along the Front Range, and the I-70 Mountain Corridor. More recently in July 2017, Senate Bill (SB) 17-153 created the Southwest Chief and Front Range Rail Commission. In 2018, the Colorado General Assembly made a $2.5 million General Fund transfer to fund the work of the "Rail Commission", including the development of a rail passenger service plan for the Front Range corridor. The state will be reviewing several alternatives, at varying price points, for advancing innovative yet practical pathways for planning and coalition building in pursuit of funding. In July 2019, the Rail Commission selected a consultant to develop the Rail Passenger Service Development Plan and provide project specific National Environmental Policy Act (NEPA) engineering.

9.2.2.3. *Other Mobility Solutions*

Driven by the same economic factors that propelled growth in commercial aviation, all major modes of passenger travel have experienced steady growth. So too has there been a convergence of digital companies, transport operators, and innovative startups combining efforts to advance new mobility solutions such as autonomous vehicles, eVTOLs, and hyperloops. Smart mobility applications that manage a traveler's journey end-to-end are likely to reshape mobility ecosystems over the next 20 years.[17] Combine a smart mobility app with self-driving vehicles, hyperloops, high-speed trains, inner-city eVTOL stations, and other new mobility-related technologies, and it is possible to imagine coherent end-to-end travel that looks very different than today's segmented trips.

Early research on these mobility solutions suggest the potential to transform air demand and operations at airports. The ACRP has pursued three research projects that begin to address the impacts of new modes of transportation on airports:

- ACRP Report 204, "Air Demand in a Dynamic Competitive Context with the Automobile," (2019)
- ACRP Report 215, "Transportation Network Companies (TNCs): Impacts to Airport Revenues and Operations," (2019)
- ACRP 03-47, "Rethinking Airport Parking Facilities to Protect and Enhance Non-Aeronautical Revenue" (likely publication in 2020)

Each of these reports examines how changes in the use of emerging technologies and adoption rates by different demographic groups will affect activity and revenue at airports. Among the major themes discussed are:

- Increased competition between air travel and the car, especially when self-driving vehicles can offer a private trip with higher levels of amenities and improved communication platforms. A door-to-door solution, if it gained traction, would impact short-haul trips more than long-haul air trips and probably reduce air connectivity at small airports more than larger ones.
- As a contrary scenario, if small aircraft technology improves in terms of comfort, cost, connectivity options, and fuel, these aircraft (e.g., electric aircraft or eVTOL vehicles)

[17] Oliver Wyman. "Mobility 2040, the Quest for Smart Mobility." 2018.

could compete with self-driving cars and lead to more direct short- and medium-distance flights. This scenario would provide a positive outlook for smaller airports.

- To better gauge mode preferences for emerging technologies, it is important to separately analyze both the hard factors (e.g., travel time and cost) and the soft factors (e.g., attitudes and preferences) that go into a mode choice. Demographic groups differ on important matters such as the value of car ownership, desire for privacy, distaste for long-distance trips, stress levels around travel, and appetite for multiple trip connections.
- Increased use of TNCs and self-driving vehicles may have a significant impact on demand for parking and inventory of rental cars at airports. Since parking garages and rental car facilities require long lead times, airport sponsors are already factoring in flexible designs of these facilities for future reuse.

As artificial intelligence (AI) technologies improve and self-driving vehicles move from testing to wider use, these new transportation modes will impact daily life. Early optimism for autonomous cars and hyperloop pilot programs in Colorado has given way to more measured progress. That said, these emerging mobility solutions invite ongoing observation and reassessment in the next Colorado Aviation System Plan (CASP).

9.2.2.4. *Changes in Attitudes about Flying*

The movement to fly responsibly (or not fly at all) speaks to growing awareness of climate change and the desire to reduce carbon emissions to the atmosphere. In 2019, a recognizable group of "flight-shamers" coalesced in Europe to call attention to the effects of air travel on climate change. Flying responsibly has become a global movement that has had an impact on both airlines and air travelers.

On the customer side, activists are urging air travelers to:

- Use online platforms to conduct meetings and conferences
- Consider the least impactful mode of travel, be it carpooling, trains, or air depending on the distance traveled based on carbon emission calculations
- Avoid short-haul flights as 25 percent of airplane emissions occur during take-off and landing; non-stop versus connecting flights also result in fewer overall emissions
- Buy carbon offsets or participate in projects such as planting trees or clean water initiatives that reduce overall emissions[18]

Airlines are also responding to and participating in alternative fuel and carbon offsetting programs. For example, JetBlue aims to be "the first carbon-neutral carrier in the U.S. in 2020."[19] As part of their program, they are powering some transcontinental flights partially with biofuels and revamping their fleet to include more fuel-efficient aircraft. Other carriers are ending on-board duty-free sales to reduce aircraft weight and in Europe, some carriers are charging extra fees to offset emissions. United Airlines has a CarbonChoice carbon offset sponsorship program with its corporate customers where United will purchase carbon offsets for corporate travel and invest in projects that will reduce GhG.

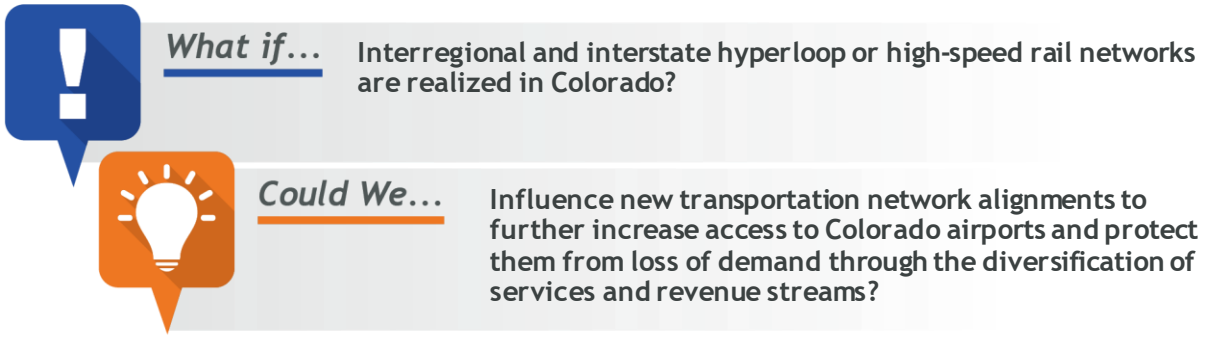
[18] https://www.nomadicmatt.com/travel-blogs/flight-shaming-flying-environment/, posted January 21, 2020.
[19] https://skift.com/2020/01/23/jetblue-ceo-warns-flight-shaming-is-coming-to-the-u-s/, posted January 23, 2020.

Currently, the company and its corporate partners are participating in a forest conservation program in Peru.[20]

Climate action is taking place on a project-by-project basis. If climate change conviction increases, actions to reduce carbon emissions are likely to increase and become more coordinated. For Colorado, this is a timely issue that merits ongoing monitoring as concerted efforts to address climate change will undoubtedly affect travel patterns and the Colorado system of airports.

Infrastructure

Multiple and extensive feasibility studies for high-speed rail have already been completed in Colorado, helping position the state to break ground on new transit networks. Furthermore, Colorado's potential for hyperloop development has led to expedited research, testing, and potential implementation in the future. If these developments were to be realized, Colorado would have supplemental transportation networks and modes to quickly move people and goods over long distances across the state. Although these additions would enhance the overall multi-modal transportation system in Colorado, airport users may transition to these new modes for travel, which could decrease aviation activity for some airports.

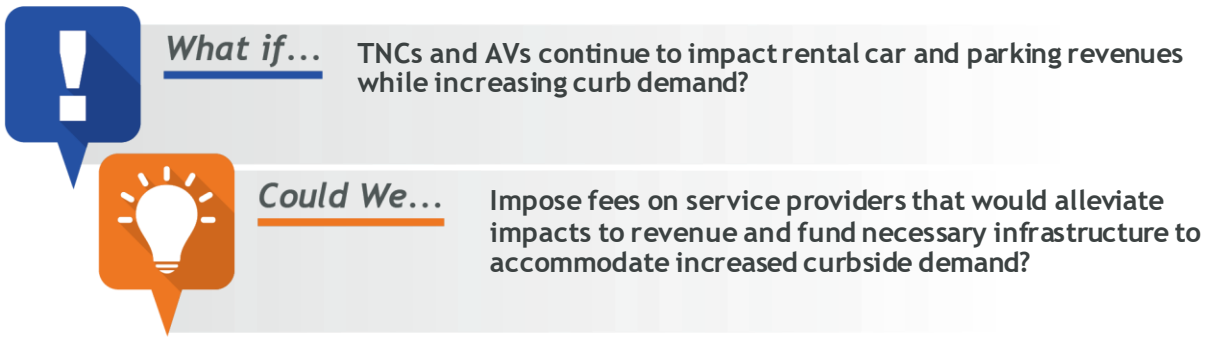


Funding

The two greatest concerns pertaining to TNC operations and self-driving vehicles at airports are the loss of revenues from airport parking, rental cars, and CFCs, and curbside management due to congestion. The use of TNCs in favor of driving to the airport or renting a car has reduced parking revenue at some large airports. As more users favor TNCs for transportation to and from the airports over renting cars, airports may continue to see reduced collection of CFCs and revenue generated from rental car agencies. For large- and medium-hub airports, parking revenues and rental car revenues (including CFCs) are the largest sources of income, so any reduction can be impactful.[21] Airports can help to reduce the impacts of parking revenue loss by implementing fees for TNC pick-up and drop-off, but often these fees are not enough to overcome the overall revenue loss, particularly if parking revenues decline. Moreover, curbside management concerns result in the designated pick-up/drop-off lanes becoming overly congested, reducing traffic flow and creating safety concerns particularly in

[20] https://www.united.com/ual/en/us/fly/company/global-citizenship/environment/carbon-offset-program.html
[21] Ricondo and RSG, ACRP Report 215, Transportation Network Companies (TNCs): Impacts to Airport Revenues and Operations, August, 2019.

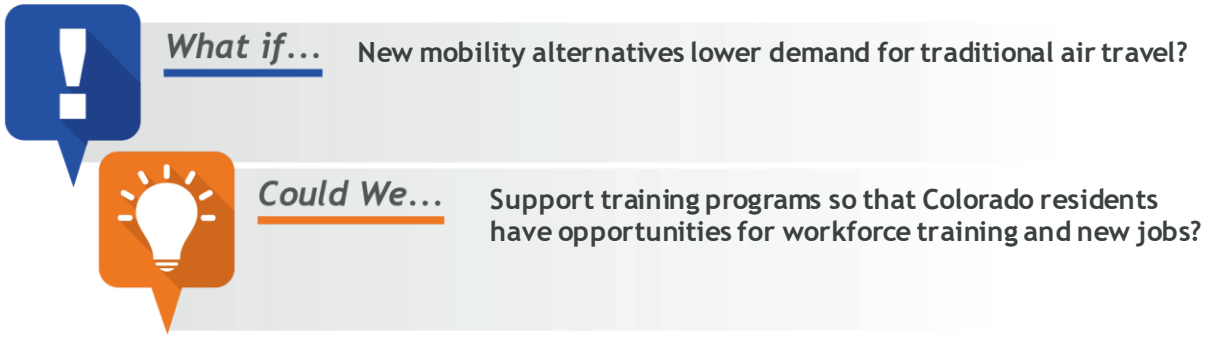
front of the terminal. It is anticipated that these issues will continue to worsen over time without the appropriate policies in place.



In May 2019, the Colorado State Legislature passed SB 19-239, which directed CDOT to convene a group of appointed stakeholders (the Working Group), to conduct a study, and solicit policy recommendations. The Working Group was charged with evaluating impacts of the emerging mobility providers and providing feedback on a range of potential fee structures on motor vehicles used for commercial purposes, as defined by SB 19-239, that could be used to encourage the use of zero-emission vehicles (ZEVs) and shared rides in emerging mobility providers.

Workforce

The prospect of new mobility alternatives may lower demand for air service and its supporting workforce. Self-driving vehicles could replace taxi, limousine, and TNC drivers engaged in 'car-for-hire' services. That said, this next generation of sophisticated alternatives to air travel will also spawn new employment opportunities. It may be too early to build new training programs around these emerging industries; however, new mobility alternatives present opportunities for workforce development.



Environmental

Advocacy groups that favor reductions in carbon emissions strive to lower demand for air travel in European countries in favor of alternate ways of travelling. Environmentally conscious travelers in the U.S. may evaluate alternative forms of transportation when GhG emission concerns become more widespread and begin to affect modal choices of travel.

What if... Climate change advocates are successful in reducing aviation demand nationally and in Colorado?

Could We... Support Colorado-specific sustainability certification programs for aviation professionals and airports while promoting current sustainability practices and commitments to the public?

Conclusion

The integration of new transportation technologies into a robust ground transportation network in Colorado could vastly improve mobility and access across the state. Implementation of high-speed rail or regional hyperloop would increase inter-regional connectivity and much larger interstate development would provide long-distance transportation opportunities. Other changes such as the continued popularity of TNCs and the rise of the social movement targeting carbon-emitting industries could affect airports in the future.

9.2.3. Economic Changes

This section explores changes in the economy that could potentially impact aviation demand in Colorado.

9.2.3.1. *Economic Changes due to Climate Change*

Colorado's outdoor recreation industry is a significant contributor to the state's economy and its winter tourism industry makes up a large portion of it.[22] Since Colorado's winter tourism is weather dependent, and by extension, climate dependent, climate change will affect winter tourism in the state. Climate change impacts of reducing snow cover or changing the patterns of annual snowfall have shown to have negative consequences to Colorado's winter tourism and air and aerospace industries. Studies by Colorado Ski Country USA and REI found that the state's winter sports industry and winter tourism generate between $2.5 and $4.8 billion in economic activity.[23] This activity supports the tourism and recreation sector creating up to 43,000 jobs and a large contribution to state revenues.[24]

The economic impact of the state's winter sports industry also extends beyond Colorado's ski communities. It has a symbiotic relationship with the aviation industry in that the winter sports industry depends on air transportation to bring domestic and international visitors, while the aviation industry depends on the state's winter sports industry to generate demand for its services. During the 2013-14 winter season, winter sports enthusiasts accounted for 588,000 deplanements at DEN, or 8

[22] Shelesky, Stephen. 2016. Examining the Economic Impacts of Climate Change on Colorado Ski Communities Through 2050. University of Colorado at Boulder.
[23] 1) Colorado Ski Country USA. "Economic Study Reveals Ski Industry's $4.8 Billion Annual Impact to Colorado." https://www.coloradoski.com/media_manager/mm_collections/view/183; 2) Protect Our Winters. "The Economic Contributions of Winter Sports in a Changing Climate." https://gzg764m8l73gtwxg366onn13-wpengine.netdna-ssl.com/wp-content/uploads/2018/02/POW_2018_economic_report-1.pdf
[24] Ibid.

percent of all non-connecting arrivals to DEN in that period.[25] As a response, winter sports destinations like Vail and Aspen are implementing environmental actions to reduce the impacts of climate change on their communities and supporting climate advocacy groups such as Protect Our Winters (POW) to influence climate policy changes at the national level. POW advocates for policy changes such as transit electrification, increased renewable energy generation, etc. to protect alpine and other winter environments for current and future generations to enjoy.[26]

Sensitivity Analysis Methodology

The sensitivity analysis used the Colorado Dynamic Calculator[27] to evaluate how an incremental change in snowfall would impact Colorado's economy due to a decline in visitor spending and airport operations, with the assumption that there will be some mitigation from attempts to substitute winter sports revenues with more non-snow-based options. Other assumptions that were referred to in the sensitivity analysis include:

- A decrease in precipitation due to climate change, leading to a 10 percent decline in number of annual visitors to Colorado for winter tourism.
- National Ski Areas Association's (NSAA's) estimated number of visitors participating in winter tourism or winter sports in Colorado (**Table 9.4**).
- Declines in visitor spending by visitor type focus only on international and domestic air travelers, and therefore represent a more conservative estimate if you consider day-trippers and others traveling from the region by car.
- Airport-specific visitor spending parameters within Colorado's Dynamic Calculator were used since spending was by category and specific to each region. Eight airports were modeled in this scenario including Denver International, Eagle County Regional, Aspen-Pitkin County, Gunnison-Crested Butte Regional, Durango-La Plata County, Grand Junction Regional, Telluride, and Yampa Valley Regional Airports.

Table 9.4. Total Annual Winter Tourism Visitors to Colorado

Type of Visitors for 2018 Season	Number of Winter Sports Visitors
International Visitors[28]	552,000
Domestic (non-Colorado Resident) Visitors	7,038,000
Local Visitors/Colorado Residents	6,210,000
Total	**13,800,000**

Sources: Fly Denver, "International Traffic at DEN accounts for over 4% of the airport's total passenger traffic," 2019; Coloradoan News, "Colorado Ski Industry Economy", 2015

[25] Colorado Ski Country USA. "Economic Study Reveals Ski Industry's $4.8 Billion Annual Impact to Colorado." https://www.coloradoski.com/media_manager/mm_collections/view/183

[26] Protect Our Winters. "Our Work". https://protectourwinters.org/

[27] The Colorado Dynamic Calculator was developed by EBP US to enable CDOT to perform simple updates when airport conditions change and to conduct "what-if" analyses to estimate economic impacts of airport conditions or regional economies in the future.

[28] International visitors account for four percent of total overnight visitation, but their impact is significant due to their high rate of spending.

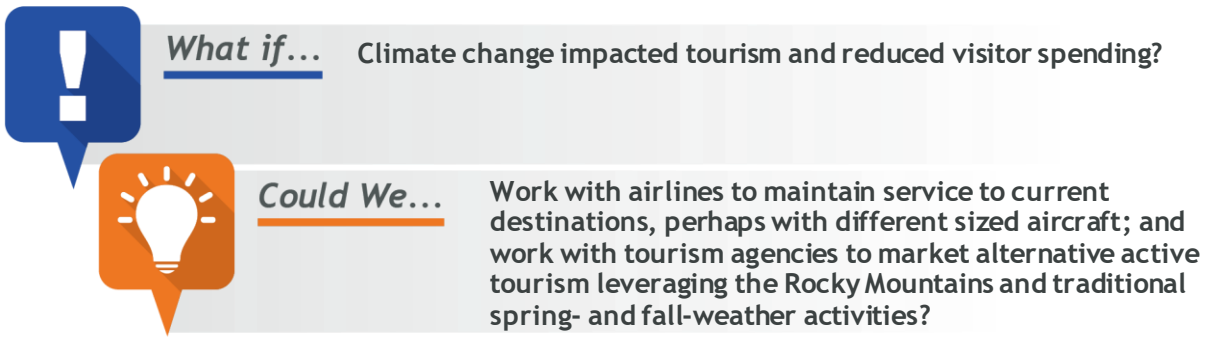
9.2.3.2. *Infrastructure*

With a decline in winter sports-related tourism, airports in the state that serve visitors could find themselves overbuilt for servicing reduced passenger levels. The exact impact on airport infrastructure from declining winter tourism would depend on whether or not the remaining seasons' travelers were also reduced.

9.2.3.3. *Funding*

The combined statewide impacts of lost visitor spending and decreased airport operations of 10 percent results in losses of $990 million in value-added and $1.5 billion in business revenues. Reductions in visitor spending were distributed to each of the eight airports based upon proximity to large regional resort destinations. Analysis was constrained to the 20 largest resorts in Colorado due to availability of visitor data. Included in the $1.5 billion of lost business revenue is a $476 million reduction expected from declining supplier sales and income re-spending.

In addition to visitor spending losses, reductions in on-airport activity due to reduced passenger volumes will also be felt. Based on the decline of assumed airport visitors to these eight airports, the estimated economic loss to proportional airport operations would be $708 million in value-added and over $1 billion in business sales leading to losses in sales tax revenues.



9.2.3.4. *Workforce*

The combined impacts of lost visitor spending and decreased operations of 10 percent to the air industry could result in losses of 12,184 jobs and $645 million in payroll. The most impacted industries relating to direct visitor spending losses would be services, retail, transportation, and health services. These industries predominantly serve the tourist and visitor markets with lower wages, less than full-time employment, and are often seasonal. Short-term wage earners may rely on this income as employment opportunities in other industries outside of tourism may be scarce. **Table 9.5** shows that 4,465 additional jobs would be lost due to reduced visitor spending in winter tourism.

Table 9.5. Job Impacts of Reduced Visitor Spending Due to a 10 Percent Decline in Winter Tourism

Sector	Jobs			
	Direct Impact	Supplier Sales	Re-spending of Income	Total Impact
Agriculture & Extraction	0	-9	-6	-15
Utilities	0	-5	-2	-7
Construction	0	-19	-9	-28
Manufacturing	0	-14	-8	-22
Wholesale Trade	0	-20	-25	-45
Retail Trade	-186	-25	-126	-337
Transportation	-257	-21	-19	-297
Postal & Warehousing	0	-43	-7	-50
Media and Information	0	-24	-14	-38
Financial Activities	0	-135	-133	-268
Professional & Business Services	0	-246	-106	-352
Education & Health Services	0	-4	-164	-168
Other Services	-2,467	-138	-229	-2,834
Government	0	-2	-2	-4
Total	**-2,910**	**-705**	**-850**	**-4,465**

Source: EBP US; Colorado Dynamic Calculator, 2020

In addition to the visitor spending losses, reductions in on-airport activity due to reduced passenger volumes would also experience a loss in additional jobs and payroll (7,719 additional jobs and a loss of $480 million in payroll). The job losses by sector are displayed in **Table 9.6.**

Table 9.6. Job Impacts of Reduced Airport Operations Due to Air Visitor Losses

Sector	Jobs			
	Direct Impact	Supplier Sales	Re-spending of Income	Total Impact
Agriculture & Extraction	-1	-100	-15	-116
Utilities	-2	-5	-6	-13
Construction	-0	-59	-25	-84
Manufacturing	-57	-22	-25	-104
Wholesale Trade	-4	-54	-70	-128
Retail Trade	-17	-17	-341	-375
Transportation	-2,984	-237	-53	-3,274
Postal & Warehousing	-8	-502	-23	-533
Media and Information	-17	-29	-42	-88
Financial Activities	-46	-195	-364	-605
Professional & Business Services	-124	-477	-300	-901

Sector	Jobs			
	Direct Impact	Supplier Sales	Re-spending of Income	Total Impact
Education & Health Services	-26	-4	-449	-479
Other Services	-200	-133	-620	-953
Government	-49	-10	-7	-66
Total	**-3,535**	**-1,844**	**-2,340**	**-7,719**

Source: EBP US; Colorado Dynamic Calculator, 2020

What if... CDOT supported a statewide program to help train airfield and terminal airport workers for other potential airport- and transportation-related jobs?

Could We... Work with other state agencies to support workforce training and implement economic development strategies to bolster impacted segments of the labor force and help foster career ladders across airports?

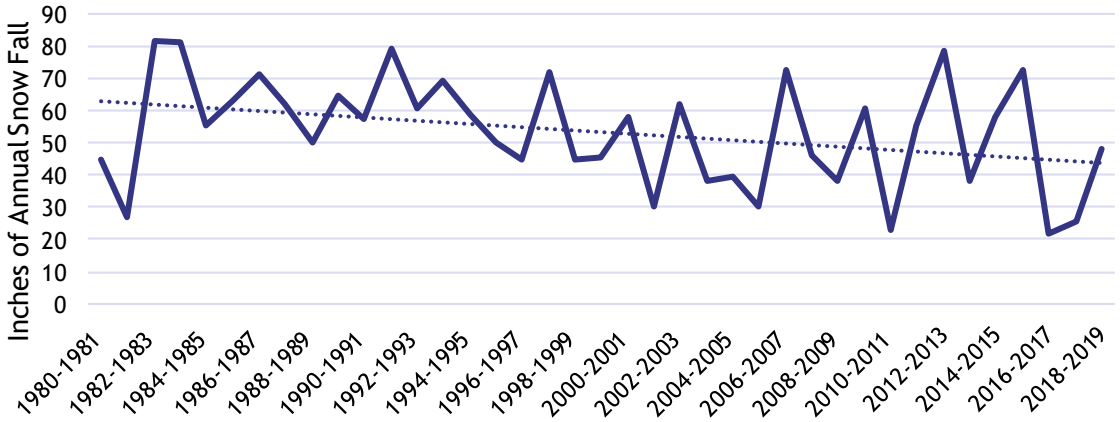
9.2.3.5. *Environmental*

Winter sports resorts and supporting industries rely on good snowfall conditions for profitable seasons. Climate warming can reduce snowfall and cause shorter snow cover seasons.[29] Seasons with warmer temperatures or low precipitation impact the industry. Although resorts can make up for periods of low precipitation via snowmaking, temperatures above freezing limit the effectiveness. Climate change poses a possible threat in both regards.

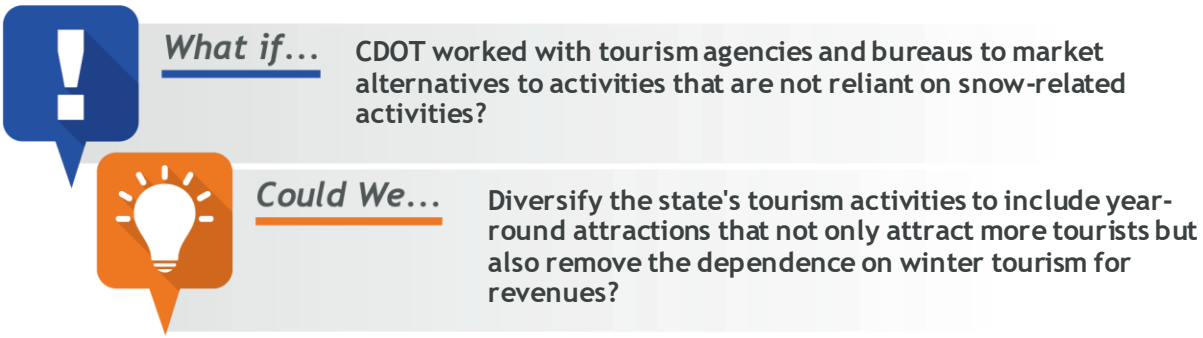
The 30-year average for annual snowfall is 55.7 inches per season for Colorado. Despite some recent years with over 70 inches of snow, there is growing variation in snow totals from year to year, and the overall trend is showing a slow decline in annual snow totals as shown in **Figure 9.1**. Forecasts suggest reductions in winter precipitation in the lower Colorado region (Gergel et al., 2017). An analysis of the correlation between skier visitations and Snow Water Equivalent (SWE)[30] serves as a proxy for the relationship between snowfall and skier visits. Results from that analysis showed strong positive correlation between skier visits and total SWE for most states in the western U.S. Shelesky (2016) also found that average SWE is a significant driver of skier visitation in Colorado.

[29] National Snow & Ice Data Center. "Snow and Climate." https://nsidc.org/cryosphere/snow/climate.html
[30] Snow Water Equivalent is a snowpack measurement in which the amount of water within a snowpack is evaluated. This is then thought of as the depth of water that would result if the snowpack were to melt entirely (USDA Natural Resources Conservation Service). https://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/snow/?cid=nrcs142p2_046155).

Figure 9.1. Annual Snow Totals in Inches, 1980-2019



Source: National Oceanic and Atmospheric Administration (NOAA), National Weather Service, 2019



9.2.3.6. *Conclusion*

The winter tourism industry is important to the economic vitality of Colorado. A few bad seasons could result in major impacts to supporting industries and impact rural parts of the state the most. A permanent shift in snowfall due to climate change would require a strategic response including economic development, workforce training, and proactive promotion to bolster the economy, real estate markets, and seasonal aviation.

9.2.3.7. *Economic Changes in Aerospace*

This scenario considers economic loss or gain from changes in Colorado's aerospace industries and is focused on aerospace equipment manufacturing and local industry supporting air operations. The scenario also examines the impact of higher operating costs and reductions in service.

Sensitivity Analysis Methodology

Colorado's aerospace industries include many companies that are developing a complete spectrum of products and systems for commercial, military, and civil space applications. The state hosts the second largest aerospace economy in the U.S., with more than 55,000 workers and 997 companies across Colorado. Two sectors that play a major role in Colorado's aerospace industry are aerospace product

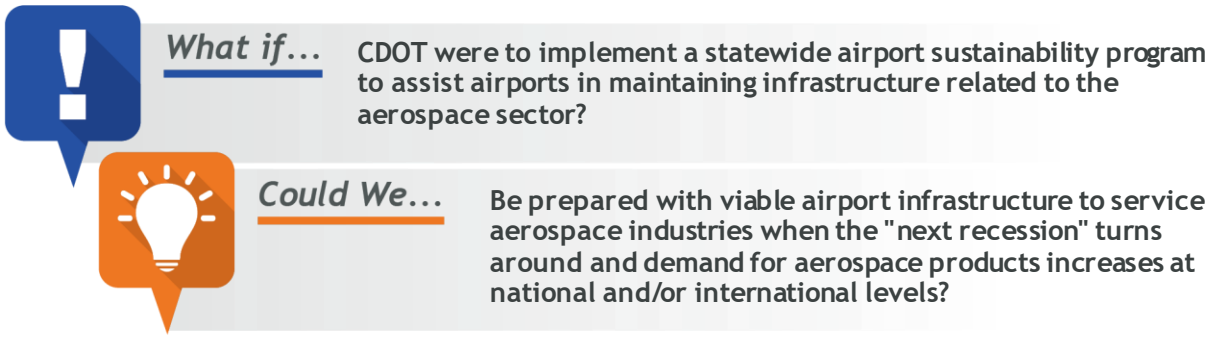
and parts manufacturing and support activities for air transportation. These industries support the state's large aerospace presence, commercial aviation, and GA operations.

This aerospace alternative estimates a scenario in which these two industries decline back to 2008 recession levels, including a 14-percent decline in the Aerospace Industry and a 20-percent decline in Support Activities for Air Transportation.

9.2.3.8. *Infrastructure*

Aerospace Product and Parts Manufacturing and Support Activities for Transportation are two supporting industries that play an important role in affording airlines, passengers, and cargo a safe and functional infrastructure to operate in airports. Aerospace Product and Parts Manufacturing generally includes establishments that are engaged in activities such as manufacturing aircraft, missiles, space vehicles and their engines, propulsion units, and auxiliary equipment. As of 2017, this industry saw a total revenue of $244 billion across 1,754 establishments in the U.S.[31] Industries in the Support Activities for Transportation subsector provide services which support transportation. These services may be provided to transportation carrier establishments or to the general public. This subsector includes a wide array of establishments, including air traffic control services, cargo handling, and motor vehicle towing. As of 2017, this industry saw a total revenue of $26.9 billion across 6,105 establishments in the U.S.[32]

Declines in these two aerospace-related sectors would have an impact on general state infrastructure. Depending on the locations of the businesses, the most likely impact on airport infrastructure would be due to lost commercial service and GA passengers who are no longer flying due to the declines in business activity.

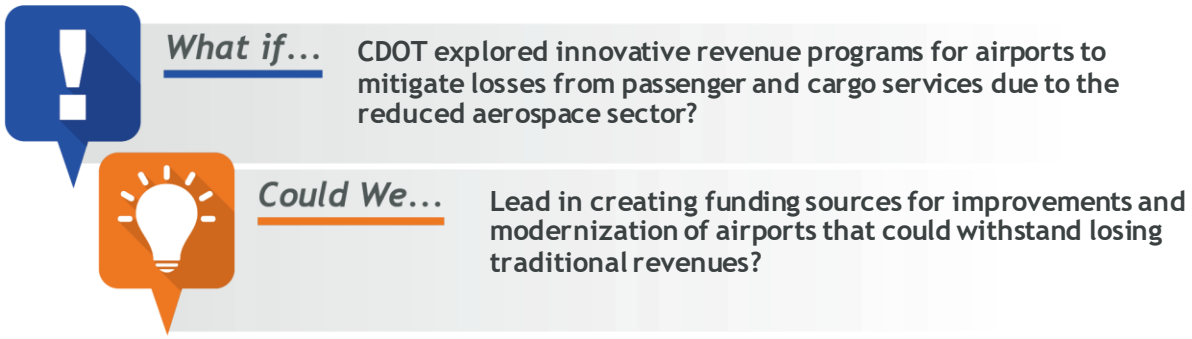


9.2.3.9. *Funding*

The overall impact of the 14-percent and 20-percent reductions to Colorado's Aerospace Product and Parts Manufacturing and Support Activities for Air Transportation industries includes a loss of $1.3 billion in business sales within Colorado. This is due to direct industry losses, a decline in purchases of supplier goods and services (for example, air passenger transportation services at Colorado airports and

[31] United States Census Bureau. Table EC1731BASIC: Manufacturing: Summary Statistics for the US: 2017. Dataset: ECNBASIC2017.
[32] Table EC1748BASIC: Transportation and Warehousing Statistics for the US: 2017. Dataset: ECNBASIC2017. Economic Census. United States Census Bureau.

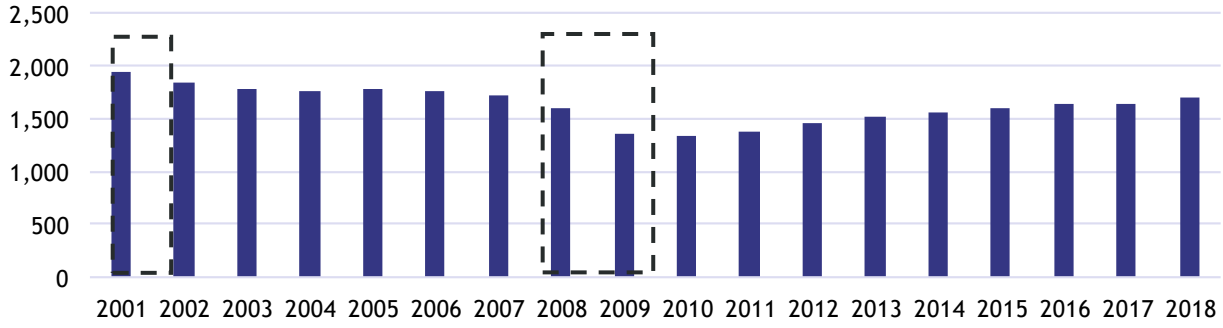
the purchase of tires from wholesalers and retailers in the state), and the income impact from reduced jobs and resident spending. The decline in sales corresponds to a loss of $367.8 million in labor income and a decline of 5,050 jobs. Overall statewide economic activity would decline by $558 million, with an additional loss of significant income tax revenue.



9.2.3.10. *Workforce*

In 2018, the Aerospace Product and Parts Manufacturing industry had 1,702,100 employees nationwide. Two periods that saw a drop in employment growth were from 2001 to 2003 and 2008 to 2010. These two time periods correspond with the economic recessions the U.S. experienced in the early 2000s and in 2008. The Great Recession in 2008 had the more significant effect, where employment growth was more stagnant (**Figure 9.2**).

Figure 9.2. Transportation Equipment Industry Jobs (NAICS 336), Nationwide (in Thousands)

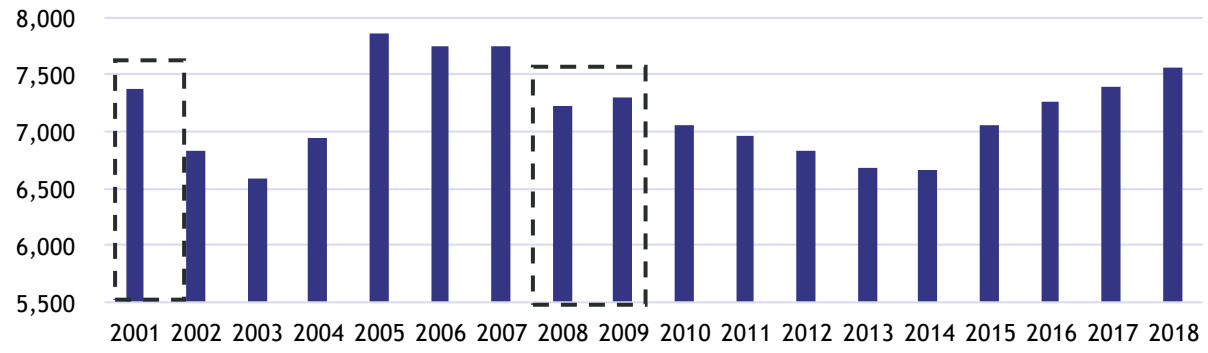


Note: the boxes represent recession periods

Source: Bureau of Labor Statistics (BLS), Quarterly Census of Employment and Wages (QCEW), 2019

The job trends for the Aerospace Product and Parts Manufacturing industry in Colorado were more variable than the national trend during the same time period. As the bars for the 2001 and 2008 recessionary periods show, Aerospace Products and Parts Manufacturing employment also shows declines following the recessions and eventually returns to positive growth (**Figure 9.3**). Job growth since 2015 averaged 3.3 percent for Aerospace Products and Parts Manufacturing through 2018.

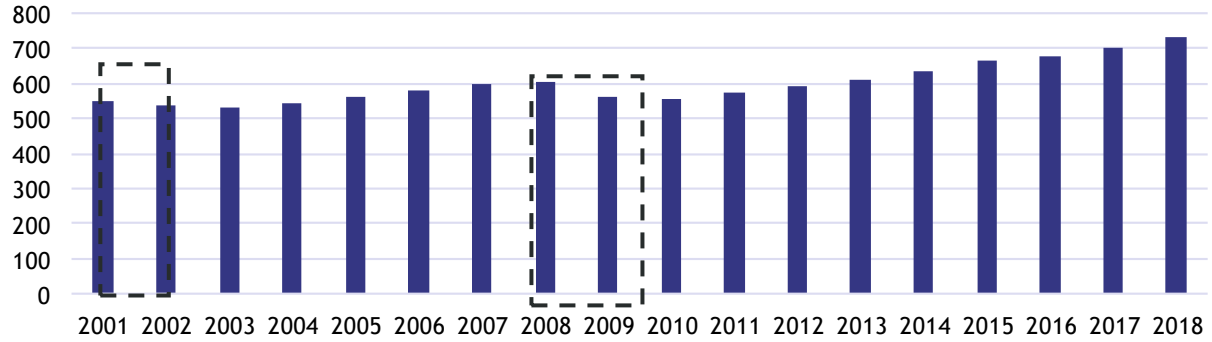
Figure 9.3. Aerospace Products and Parts Manufacturing in Colorado[33]



Note: the boxes represent recession periods
Source: Bureau of Labor Statistics (BLS), Quarterly Census of Employment and Wages (QCEW), 2019

The Support Activities for Transportation Industry had an average nationwide number of 729,500 employees in 2018. Similar to the Aerospace Product and Parts Manufacturing, the Support Activities for Air Transportation industry also saw a decline during the two economic recession in the early 2000s and in 2008. As shown in **Figure 9.4**, compared to NAICS Sector 336, the 2000 and 2008 recessions did not have as much of a significant effect on NAICS Sector 488 (Support Activities for Air Transportation).

Figure 9.4. Support Activities for Air Transportation Jobs (NAICS 488), Nationwide (in Thousands)



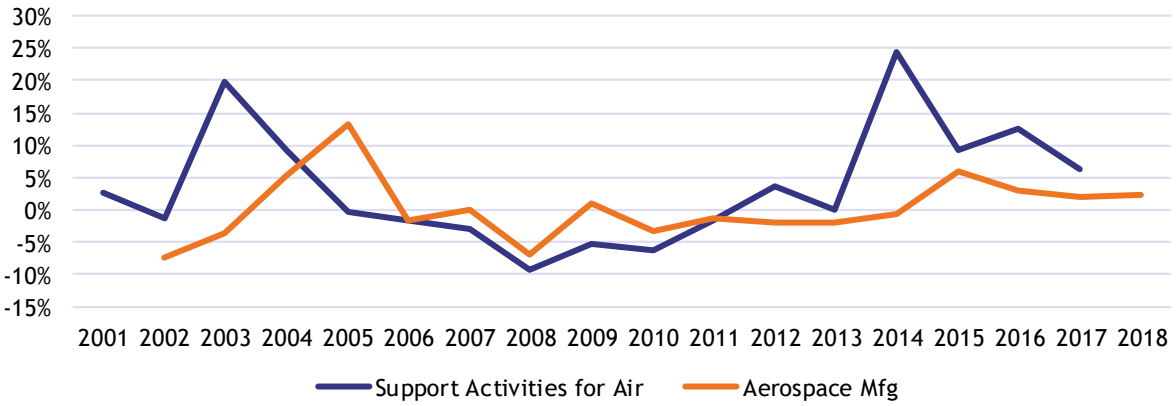
Note: the boxes represent recession periods
Source: Bureau of Labor Statistics (BLS), Quarterly Census of Employment and Wages (QCEW), 2019

The Support Activities for Air Transportation industry in Colorado fluctuated more than the national trend for the same time period. Like the Aerospace Product and Parts Manufacturing industry, the Support Activities for Air Transportation employment declined in the 2008 recession and then saw positive growth starting in 2015 that continued through 2018 at a growth rate of 13.1 percent (**Figure 9.5**). In 2001, the industry did not see a decline, but instead saw a positive change of 2.7 percent between 2001 and 2002. The recession hit the industry in 2002 with job losses of 1.4 percent between

[33] Note: dashed bar represents recessions.

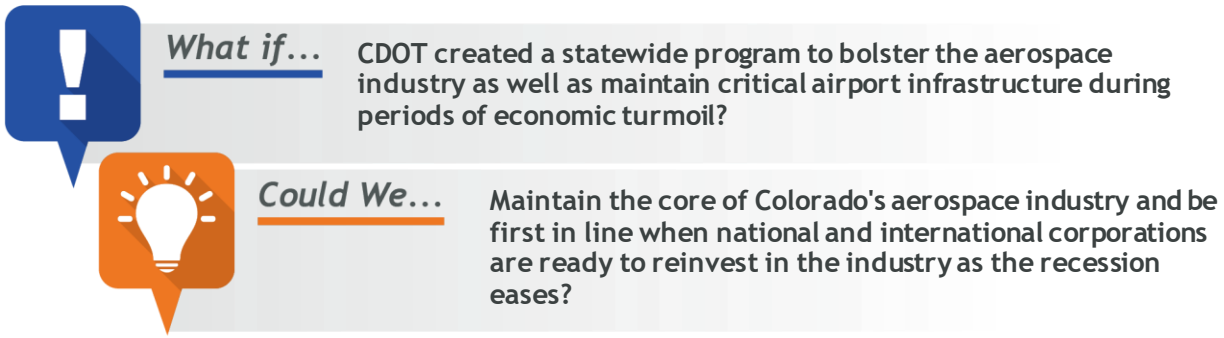
2002 and 2003 and returned to positive growth from 2003 to approximately when the next recession hit the U.S. economy in 2008. The annual growth trends for both industries are shown in **Figure 9.5**.

Figure 9.5. Job Growth by Industry, 2001-2018



Source: Bureau of Labor Statistics (BLS), Quarterly Census of Employment and Wages (QCEW), 2019

Sending the industry back to recession levels would result in a direct loss of 1,070 jobs for Aerospace and a loss of 1,050 jobs for Support Activities in Colorado. The drivers behind these reductions could be another recessionary period, declines in flight operations, or general domestic declines in aviation manufacturing. While impacts to the broader aviation industry will have national impacts, a recession would have a larger impact across all sectors of the Colorado economy. Therefore, this is just a snapshot of how the economy will respond to these two industries returning to recession levels.



9.2.3.11. *Environmental*

No tangible environmental impacts were identified from potential industry reductions. The reductions are likely to result in fewer cars on the road due to less workers and less energy consumption by the businesses.

9.2.3.12. *Conclusion*

The aerospace industry is a major contributor to the Colorado economy. Every job gained in these industries results in another two and a half jobs across other sectors of the economy. This scenario demonstrates that returns to recession levels in the Aerospace and Support Activities for Air

Transportation industries results in reductions of 14 percent and 20 percent, respectively. This means a loss of $558 million in economic activity to Colorado's economy. While CDOT cannot individually affect national and international economic trends, the analysis demonstrates the importance of maintaining Colorado's position and preserving the core of its aerospace industry. This industry has a significant reliance on airports and can be a major contributor to the state's quick emergence from a recession.

9.3. Summary of Alternatives

This analysis summarizes the potential impacts of seven alternative categories, some of which had multiple events that could affect the aviation system. Each alternative scenario was examined to determine infrastructure, funding, workforce, and environmental impacts, with identification of a potential action that could be considered by CDOT Division of Aeronautics to address the scenario. The use of new aviation and transportation technologies may have the most significant influence in the future facilities and services airports deliver to meet changing needs. Changes in population and economic environs may also influence the system by influencing aviation needs at the state and regional levels. It will be important for airports to increase their resiliency against future effects diversifying revenue streams and funding opportunities, growing the aviation workforce, and incorporating sustainable practices.