

Working Paper



Arizona State Freight Plan

(ADOT MPD 085-14)

Phase 3 Working Paper High-Tech Manufacturing Sector Profile and Transportation Performance Needs

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Working Paper

This working paper is one of 10 focusing on key Arizona economic sectors. Its purpose is to document the economic profile, outlook and transportation performance needs of Arizona's high-tech manufacturing sector. This working paper will later inform system improvement needs to increase Arizona's economic competitiveness and growth. This working paper is provided for comment and discussion and should not be interpreted as final.

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Opinions

Unless otherwise indicated, the opinions herein are those of the author and do not necessarily reflect the views of ADOT or the State of Arizona.

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Executive Summary

Economic and Traffic Profile

The high-tech manufacturing sector in Arizona consists of semiconductor companies and other advanced technology manufacturers producing communication, optical, and related instruments.

The three largest semiconductor companies in Arizona, each among the Top Employers, are Intel, 100 Microchip Technology, and Freescale Semiconductor. These companies operate wafer fabrication plants (fabs) in the state. Many small businesses producing advanced instruments are located in "Optics Valley" in the Tucson area. Companies involved in

	Measure	High-Tech Manufacturing Sector	Arizona (statewide)		
Economy	GDP (2012, \$ million)	\$7,896	\$271,503		
	GDP Annualized Growth (1997-2012)	-2.6%	4.9%		
Jobs	Employment (2013)	39,167	2,619,055		
	Compensation per Employee (2013)	\$121,004	\$57,393		
Transportation	Total Commodity Flows (2012, Mt)	0.1	138.2		
	Top Origin (2012, Mt)	Texas (0.01 Mt)	California (9.5 Mt)		
	Top Domestic Destination (2012, Mt)	Mexico (0.4 Mt)	Mexico (5.6 Mt)		
	Intrastate Flows (2012, Mt)	-	101.8		
	% Truck (2012)	86.2%	87.2%		
Source: CPCS analysis of data from Bureau of Economic Analysis and 2012 Commodity Flow Survey					

producing high-tech equipment (such as navigation equipment) specifically for the aerospace sector are profiled in the Working Paper on the Aerospace & Defense Sector.

Arizona's high-tech manufacturing sector contributed \$7.9 billion to the state's gross domestic product (GDP) in 2012, representing 2.9 percent of the state's total economic output. However, since 1997, GDP in the high-tech manufacturing sector has contracted at a rate of -2.9 percent annually, underperforming compared to the growth of the overall Arizona economy which has grown by an average annual 4.9 percent.

Exports from Arizona in the high-tech manufacturing sector totalled \$6.5 billion in 2014 while the state imported \$5.6 billion of goods from the same sector. The largest destinations were Mexico and Asia (each 38 percent); the largest import source was Asia (52 percent). Notable clusters of high tech manufacturing are located in Tucson, Oro Valley, and the Phoenix area (specifically Tempe, Chandler, and Phoenix).

Trucking is the dominant mode by tonnage, but in value terms the major modes of transportation are air and multiple modes (including small package/parcel). Specifically, around 70 percent of inbound and 85 percent of outbound freight by value is shipped by air or multiple modes (see Figure ES-1).





Source: CPCS analysis of Commodity Flow Survey, 2012.

Supply Chain Structure and Transportation Performance Needs

The products shipped by the high-tech sector are high-value and low-density, and the sector is both internationally and nationally oriented. The Arizona high-tech companies consulted stressed reliability as an important factor; time and cost are also important. Most of the barriers identified by high-tech companies are related to air service.

The competitiveness of Arizona's high-tech manufacturing industry must be assessed across two dimensions: global and national. Globally, America's major advantages lie in its strong intellectual property laws, high-quality higher education system, and advanced capital markets. Domestically, Arizona has relatively strong universities, and a mix of good climate and inexpensive housing attracts trained workers. Arizona also has competitive tax rates and concessions. On a relative basis, it is somewhat close to West Coast transportation gateways and tech hotbeds. Overall, the semiconductor industry is a mature one and Arizona's success will depend on the performance of its large semiconductor companies. For non-semiconductor manufacturers, linkages with the state's universities and the aerospace/defense industry will continue to play an important role in their competitiveness. As is the case with many sectors, high-tech manufacturing has a certain demand component tied to national defense spending, which is uncertain and likely to decrease over the next several years.

Notable Barriers and Related Priority Improvements to Enhance Competitiveness and Growth

There are three key aspects to the goods movement needs of high-tech sector companies in Arizona: the competitiveness of Sky Harbor Airport (PHX), connections to Los Angeles, and border crossings to Mexico. High-tech manufacturers are interested in more international flights from PHX, but these services are highly concentrated in airports like Los Angeles (LAX). ADOT can support any future service increases at PHX by ensuring good access to the airport (low congestion, effective truck routes). Since LAX is the most important airport internationally for Arizona manufacturers, reliable, congestion-free travel along I-10 to California is important for the competitiveness of these companies. Finally, ensuring necessary border staffing is in place at the expanded Nogales (Mariposa) Port of Entry will support companies shipping high-tech and electronic products to and from Mexico.



Acronyms / Abbreviations

ACA	ARIZONA COMMERCE AUTHORITY
ADOT	ARIZONA DEPARTMENT OF TRANSPORTATION
CFS	COMMODITY FLOW SURVEY
FABS	FABRICATION PLANTS
GDP	GROSS DOMESTIC PRODUCT
IDM	INTEGRATED DEVICE MANUFACTURER
IoT	INTERNET OF THINGS
IWA	PHOENIX-MESA GATEWAY AIRPORT
LAX	LOS ANGELES INTERNATIONAL AIRPORT
MPD	MULTIMODAL PLANNING DIVISION
Mt	MILLION TONS
OEM	ORIGINAL EQUIPMENT MANUFACTURER
OSAT	OUTSOURCED SEMICONDUCTOR ASSEMBLY AND TEST (COMPANY)
РНХ	PHOENIX SKY HARBOR INTERNATIONAL AIRPORT
SoC	SYSTEM-ON-CHIP
SSD	SOLID-STATE DRIVE
TUS	TUCSON INTERNATIONAL AIRPORT



Introduction

Key Messages

The Arizona Department of Transportation, Multimodal Planning Division, retained a team led by CPCS Transcom, Inc. to assist in the development of Arizona's State Freight Plan.

The aim of this working paper is to establish the freight transportation performance needs, outlooks, and economic contribution of Arizona's high-tech manufacturing sector (defined here as NAICS Codes 334 and 335). This will later inform the analysis of broader transportation system based needs and priorities.

This working paper was developed in large part through stakeholder consultations and analysis of high-tech manufacturing sector data.



1.1 Introduction: Why an Arizona State Freight Plan?

Arizona's economic potential is supported by the state's transportation infrastructure, which connects sources of production to markets.

When transportation infrastructure and related services are efficiently designed and competitively positioned, businesses benefit from lower transportation costs, faster and better transportation services, and increased reliability, which in turn contribute to their own competitiveness and growth, and that of the broader region.

Jurisdictions with access to competitive transportation infrastructure and services are at a competitive advantage in attracting investment, creating jobs and realizing economic growth. Arizona's State Freight Plan can help enable this outcome.

To this end, the ADOT's Multimodal Planning Division (MPD), is developing Arizona's State Freight Plan which will provide strategic guidance to enhance Arizona's economic competitiveness and facilitate economic growth.

1.2 Project Objectives

The State Freight Plan will define immediate and long-range investment priorities and policies that will generate the greatest return for Arizona's economy, while also advancing other key transportation system goals, including national goals outlined in MAP-21. It will identify freight transportation facilities in Arizona that are critical to the State's economic growth and give appropriate priority to investments in such facilities.

The State Freight Plan will ultimately provide Arizona with a guide for assessing and making sound investment and policy decisions that will yield outcomes consistent with the state's visions, goals, and objectives, and notably, promote regional competitiveness and economic growth.

1.3 Purpose of this Working Paper

Since it is economic activity – particularly from goods movement sectors – that drives demand for freight transportation infrastructure and services, optimization of the state's freight transportation system, and related strategies, goals and investments, must start by addressing the transportation performance needs of the sectors moving freight. Yet, the transportation performance needs of freight can differ by sector and commodity group, locations, and even company.



For this reason, the team identified 10 key freight sectors in Arizona for specific focus: wholesalers and retailers, food and beverage, high-tech manufacturing, general manufacturing, transportation equipment manufacturing, transportation and logistics, mining (except oil and gas), energy (oil and gas), agriculture, and forestry.

The purpose of this working paper is to provide a focused assessment of the transportation performance needs, outlooks and economic contribution of the high-tech manufacturing sector (defined here as NAICS Codes 334 and 335).

Specifically, it addresses the following key questions:

- At a high level, what is the profile and economic contribution of the high-tech manufacturing sector to Arizona's economy?
- How do the supply chains of Arizona's high-tech manufacturing sector utilize the transportation system and what are the major origins, destinations, intermediate points, and final products of these chains?
- How are high-tech manufacturing sector supply chains structured, managed, and what are the primary drivers of transportation decisions and related performance needs?
- What are the key trends in the high-tech manufacturing sector, how are these influencing freight flows, and what are the implications, opportunities and challenges for the competitiveness of Arizona's freight system going forward?

1.4 Methodology

This working paper is informed by a combination of literature review, data collection and analysis, and extensive consultation with high-tech manufacturing sector stakeholders. Documents reviewed are footnoted throughout the working paper, as appropriate. A list of those consulted is provided in Appendix A (unless the stakeholder has specifically requested non-attribution).

1.5 Limitations

This working paper is in many cases informed by data and input provided by third parties. CPCS has verified this information to the extent possible through analysis and cross-checking with other sources but cannot guarantee the accuracy of data received from third parties.



Working Paper | High-Tech Manufacturing Sector

High-Tech Manufacturing Sector Profile

Key Messages

The high-tech manufacturing sector in Arizona consists notably of semiconductor companies as well as other advanced technology manufacturers making communication, optical, and related instruments.

The three largest semiconductor companies in Arizona, each among the Top 100 Employers, are Intel, Microchip Technology, and Freescale Semiconductor.

Exports from Arizona in the high-tech manufacturing sector totalled \$6.5 billion in 2014, and imports \$5.6 billion. The largest export destinations were Mexico and Asia (38 percent each) and the largest source of imports was Asia (52 percent).

Notable clusters are in Tucson, Oro Valley, and the Phoenix area (specifically Tempe, Chandler, and the northern part of Phoenix).

By value, around 70 percent of inbound and 85 percent of outbound freight is shipped by air or multiple modes (including parcel), with the balance by truck.



2.1 Overview of High-Tech Sector

The high-tech manufacturing sector in Arizona consists notably of semiconductor companies as well as other advanced technology manufacturers making communication, optical, and related instruments.¹

The three largest semiconductor companies in Arizona, each among the Top 100 Employers,² are Intel, Microchip Technology, and Freescale Semiconductor. These companies all have wafer fabrication plants (fabs) in the State (there are some other large companies in the industry with headquarters in the Phoenix area, notably ON Semiconductor and Amkor, but their manufacturing is offshored). The high-tech sector is not very labor-intensive, and no companies producing advanced electronic instruments rank among the Top 100 Employers. Many of these smaller businesses producing advanced instruments are located in "Optics Valley" in the Tucson area.³ There are two large electronics distributors ranked among the Top 100: Avnet and Arrow. The former is headquartered in Arizona, and its primary global distribution center is located in Chandler. Although these companies are not directly engaged in manufacturing, because they are involved in specialized distribution, they are included in this working paper given their role in the electronics supply chain.

Companies involved in producing high-tech equipment (such as navigation equipment) specifically for the aerospace sector are profiled in the Aerospace & Defense working paper.

2.2 Economic Profile and Importance to Arizona's Economy

2.2.1 GDP

Arizona's high-tech manufacturing sector contributed \$7.9 billion to the state's gross domestic product (GDP) in 2012, representing 2.9 percent of the state's total economic output. Since 1997, GDP in the high-tech manufacturing sector has contracted at a rate of -2.9 percent per annum. Overall the state economy grew 4.9 percent annually in the same period.⁴

2.2.2 Commodity Flows

Overall, \$11.8 billion of goods in the high-tech manufacturing sector traveled into, out of, or within the State of Arizona in the year 2012. Of this, \$7.1 billion of goods originated in other

⁴ Bureau of Economic Analysis Regional Economic Accounts, GDP by State. GDP in current dollars.



¹ For transparency, for the purposes of this working paper, high-tech manufacturing is defined as consisting of NAICS segments 334 computer and electronic product manufacturing and 335 electrical equipment, appliance, and component manufacturing. Other advanced manufacturing operations such as biomedical and precision machining are covered in the general manufacturing working paper. To the extent that there is overlap with the aerospace and defense industry, for example in navigational equipment, this is addressed in the transportation equipment working paper.

² AZCentral, "Arizona Republic 100: State's Largest Employers," 2015.

³ The exact definition of the Optics industry is contentious, as the NAICS codes do not precisely capture optics firms because of their interdisciplinary nature. This leads to discrepancies in estimates of the size of the industry in Arizona. Source: Wiggins, Geoffrey, "Moving Optics and Nanotechnology Forward in Arizona." University of Arizona. Jan, 2008. This source estimates employment in optics and nanotechnology as 25,535 statewide.

states and were destined to Arizona, \$3.53 billion originated in Arizona and were destined for other states, and \$1.1 million in goods traveled within the state of Arizona.



Figure 2-1: Value of Flows Into, out of, and Within Arizona in 2012 (\$millions)

Source: CPCS analysis of Commodity Flow Survey, 2012.

Origins of Inflows to Arizona

The figure below summarizes the origins of high-tech manufacturing products that were shipped to Arizona from other states. California was the largest origin of high-tech manufacturing products destined for Arizona with \$3.46 billion in products shipped to Arizona, followed by Texas and Pennsylvania at \$1.16 billion and \$436 million respectively.





Source: CPCS analysis of Commodity Flow Survey, 2012.



Destinations of Outflows From Arizona to Other States

The figure below summarizes the destination of high-tech manufacturing products originating in Arizona. California was the largest destination for Arizona products, where \$1.66 billion worth of products was destined. Some of these flows may have been subsequently destined for international destinations through ports located in California. A review of international trade flows to and from Arizona is contained in Section 2.2.3.



Figure 2-3: Value of Top 10 High-Tech Manufacturing Sector Outflows from Arizona by State of Destination (2012)

Source: CPCS analysis of Commodity Flow Survey, 2012

2.2.3 International Trade

Exports from Arizona in the high-tech manufacturing sector totalled \$6.5 billion in 2014 while the state imported \$5.6 billion of goods from the same sector. The largest destinations for exports of goods from the high-tech manufacturing sector were Mexico and Asia (each 38 percent). The share destined to Mexico includes electronic components, including ones originally sourced from Asia, which are used as inputs in cross-border maquiladoras in other sectors. (Incidentally, this part of Mexico is underserved by international air freight services, according to some consultees, which may help explain the trucking flows through Arizona).





Figure 2-4: Destinations of Arizonan High-Tech Manufacturing Exports (2014)

Source: CPCS analysis of United States Census Bureau Electronic Export Information. Accessed April 2015.

Of the \$5.6 billion in Arizona imports in the high-tech manufacturing sector, \$2.9 billion (52 percent) came from Asia.



Figure 2-5: Origins of Arizonan High-Tech Manufacturing Imports (2014)

Source: CPCS analysis of United States Census Bureau Electronic Export Information. Accessed April 2015.

The semiconductor and other electronic component industry is the largest generator of international trade in the sector to and from Arizona, with \$2.9 billion in exports and \$2.3 billion in imports.





Figure 2-6: Top Traded Products in the High-Tech Manufacturing Sector (2014)

Source: CPCS analysis of United States Census Bureau Electronic Export Information. Accessed April 2015. Nesoi means "Not elsewhere specified or indicated"

2.2.4 Employment and Wages

In 2013 the sector employed 39,167 people in Arizona, representing 1.5 percent of total employment in the state.^{5,6} The total wages and salaries paid to employees in 2013 was approximately \$4.74 billion dollars,⁷ making the average annual earnings per employee in 2013 approximately \$121,000 for the sector. Annual earnings per employee were highest in the computer and electronic products manufacturing industries at around \$123,500.

⁷ Ibid.



⁵ Excludes self-employment.

⁶ Bureau of Economic Analysis Regional Economic Accounts, Personal Income and Employment by State, Wages and Salaries by NAICS Industry

Figure 2-7: Breakdown of Employment in the High-Tech Manufacturing Sector in Arizona (Q1 2014)



Source: CPCS analysis of Quarterly Workforce Indicators dataset, United States Census Bureau

The largest industry generating employment in the high-tech manufacturing sector is semiconductor and other electronic component manufacturing, which notably includes production of components for circuit boards. The second largest industry is navigational, measuring, electromedical and control instruments manufacturing, notably as inputs for the aerospace and satellite industries.

2.3 Locations and Traffic Profile

As illustrated in Figure 2-8, the high-tech manufacturing sector generates only 0.04 percent of overall freight tonnages in Arizona (58,000 tons). Of this volume, 86% is inbound and the remaining 14% outbound. There are no intrastate tonnages reported in the 2012 Commodity Flow Survey (CFS), from which this information was extracted, likely because of data suppression implemented for smaller numbers (tons/dollar values) that do not meet certain sampling criteria. As is evident from the above discussion, the dollar value of intrastate shipments is quite significant, indicating a high-value, low-weight nature of these shipments.

CFS accounts only for domestic movements. These include domestic shipments as well as the domestic components of international supply chains.⁸

⁸ In CFS, the sum of individual state volumes is slightly lower than the national volume which is due to data suppression and rounding in individual state-to-state movements. For consistency across all the graphics (maps and charts), this paper presents the total of state level volumes.







Source: CPCS analysis of Commodity Flow Survey, 2012.

2.3.1 Activity Clusters

The activity clusters in high-tech manufacturing are illustrated graphically in Figure 2-9. The overwhelming majority of employees in the sector are clustered in Phoenix region, Tucson and Oro Valley (near Tucson). In the Phoenix area, the clusters are mostly located in the East Valley, notably in Tempe, Chandler and northern Phoenix.





Figure 2-9: Arizona High-Tech Manufacturing Sector Employment Clusters

Source: CPCS analysis of County Business Pattern Data, 2013 by US Census Bureau.



Figure 2-10 combines High-Tech Manufacturing sector commodity flow on highways with their area of production. The clusters were identified from kernel density estimation in ArcGIS using Global Insight's Freight Finder dataset. The estimated outbound volumes produced by this sector are clustered in the southeast part of the Phoenix area and southern Tucson. In Phoenix, the major concentrations are at Tempe, Chandler, Peoria and north of Scottsdale.

The commodity flow information was extracted from Global Insight's Transearch dataset for 2013. Only Arizona-generated (originated or destined) flows are shown on the map, which excludes any through traffic. The major corridors used by this sector are I-10, I-17 leading to I-40 and U.S. 89 northbound (though a certain degree of caution should be exercised in interpretation, as discussed in Section 2.3.2).



Figure 2-10: Arizona High-Tech Manufacturing Sector Freight Cluster and Commodity Flow

Source: CPCS analysis of Freight Finder and Transearch 2013



2.3.2 Major Origins and Destinations

Mexico is the largest origin and destination for high-tech manufacturing products. Approximately 0.4 Mt (94 percent) of outbound traffic is destined to Mexico, and 0.1 Mt (60 percent) of inbound traffic originates in the country. Domestically, Arizona receives most inbound high-tech manufacturing commodities from the Midwestern and Southern states, notably Texas, Mississippi, Georgia, South Carolina, Ohio and Illinois.

It is notable that the aggregate flows to/from Mexico in Figure 2-11 broadly align with the flows on I-19 in Figure 2-10. However, the US flows appear to be far overstated in Figure 2-10, which is based on Transearch data. Because both figures involve tonnages and these are very low in the sector, caution should be exercised in interpretation. It is believed there may be differences in commodity categorization that cause such a large overestimate in the Transearch data compared to the FAF/CFS data, and the discrepancy may be amplified by the low overall tonnages.



Figure 2-11: Arizona High-Tech Manufacturing Sector Inbound-Outbound Tonnages

Source: CPCS analysis of Commodity Flow Survey, 2012. The import/export figures were obtained from Freight Analysis Framework 3 estimates for 2012.



2.3.3 Modal Breakdown

In terms of weight, trucking is the primary mode of shipment for both inbound and outbound moves.⁹ Due to data suppression in the CFS, there is no information on intrastate tonnage. In terms of dollar values, however, the major modes of transportation are air and multiple modes, which includes small package/parcel. Around 70 percent of inbound and 85 percent of outbound dollar values are shipped by air or multiple modes. It is no surprise that the heavier, lower-value commodities are shipped by trucks while more valuable and lighter commodities are shipped by air. As for shipments within the state, trucking is the main mode.



Source: CPCS analysis of Commodity Flow Survey, 2012.



Figure 2-13: Arizona High-Tech Manufacturing Sector \$ Value by Mode

Source: CPCS analysis of Commodity Flow Survey, 2012.

⁹ In CFS dataset, the individual mode volumes do not add up to the aggregate "All Mode," due to data suppression and rounding at detailed mode level.



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5 Supply Chain Structure and Transportation Performance Parameters

Key Messages

Arizona stands out among U.S. states, along with Texas and Oregon, for its concentration of semiconductor fabrication plants (fabs). These are large, costly, technologically advanced facilities where integrated circuits (chips) are made.

The Arizona high-tech companies consulted move most of their freight by air or small package services (trucking and air). Reliability was stressed; time and cost are also important. Most of the barriers identified by high-tech companies related to air service.

Arizona's competitiveness must be assessed across two dimensions: global and national. Overall the sector's success in the state will depend on the performance of its large semiconductor companies, as well as (for non-semiconductor manufacturers) linkages with the University of Arizona and the aerospace/defense industry.



3.1 Supply Chain Structure

Figure 3-1 displays a typical electronics supply chain, with a focus on semiconductors, an aspect of particular relevance for Arizona.



Source: CPCS

The Wafer Production box shows the manufacturing process used to produce inputs for the semiconductor industry. Silicon, the foundation of electronic devices, is naturally abundant and is widely used for many other applications in lower-grade forms. Silicate materials are used in direct building (as clays, stone) and for production of Portland cement, ceramics, and glasses. Most reduced elemental silicon is alloyed with iron for use in steel production, while most of the remainder is used as silicon metal in aluminum casting. Higher grade silicon is used for solar applications, while only the highest grades are suitable for electronics. In order to produce semiconductor wafers, melted high-purity silicon is crystallized into a cylindrical ingot (boule) and sliced to appropriate dimensions. Semiconductor fabrication involves subjecting the pure wafers to hundreds of processes and dicing them into chips.



Semiconductor fabrication is technically demanding and highly automated, partly because of exacting cleanliness requirements (small dust particles are highly harmful to silicon wafers). The industry includes a variety of participants involved in different stages of the supply chain:

- Integrated device manufacturers (IDMs) are firms that design, produce, and sell integrated circuit products, thus being actively involved at all stages
- "Fabless" companies retain design but outsource the actual fabrication of the semiconductors¹⁰
- Foundry companies are involved in frontend manufacturing, i.e. fabrication
- Outsourced semiconductor assembly and test

Semiconductor Fabs

Semiconductor fabrication plants (fabs) are large, complex facilities where integrated circuits (ICs or chips) are manufactured. Central to the fab is the clean room, a highly controlled setting in which small particles of dust are minimized.

Arizona is rather noteworthy among U.S. states, along with most notably Texas and Oregon, in being home to several companies' fabs. Internationally, many fabs are also located in Europe and especially Asia. Intel, the world's number one semiconductor

company, has three fabs in Chandler. Other



locations are New Mexico, Oregon, Massachusetts, Ireland, Israel, and China. Texas-based Freescale Semiconductor, ranked Top 20 globally by sales, as well as Arizona-based Microchip Technology, each have a fab in the Phoenix area (Chandler and Tempe).

Because of the very specialized technology required, fabs are extremely costly to construct – on the order of several billion dollars. Approximately two-thirds of the cost is the precision machinery within.

Text Source: Intel.com; "Semiconductor Sales Recover in 2013; Micron Surges to Fourth Place in Global Chip Market," iSuppli.com, Dec. 2013; Mitchell, M., "Intel says factory to stay shut for now," AzCentral.com, Jan. 2014. Intel.com. Photo Source: Intel.com

(OSAT) companies add value on the back-end with testing and packaging

Historically, both foundries and OSATs have gained much of their advantage from low-cost production, although this is changing as both begin to diversify their offerings. In reality, many IDMs, too, outsource some manufacturing. One trend has been "fab-lite," whereby a semiconductor company will reduce but not eliminate its own (capital-intensive) fabrication processes by outsourcing to foundries.

The semiconductor industry produces various kinds of integrated circuits (chips), such as memory chips, microprocessors, standard chips, and SoC (system on a chip). Additional products include controllers and sensors (e.g. for touchscreens) and wifi chipsets (e.g. for the Internet of Things (IoT) applications).

¹⁰ According to McKinsey, there are three broad models in the fabless space: innovators (constantly expanding their intellectual property), fast followers (offering lower-cost, streamlined alternatives in rapidly growing markets), and mature-market attackers (offering simplified value-for-money offerings with efficient development and fast production). McKinsey, "The evolution of business models in a disrupted value chain." *McKinsey on Semiconductors*. Number 1, Autumn 2011, p.33



Original equipment manufacturers (OEMs) purchase these semiconductor products for use in devices or components. For example, in 2014, the largest semiconductor customers globally were Samsung, Apple, HP, Lenovo, Dell, and Sony.¹¹ After divesting their semiconductor arms over the past three decades due to their capital intensiveness, some OEMs are taking increasing ownership of integrated circuit design. Large OEMs can have the scale and capability to function as fabless semiconductor companies.¹²

Although a lot of semiconductor fabrication has been offshored to Asia, Arizona has retained much of its activity and is home to several large fabs. Arizona is also home to many other advanced technology manufacturers, including in the fields of aerospace-defense, bioscience, and optics (the latter concentrated in the Tucson area). Many of these companies are national or global in the reach of their supply chains, even smaller firms. The world's largest electronics distributor,¹³ Avnet, has its global distribution center in Chandler.

3.2 Transportation Performance Parameters

The products shipped by the high-tech sector are high in value and low in density, and rely heavily on parcel and air modes (shown previously in Figure 2-13). Time in transit is associated with high inventory cost and risk of damage, loss, depreciation, and obsolescence. The sector is also highly internationally oriented. Simple and highly scalable value-added processes, notably assembly, are commonly outsourced to Asia and raw materials (except chemicals and gas) are also sourced internationally. While lower-value end-use consumer electronics may be shipped in bulk from Asia by container,¹⁴ air is the dominant mode for components, instruments and higher-value devices.

The Arizona high-tech companies consulted move most of their freight by air or small package services (truck and air). Larger freight may be moved by truck, or by air via freight forwarders. Transit time is an important criterion, but consultees stressed reliability and on-time performance as being key indicators used to evaluate transportation providers. Cost, too, is a relevant consideration given the heavy reliance on expensive modes of transportation and the competitiveness of the industries.

Although the quantity of shipments in this sector in terms of tonnage is not large, the value of these shipments in dollars is appreciable. For comparison, while the high-tech sector is approximately equal to the food and beverage sector in terms of value of shipments, the former has less than 1 percent of the latter's volumes by volume.¹⁵

¹⁵ 2012 Commodity Flow Survey. Total shipments by value for high tech sector is approximately 80% of food & beverage manufacturing sector, but 0.06% by tonnage (both AZ origin and AZ destination are similar in this regard)



¹¹ Gartner, "Samsung and Apple Continue to Lead as Top Global Semiconductor Customers in 2014, According to Gartner." Press release. January 21, 2015.

¹² See McKinsey, 2011

¹³ Kickham, V., "Top 50 Distributors 2014." Global Purchasing.

¹⁴ Ocean also enters into the supply chain for moving scrap and reclaimed materials.

3.3 Barriers to Transportation Performance

Neither regulations nor road congestion were mentioned as significant issues for high-tech companies. In general, proximity to transportation facilities did not appear to occupy a primary role in manufacturing facility location decisions.

Most of the barriers identified by high-tech companies related to air service. Lack of direct flights to Asia and Europe was cited as a barrier (see text box), as increased international passenger flights would provide opportunities for belly cargo and better connect manufacturers with international markets.

Limited customs airport services was also mentioned as a challenge. Specifically, coverage is lacking on the weekends and during off-hours, and otherwise is oriented overwhelmingly to passenger operations.

No pressing issues were presented concerning Tucson International Airport (TUS), suggesting performance is in line with expectations.

It appears some manufacturers, especially smaller ones, rely almost entirely on small package companies to transport their products. For companies large without a customer receiving regular large shipments, there appears to be general faith in these а transportation companies as providing an acceptable level of service and a sentiment that transportation neither positively nor negatively impacts their business, relative to competitors.

Phoenix Sky Harbor International Airport

Sky Harbor (PHX) is the major airport serving the Valley. Centrally located, it offers direct service to over 80 locations in the United States, including Alaska and Hawaii. According to the Federal Aviation Administration, PHX ranks 10th nationally in passenger enplanements and in the Top 20 in cargo landed weight.



However, several manufacturers, especially in the high-tech sector, expressed dissatisfaction with the present international offerings at PHX. As of this writing, PHX has 20 international destinations, of which all but two are in Mexico or Canada. The only non-North American destination is London Heathrow, and the only non-North American carrier is British Airways.

California airports such as LAX are within a day's drive by truck, for which reason the limited offerings at PHX are not necessarily a dealbreaker for Arizona manufacturers. Nonetheless, the minimal service to Europe and Asia results in heightened complexity, risk, and cost. Even a single Asian destination, such as Shanghai, would be a considerable improvement, according to these manufacturers.

Text Sources: "Where we fly," SkyHarbor.com; "Passenger & All-Cargo Statistics," Federal Aviation Administration. Photo Source: Wikipedia (User ZHoover123)

3.4 Trends and Implications

Growth for semiconductors and electronics overall is expected to remain strong. The IT consultancy Gartner predicts a 4% revenue increase worldwide in 2015, driven by smartphones, solid-state drives (SSDs) and ultramobiles.¹⁶ Over the near term, the fragile global economic outlook represents a risk, as the semiconductor industry is very sensitive to downturns.¹⁷ economic However, in general the industry a bright outlook, has as semiconductor use continues to expand from traditional electronic devices to things like automobiles, appliances, and intelligent energy grids. The rise of "immediacy" - a need for real-time data - is expected to increase demand for smart technology in businesses from medical devices to logistics.¹⁸

The state of semiconductor manufacturing in Arizona is tied

Arizona's Competitiveness in High-Tech

Arizona's competitiveness must be assessed across two dimensions. Internationally, the United States competes with countries like Ireland, Germany, Israel, and above all East Asian nations such as China, Japan, and Taiwan. Domestically, Arizona competes with other tech hubs in states like California, New York, and Texas.



America's major advantages lie in its strong intellectual property laws, high quality higher education system, and advanced capital markets. On the other hand, other countries are catching up, and building a fab abroad can save \$1 b. due to tax incentives and other benefits. In addition, given that much assembly is already in Asia, moving advanced manufacturing there can have supply chain benefits.

Domestically, Arizona has relatively strong universities, and a mix of good climate and inexpensive housing attracts trained labour. Arizona also has competitive tax rates and concessions. On a relative basis, it is somewhat close to West Coast transportation gateways and tech hotbeds. However, Arizona's venture capital funding is underdeveloped and the state must continually actively attract business and engineering talent from out of state.

Text Sources: Randewich, N., "Insight: As chip plants get pricey, U.S. risks losing edge," Reuters, Mar 2012; Yinung, F., "SIA White Paper: U.S. Semiconductor Industry is America's Most Innovative Manufacturing Industry," SIA, Aug, 2015; Marsh, R., "Tech Sectors: The Technology Advantage, Sustaining Arizona's Economy," Inbusinessmag.com, June 2015; Nuttall, C., "Intel chip plants bloom in Arizona desert," Jan 2012.

Photo Source: Wikipedia, user Wing-Chi Poon

broadly to the ongoing performance of its top companies. Intel is considered the market leader in the industry, but by its own admission the company was slow to adapt to the trend of ultramobile PCs, which demands a focus on minimizing power rather than maximizing performance.¹⁹ It is also notable that Intel's new multi-billion-dollar Fab 42 plant in Chandler has never started production since it was completed in late 2013, evidently due to excess

¹⁹ Brian Krzanich cited in Hachman, Mark, "The future is 'ultramobile:' Intel makes the PC persona non grata." July 2013, PCWorld.com.



¹⁶ Gartner, "Gartner Says Worldwide Semiconductor Sales Expected to Reach \$354 Billion in 2015, a 4 Percent Increase from 2014." Press release, April 22, 2015.

¹⁷ Ballhaus et al, "Faster, greener, smarter – reaching beyond the horizon in the world of semiconductors." PricewaterhouseCoopers report, January, 2012.

¹⁸ Aboagye, Kaza and Santhanam. "Finding the next \$100 billion in semiconductor revenues." McKinsey on Semiconductors article, Autumn, 2012.

capacity.²⁰ Overall, semiconductor exports for the state have declined by about a third between 2006 and 2014, while employment has declined by almost half.²¹ Nonetheless, it is important to note that Arizona semiconductor manufacturers have significant capital investments in the state and would have few incentives for simply abandoning this infrastructure. Thus, industry changes will play out over a longer time span.

Tucson's cluster of advanced instrument manufacturers – many of which are in the field of optics – consists of many smaller companies, with none among the state's Top 100 Employers.²² Many of these companies are spinoffs from the University of Arizona, and proximity to the aerospace industry is also an advantage.²³ There is every reason to expect that the fortune of this cluster will continue to be tied to these linkages. For example, in August 2015 it was announced that Uber has signed a partnership with the University of Arizona to support research and development in optics, including working with U of A experts to improve the imagery the company captures for its mapping and safety features.²⁴

The electronics distribution industry is relatively stable: two companies with significant operations in the state – Avnet and Arrow – have ranked first and second globally in sales for four years running.²⁵ In this industry customers are increasingly asking for distributors to take on additional value-added roles, but the transportation component of these businesses is fairly stable.

It is also worth noting the 2012 merger between Phoenix-based U.S. Airways and American Airlines; although Phoenix remains a hub, Dallas is presently the largest. Under terms of a settlement with the U.S. Department of Justice, the new American is required to maintain PHX as a hub for 3 years as of November, 2013.²⁶ It remains to be seen what kind of impact the lapse of this restriction might have on Phoenix's hub status, or how this would impact freight.

²⁶ Hansen, Kristena. "US Airways, American merger deal maintains Phoenix, other hubs for 3 years." Phoenix Business Journal. Nov, 2013



²⁰ Mitchell, Michelle, The Republic, "Intel says factory to stay shut for now." AzCentral, January, 2014

²¹ Employment data from Arizona Department of Administration, Export data from U.S. Commercial Service. Cited in Sunnucks, Mike, "Arizona's shrinking semiconductor sector forcing real estate fallout." April, 2015

²² AZCentral, "Arizona Republic 100: State's Largest Employers." 2015

²³ Levine, Alaina, "Shining a light on Tucson's optics Valley." PhysicsToday. June, 2014

²⁴ Thompson, Steve, "Driving Innovation in Arizona." Newsroom, uber.com. August, 2015

²⁵ Global Purchasing, Top 50 Distributors 2014

Working Paper | High-Tech Manufacturing Sector

Sector Priorities for Transportation System Performance Improvement

Key Messages

There are three key aspects to the goods movement needs of high-tech sector companies in Arizona: the competitiveness of Sky Harbor Airport (PHX), connections to Los Angeles, and border crossings to Mexico. High-tech manufacturers are interested in more international flights from PHX, but these services are highly concentrated in airports like Los Angeles (LAX). ADOT can support any future service increases at PHX by ensuring good access to the airport (low congestion, truck routes).

Since LAX is the most important airport internationally for Arizona manufacturers, reliable, congestion-free travel along I-10 to California is important for the competitiveness of these companies.

Finally, ensuring necessary border staffing is in place at the expanded Nogales (Mariposa) Port of Entry will support companies shipping high-tech and electronic products to and from Mexico.



4.1 **Priority Improvements Needs**

The high-tech manufacturing sector in Arizona is highly globally oriented (Asia, Mexico, Europe), and highly dependent on air and trucking as modes. There are three key conclusions relating to the goods movement needs of high-tech sector companies in Arizona.

Competitiveness of Sky Harbor

First, there is interest in improved international air service from Sky Harbor (PHX). Manufacturers, especially in the high-tech sector, would like to see direct flights to Europe and especially Asia. Presently there is a single destination outside North America, which is British Airways' service to London Heathrow. One manufacturer noted that even a single Asian airline traveling to, for example, Shanghai, would be helpful.

The international air cargo market in the US is very concentrated, with the top four airports (JFK, ORD, MIA, LAX) representing 54% of US international cargo traffic.²⁷ The airport has investigated several options for making PHX more attractive, such as constructing a centralized cargo screening facility or investing in an on-airport temperature control facility, but these have not been recommended.²⁸

While trends do not point to mid-size airports like PHX becoming more competitive in the international cargo market, it is important that the airport be prepared should the industry shift. Part of this is ensuring excellent access to the airport. In particular, roadway congestion and limited truck access routes to the airport were identified in Working Paper 2 as a mobility constraint for air cargo at PHX. Working to improve access may not attract the services demanded, but would support use of these services were they to be developed. It would also benefit ongoing domestic shipments of high-tech products to and from PHX.

In terms of other Arizona airports, Phoenix-Mesa Gateway Airport (IWA)'s ability to compete for freight in the Phoenix area is mostly dependent on the level of industrial development in its vicinity.²⁹ As of November 2015 there is one company providing freight/supply chain services at the airport.³⁰ Although Tucson (TUS) has only one tenth the cargo of PHX,³¹ it effectively serves the local industry, including optical manufacturing, and consultations did not reveal dissatisfaction with the service provided. Good state of repair of access routes (and the road/highway network more generally) was identified as an important ongoing consideration, since damage to expensive optical instruments would be extremely costly.

³¹ FAA, All Cargo Data for Calendar Year 2014: 2014 Landed Weight



²⁷ This excludes the Anchorage hub, which is a special case as a refueling hub, and the hubs of integrated carriers such as Fed Ex in Memphis and UPS in Louisville. By comparison the top four passenger hubs account for 42% of US international passenger traffic. Source: "Phoenix Regional Air Cargo Planning Study, Final Report," prepared for Phoenix Sky Harbor International Airport by InterVISTAS. Jan, 2014.

²⁸ Ibid.

²⁹ Ibid.

³⁰ Phx Mesa Gateway Airport: Companies on Site. Accessed Nov 2015

Connectivity to Los Angeles

Second, since the vast majority of international air shipments from Arizona go through non-Arizona airports, the highway connections to these airports will continue to be critical. In particular, Los Angeles (LAX) because of its proximity is vital for the Arizona high-tech sector. For example, even accounting for the nonstop service to London from PHX, in 2012 only 12% of Arizona-origin air exports to Europe exited the country from PHX, with LAX responsible for 43%.³²

Reliability of travel along I-10, the primary artery to Los Angeles, is thus of high importance in ensuring Arizona high-tech manufacturers can get products to market. High levels of congestion or poor state of repair on this critical artery would harm the competitiveness of the high-tech sector in Arizona.

Border Crossing to Mexico

As was shown in Section 2.2.3, Mexico receives approximately the same value of Arizona hightech manufacturing sector exports as Asia. However, Latin America collectively receives only 6.4% of Arizona air exports, far less than Asia, Europe, and even Canada.³³ This suggests the land border crossing is the dominant gateway for trade with Mexico.

Indeed, in 2014, Nogales handled \$2.4 b. of US electric/electronic manufacturing exports to Mexico. This compares to \$2.9 b. for all Arizona border points but \$52 b. for all southern ports of entry (Nogales ranks behind Laredo, El Paso, and Santa Teresa, and on par with Hidalgo and Calexico).³⁴

The Nogales (Mariposa) Port of Entry has received significant investment to increase the number of inspections booths and spaces, which is expected to significantly speed up traffic. However, concerns remain about border staffing as well as congestion on the Mexican side of the border.³⁵ These issues, unless resolved, can act as a bottleneck on freight shipments to/from Mexico.

³⁵ Reynolds, Christa. "Expansion of Nogales port should ease border wait times." Arizona Daily Star. August, 2014.



³² "Phoenix Regional Air Cargo Planning Study, Final Report," prepared for Phoenix Sky Harbor International Airport by InterVISTAS. Jan, 2014, statistics from the US Census Bureau, Foreign Trade Statistics. According to the same source over half of the state's air exports are of electric, industrial and optical machines and electronics (not including aircraft/spacecraft parts).

³³ Ibid, underlying data from US Census Bureau Foreign Trade Statistics (2012) via WISERTrade

³⁴ In terms of imports of electric/electronic products, the values are similar, with Nogales handling \$2.5 b. worth annually, compared to \$3.2 b. for Arizona and \$78 b. for all southern ports of entry. Nogales ranks behind Laredo, El Paso, Hidalgo, Santa Teresa, and Calexico. University of Arizona Eller, "Arizona-Mexico Economic Indicators, US Exports to Mexico by AZ BPOE, Electric/Electronic Products." Accessed Nov, 2015.



Appendix A: List of Stakeholders Consulted

Name	Title	Organization			
Marianne McDonald	Vice President, Global Transportation	Avnet			
Josh Chavez	Shipping Manager	South Bay Circuits			
Greg Geyer	Director of Logistics	Zygo Electro-Optics			
Note: Contacts in the semiconductor industry requested non-attribution.					

