ECONOMIC CONTRIBUTION AND IMPACT ANALYSIS OF THE 2019 FLOOD'S DISRUPTION OF THE OKLAHOMA-MCCLELLAN-KERR NAVIGATION SYSTEM

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ECONOMIC CONTRIBUTION AND IMPACT

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NAVIGATION SYSTEM

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Abstract: Record flooding in spring 2019 caused Oklahoma's inland navigable waterways to close. Closure disrupted the supply chains of agricultural and manufacturing industries for months, causing economic loss in other industries of the state's economy. Anecdotal accounts estimated direct losses of 2 million dollars per day. This research uses a multi-regional input-output model to estimate the short term direct, indirect and induced economic impacts of the Oklahoma portion of the McClellan-Kerr Arkansas River Navigation System's disruption from the spring 2019 flood. First the contribution of the water transportation industry to Oklahoma, Arkansas, Colorado, and Kansas' economies is estimated, and the losses in economic output, employment, and value added caused by various length of flood disruption periods. We also estimate the effects the disruption had on the economies of Oklahoma's metropolitan and non-metropolitan regions. This study finds losses in employment, output, and value added for each of the congressional districts in Oklahoma, Arkansas, Colorado, and Kansas. Indirect and induced losses were disproportionately experienced in Oklahoma metropolitan and non-metropolitan agricultural and manufacturing industries. Benefits the public received were diminished due to disruption of the waterway as a result of the spring flooding.

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CHAPTER I

INTRODUCTION

1.1 Problem Identification and Explanation

Navigable inland waterways play an essential role in United States (US) freight transportation. The nation's inland navigation system lowers land traffic congestion by facilitating the shipment and transfer of freight by waterways, as well as providing employment opportunities in urban and rural areas (USDOT 2011). There are more than 40,000 km of navigable inland waterways in the US with most navigable waterways located in the Mississippi River System (USACE 2000). Navigable inland waterways provide a cost-effective and fuel-efficient alternative to road and rail freight transportation. Moving large volumes of bulky commodities over long distances by barges consumes less energy compared with other modes of transportation (Kruse et al. 2017). Kruse et al. (2017) summarized the advantages of barge transportation, indicating the capacity of a typical 15-barge river tow is equivalent to 1,050 trucks, or 216 rail cars pulled by six locomotives. Barges can also transport one ton of cargo with one gallon of diesel fuel 647 miles. Given the same amount of diesel, trains can freight one ton of cargo 477 miles, and trucks can freight haul 145 miles. Inland waterway transportation also decreases road traffic congestion, reduces carbon emissions, and provides employment opportunities in urban and rural areas (USDOT 2011; ODOT 2018; Olsen et al. 2005).

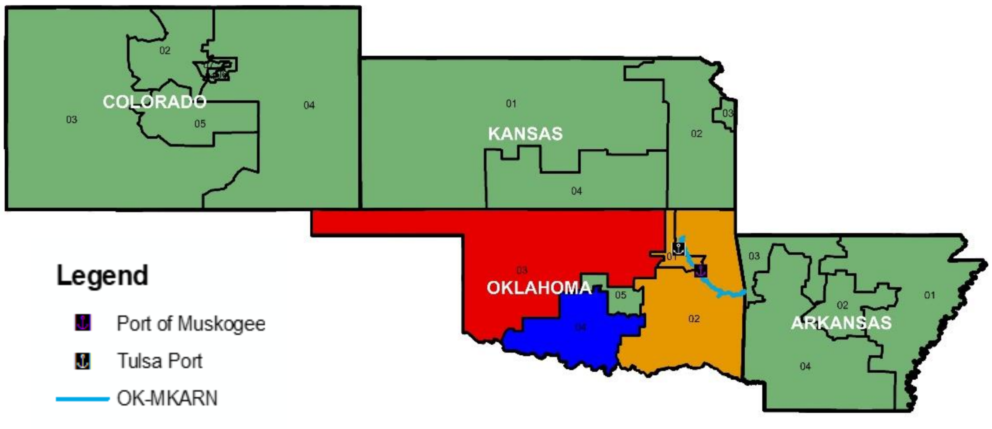
The value of commodities transported on inland waterways increased from $381 billion in 2007 to $596 billion in 2013, with a projected growth in transported value to $973 billion by 2045 (USDOT 2017).

Increased reliance on water-borne freight means that disruptions of navigable waterway operations will cause supply chain bottlenecks. Supply chain disruptions translate into financial losses for businesses that rely on water freight services. Extreme weather events such as floods and earthquakes can cause port closure and damage to waterway infrastructure, leading to industry-wide economic losses (Koetse and Rietveld 2009; Ng et al. 2013; Becker et al. 2012). Port closures and channel disruption caused by natural events may take years to repair and cause additional delays and financial costs from demurrage and other port service payments (Chang 2000; Robinson 2014). Depending on the origin, density, and material composition of freight, some businesses can quickly switch to other transportation modes during waterway closures, but other businesses that lack the capacity to adapt their supply chains promptly incurred high transportation costs or demurrage (Fuller et al. 2000).

The McClellan-Kerr Arkansas River Navigation System plays an important role in the transportation of goods into and out of the United States (US) Central Great Plains. The OK-MKARNS begins in Oklahoma at the Tulsa Port of Catoosa (TPOC) and flows southeast through Oklahoma to Arkansas and eventually to the Mississippi River. The system connects roughly 25,000 miles of inland rivers to the Gulf of Mexico (Figure 1). The OK-MKARNS hosts international ports. The TPOC is home to Foreign Trade Zone 53. The US Foreign Trade Zones are geographical areas where merchandise receives the same customs treatment as if it were outside the US, regardless the country of origin.

There are smaller ports on the OK-MKARNS located south of the TPOC, including the Port of Muskogee, Port of Keota, and others. The OK-MKARNS portion of the waterway spans 445 miles and supports multiple activities, including transportation, recreation, flood control, and hydroelectric generation (Antle 1975; Robinson et al. 2014; ODOT 2018). Major commodities transported on the OK-MKARNS are sand and gravel, steel and iron, agricultural chemicals, and minerals (ODOT 2016). According to ODOT (2018), 2017 tonnage on the entire MKARNS totaled 11.5 million tons with an estimated value of $4.7 billion. The MKARNS serves a 12-state region including Arkansas, Oklahoma, Kansas, Texas, Colorado, Missouri, Nebraska, Minnesota, South Dakota, North Dakota, Montana, and Idaho. In this research, the study region considers four states, Oklahoma, Colorado, Kansas, and Arkansas, as they are the main user of the port (Figure 1). The additional districts were selected in this study because (1) the OK-MKARNS has some impact on the rest of Oklahoma determining the value that it brings to those districts could inform policy decisions, (2) Arkansas, Colorado, and Kansas are 3 of the 12 states whose economies are supported by the OK-MKARNS, and (3) TPOC indicated there were port transactions that occurred in each of these states.

Figure 1. Map of Study Region including OK-MKARNS



In the spring of 2019, the OK-MKARNS was forced to close due to flooding of the Arkansas River. The TPOC operation was interrupted until late fall 2019. Port closures caused a loss of transportation of goods for months, resulting in the loss of output, jobs, and value to the region's economy. Businesses relying on waterborne transportation had to seek alternative transportation modes. According to existing research, the MKARNS is important to the economy of Oklahoma and surrounding states (Robinson et al. 2014, Pant et al. 2015, MacKenzie, Barker, and Grant 2012). However, the economic impact due to this disruption is unknown. It is also unclear which economic sectors were affected and by how much. A better understanding of the economic impact of port disruption could help business planning, stakeholders, and policymakers when making decisions regarding the investment for repairing, maintaining, and expanding the OK-MKARNS services.

1.2 Research Objectives

The general objective of this study is to evaluate and understand the impact the 2019 spring flood disruption of the OK-MKARNS had on the surrounding regions' economies, especially in concern to agricultural and manufacturing sectors. Two specific objectives of this study are: (1) Identify the economic contribution of the OK-MKARNS in the states of Oklahoma, Arkansas, Kansas, and Colorado, and (2) Estimate the economic impacts the OK-MKARNS' closure had on these states' economies in terms of jobs, industry output, and value-added.

CHAPTER II

REVIEW OF LITERATURE

There has been much literature on supply disruption to waterways and ports (Yu et al. 2016, Chang 2000, MacKenzie et al. 2012, Koetse and Rietveld 2009). Yu et al. (2016) and Fuller et al. (2000) analyze the impacts of waterway disruption on grain transport showing economic losses to the agriculture sector. Yu et al. (2016) found that closure of Lock 25 along the Upper Mississippi River and Illinois Waterway (UMR-IWW) for a year would result in a reduction of 8 million tons of corn and soybean exports. Fuller et al. (2000) concluded that a closure of the Panama Canal would result in a $207.2 million decrease in revenue from corn and $96.4 million dollars in revenue from soybeans to US producers.

Disruptions to water freight transfer can happen in several ways. One source of disruption is caused by inadequate channel and lock size (Yu et al. 2016, Robinson et al. 2014). Due to increases in waterborne freight, there has been an increase in the number of barges and size of barges along inland shipping routes in the United States. Yu et al. (2016) conclude the 600ft locks of the UMR-IWW are detrimental to the shipment of commodities. The additional time to decouple the 15 ft. barges resulted in inefficiencies and economic loss when a 1200 ft. lock chamber would only require a single lockage.

Robinison et al. (2014) found that the 9 ft. depth of the MKARNS is inadequate, leading to the need to dredge and deepen the channel and that constant high use of the channel has led to flood damages along the Arkansas River. Both studies show the need to address capacity constraints on the waterways: Robinson et al. (2014) estimated an increase of $221.3 million in business sales due to the deepening of the channel from 9 to 12 ft, and Yu et al. (2016) calculated the loss from the shorter locks. Improvements in navigation systems cause a chain of events that can lead to a change in relative prices, production patterns, input mixes, and consumption decisions (Robinson et al. 2014).

In other instances, losses occur through sudden port closures (Koetse and Rietveld 2009, Ng et al. 2013, and Chang 2000). Koetse and Rietveld (2009) found that extreme weather events affect the competitive position of both passenger and freight transport and inland navigations system impacts most likely were negative. Koetse and Rietveld concluded that flooding incidences cause infrastructure disruptions and these events are increasing in frequency and intensity. The uncertainty caused by weather conditions leads to negative impacts to shipping supply chains and regional economies (Ng et al. 2013, Becker et al. 2012). Ng et al. (2013) emphasized port adaptation strategies in response to weather conditions. Chang (2000) observed that an earthquake caused port disruption resulting in closure and repairs that took over two years resulting in sizable economic loss. These sudden port closures can be exacerbated from the flood damage caused by the constant high use of canals (Robinson 2014), aging locks (Yu et al. 2016), and other damages from age or overuse of waterways.

Early studies of the MKARNS's economic impact focused largely on its costs and benefits (e.g., Antle 1975). Antle (1975) estimated that $1,455,000 was saved by the

MKARNS through flood control. More recent studies focus on the direct, indirect, and induced economic impacts of the MKARNS on the region's economy and focus on the effects of the waterway's status on industry access to input and demand markets (Robinson et al. 2014; Caneday et al. 2014). Robinson et al.(2014) found that the MKARNS is a significant component of the nation's business sales and contributes an estimated $2.0 billion to the nation's gross domestic product (GDP) (Robinson et al. 2014). Complete closure of the MKARNS would result in a decrease of $4.1 billion to the nation's business sales (Robinson et al. 2014). Additional economic losses also stem from lost revenue from recreational use (Folga et al. 2009).

Previous studies on the effects of the OK-MKARNS closure on the region's economies estimated direct losses of $111.8 million and $72.9 million in indirect losses across 10 states following a 2-week shutdown (Pant et al., 2015). Other studies focused on the economic losses to state economies that depend on the OK-MKARNS for transportation (MacKenzie, Barker, and Grant 2012). Given the extensive literature on the sudden closure of inland ports, specifically the TPOC, and estimations of the economic losses to the economy of the surrounding region, effects of closure do the spring 2019 flood has not been studied previously.

This study intends to build on this literature by focusing on short-term disruption of the Oklahoma portion of the MKARNS to estimate losses from the spring 2019 flood. The economic impact of the flood's disruption on total industry output (TIO, dollars), value added (dollars), and employment (jobs) for Oklahoma, Colorado, Arkansas, and Kansas economies are estimated. The state's congressional districts were used as the economic units of analysis. Congressional districts are a logical choice as a unit of analysis because of their role in representative fiscal policy and legislation for spending on infrastructure.

CHAPTER III

METHODOLOGY

3.1 Input-output model and MRIO

3.1.1 Input-Output Model

Input-Output (I-O) model is built on the foundations of export base theory. The export base theory states that a region must produce some good or service which is demanded by an outside region in order to produce income to survive (Hughes 2003). I-O model extends this concept to sales of an industry. An industry provides a good or service demanded by another industry, or consumer, which brings sales to the region. This sale income creates a multiplier effect as it is re-spent locally. The size of this effect is determined by rounds of local purchasing. Anytime money leaves the region in the model, it is classified as a leakage.

The production and supply of an economy's goods are linked through inter-industry transactions (Leontief 1986, Miernyk 1965, Hirschman 1958). Backward linkages are inputs an industry requires to operate. Forward linkages are products an industry sells to another industry to be used as inputs in the other industry's processes. Leontif (1938) formalized the inter-industry transactions using matrices to represent the national economy of the United States.

Leontief (1938) constructed an input-output table with industries bordering the columns and rows (Figure 2). The columns represent the outlays needed by each industry in dollars and the rows represent the outputs of each industry in dollars. For example, reading down the column labeled AG in Figure 2 would show the inputs that agriculture requires from each sector, 147 from agriculture, 31 from manufacturing, etc. Reading across the row labeled Agriculture shows the outputs generated by the industry. Each row and column of the table sum to the same total indicating that supply equals demand. Final demand and value-added elements are added to this table introducing household and government spending to the model.

Figure 2: Example Transaction Table

I. Transaction table

	Purchasing sectors ($1,000s)				Final demand		
	AG	Manu	Trade	Serv	HH	Other	Tot. output
Agriculture	147	159	10	56	71	217	660
Manufacturing	31	71	2	38	24	354	520
Trade	47	43	1018	652	1039	92	2891
Services	127	107	791	1060	1674	609	4368
Households	134	28	120	1345	102	1481	3210
Imports	174	112	950	1217	300	1297	4050
Total	660	520	2891	4368	3210	4050	

(Otto and Johnson, 1993)

Leontief (1938) developed the input-output equation, $\boldsymbol{X} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{Y}$, to use in conjunction with his input-output tables to determine the impacts of economic events. The equation can be expressed verbally as total industry output ($\boldsymbol{X}$) is a function of final demand ($\boldsymbol{Y}$) and production technology ($\boldsymbol{A}$). The $\boldsymbol{A}$ matrix is constructed by taking each value from the transaction table and dividing it by the row/column total. The $\boldsymbol{A}$ matrix is subtracted from the Identity Matrix and inverted to form a matrix of multipliers called the Leontief Inverse ($(\boldsymbol{I}-\boldsymbol{A})^{-1}$).

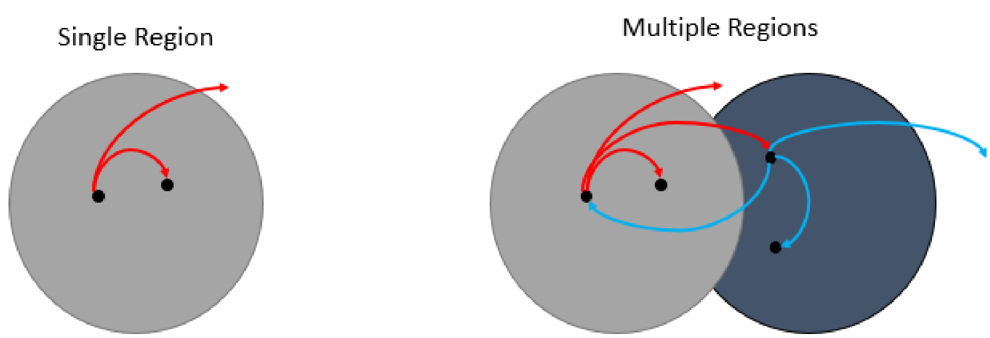
I-O models result in three types of effects: direct effects, indirect effects, and induced effects. Direct effects are the initial impact of the shock. Indirect effects are the business-to-business purchases that are a result of the initial impact. Induced effects are the purchases made by households from labor income. Each of these effects is expressed in terms of output, employment, and value-added. Value-added can also be considered as an industry's contribution to the gross domestic product (GDP). When there is a shock that disrupts an industry, the effect of that event will be experienced by other industries affecting their output, employment, and total value added to the economy.

I-O model has a basic set of assumptions. The I-O input structure is fixed, so there are no substitutions between different inputs. Each industry will produce the same mix of products each time. There are constant returns to scale and perfectly elastic supply. If an industry doubles its inputs, it will double its outputs and demand to meet the additional supply. Additionally, the increased supply of inputs is readily available to meet the affected industry's demand. These assumptions lead to the I-O model working very well for short-term analyses but limiting its forecasting ability for long-term analyses.

3.1.2 Multi-Regional Input-Output (MRIO) Model

MRIO models are used to control interdependencies between industries and exchange goods and services with industries in other regions through market-based transactions. MRIO analysis is based on Leontief's single region Input-Output model (Leontief 1936; Leontief 1951). MRIO models recover leakages that are otherwise experienced in single region input-output models (Miller and Blair 2009). Figure 3 shows how some of the effects that would be lost in a single region analysis can be recovered through MRIO. In the single region, direct, indirect, and induced effects are captured within the region, but any effects that leave the region are leakages. In the multiple regions figure, the same effects are captured in the light gray region, but some of the indirect and induced effects that would have been leakages in a single region are recovered in the darker gray linked region. Feedback effects to the first region are also captured in an MRIO which is represented by the blue arrow leading back into the light gray region.

Figure 3: Single Region vs. Multiple Region Diagram



3.2 IMPLAN

IMPLAN, Economic Impact Analysis for Planning, was first created by the United States Forest Service (USFS) in response to the National Forest Management Act of 1976 to determine the socioeconomic effects of forest management plans (Lindall et al. 2006, MIG 2020). The Minnesota IMPLAN Group (MIG, Inc.) partnered with the University of Minnesota to further develop their I-O modeling database and software in 1985. IMPLAN was used outside of the federal government for the first time in 1988.

Since, it has rapidly progressed incorporating national-level data sets, state level data sets, MRIO capabilities, and a web application. Its use has spread from government services to academic institutions and private industries.

IMPLAN can be used to model many different I-O scenarios with use of different events including industry output, industry employment, household spending, and institutional spending. It has a comprehensive dataset gathered from government sources and proprietary estimation algorithms, and the data can be edited when the researcher knows specific information. However, there are some limitations to IMPLAN. It has all the same limitations listed in the assumptions paragraph earlier. It also does not fully explain how the calculations are made within the program and many researchers build I-O models in other software to keep their research transparent.

3.3 Economic Impact Analysis using IMPLAN MRIO

In this research, a multi-regional input-output (MRIO) model was developed to estimate the short-term effects of the OK-MKARNS port closures on Oklahoma, Arkansas, Colorado, and Kansas' Congressional District economies and the differential effects closure had on jobs, total industry output, and value added in the state's metropolitan and non-metropolitan regions. We used the IMPLAN modeling system and 2018 data year (Lindall et al. 2006; MIG 2020) to construct an MRIO model using congressional districts in Oklahoma, Arkansas, Colorado, and Kansas as economic regions. All prices are in 2020 dollars.

The OK-MKARNS is the only source of water transportation in the region, so closure of the waterway only directly impacts the water transportation industry. This feature greatly simplifies the analysis because the origin of the shock is geographically isolated in Oklahoma's Congressional Districts 1 and 2 (OK-1 and OK-2, respectively). Economic impacts are quantified as direct, indirect, and induced effects. Direct effects are the initial impact of a shock on economic activity, such as port closure. Indirect effects are the business to business purchases resulting from the initial impact. Induced effects are purchases made by households with labor income. These are the indicators used here to measure the impact of the system's closure on the region's jobs, TIO, and value added. Value added can also be thought of as an industry's contribution to the gross domestic product (GDP), or net expenditures on intermediate inputs (Miller and Blair, 2009). Value added is composed of four components: proprietor income, other property income, taxes on production and imports, and employee compensation.

3.3.1 Industry Aggregation

The 546-industry definition used by IMPLAN was aggregated to 37 industries (Appendix A). The aggregation reflects the main productive activities central to Oklahoma's economy. The main industries of Oklahoma's economy are mining, manufacturing, and agriculture (BEA 2019). During the first quarter of 2019, mining contributed to 22.6% of the state's GDP, and manufacturing 8.8% (BEA 2019). Agriculture accounted for only 2% of the state's GDP, but in 2019 Oklahoma ranked fifth among all other states in terms of farm numbers, fifth in cattle production, and fourth in the production of wheat (ERS, 2019; Oklahoma Agricultural Statistics, 2017). OK-MKARNS port operators classify the goods most commonly transported on the waterway into 12 categories: chemical fertilizers, coal and coke, food and farm products, iron and steel, manufacturing equipment, minerals and building, miscellaneous products, other chemicals, petroleum products, sand, gravel, and rock (Table 1). These definitions were apportioned across the 37-industry aggregation.

Table 1. Tonnage of Commodities and Reclassification into Industry Sector

Industry Sector	**Commodity**	**Tonnage**
Agriculture Inputs	Chemical Fertilizers	1,955,104
Grain Farming	Grain	841,880
Oilseed Farming	Soybeans	881,902
Other Agriculture and Food Manufacturing	Food and Farm Products	240,500
Manufacturing	Manufacturing Equipment	2,680
	Other Chemicals	218,263
	Iron and Steel (1)	422,947
Construction	Iron and Steel (2)	172,753
Mining	Coal and Coke	358,500
	Minerals and Building Products	131,282
	Sand, Gravel, and Rock	147,000
Natural Gas and Petroleum	Petroleum Products	99,000

Most OK-MKARNS commodity definitions could be directly linked to a specific industry. For example, the OK-MKARNS commodities of coal and coke; minerals and building materials (e.g., cement); and sand, gravel, and rock were reclassified into the 37-industry category of ‘Mining’. However, some of the OK-MKARNS commodity definitions overlapped with one or more of the 37-industry definitions. For these industries, a weight was calculated using a ratio of the total industry output of the industry to a sum of the TIO of all potential industries for the industry. For example, “iron and steel” could be allocated to either construction or manufacturing. Therefore, a weight for “iron and steel” in construction and a weight for “iron and steel” in manufacturing were calculated as follows. The TIO for construction was $18 billion, and the TIO for manufacturing was $45 billion. The $18 billion was divided by the combined TIO of construction and manufacturing ($63 billion), which resulted in a construction weight of 0.29. This process was repeated for manufacturing. Next, the total value of the "iron and steel" tonnage reported by port operators was multiplied by their respective weights. Lastly, the share-weighted values were allocated to the manufacturing and construction industries of the 37-industry aggregation (Table 1).

3.3.2 Economic Regions

The analysis uses congressional districts in Oklahoma, Arkansas, Colorado, and Kansas as economic regions. This facilitates reporting of results in an accessible way for district representatives and their constituents. Each district is referred to by the two-letter state abbreviation followed by the number of the district. For example, Oklahoma's first congressional district is called OK-1.

The OK-MKARNS flows through Congressional District 1 (OK-1, the Tulsa metropolitan statistical area) and Congressional District 2 (OK-2) before reaching Arkansas. OK-2 includes counties in the state's eastern region spanning from the northern state line with Kansas to the southern state border with Texas and extends to the Oklahoma City metroplex. OK-3 covers most of the northwest portion of the state west of Tulsa, north and west of the Oklahoma City area, and the southwest corner of the state. OK-4 is located south of Oklahoma City and fills the gap between districts 2 and 3 in the southern part of the state. OK-5 is the three-county Oklahoma City metroplex. Most of the state's population lives in OK-1, OK-4, and OK-5 (Figure 1).

Arkansas contains four congressional districts. AR-1 is comprised of counties in the eastern part of the state bordering the Mississippi river. AR-2 contains the Conway and Little Rock areas. AR-3 is in the Northwest Region of the state forming a narrow bow shape that contains Fort Smith, the Fayetteville area, Harrison, and Russellville. AR-4 contains the remainder of the state which is the southwest portion including Hot Springs. Many of the counties in the Northwest portion of the state are split between AR-3 and AR-4, Appendix A.2 contains a complete list of which counties were assigned to each district.

Kansas has four congressional districts. KS-1 contains the bulk of the counties in the state and covers the entire western and north central portions of the state. KS-2 includes the Eastern strip of the state including Topeka and Lawrence but does not include the Kansas City area. KS-3 is the Kansas City area. KS-4 is the last region in Kansas and includes the south-central portion of the state including Wichita, KS-1 is to the north of it and KS-2 is to the east.

Colorado has seven congressional districts, however due to the county aggregation scheme that was used some of them had to be combined. CO-1 is composed of Denver County. CO-2,7 are a combined region to the west of Denver containing Boulder, Arvada, and Lakewood. CO-3 is the western portion of the state containing counties stretching from the northern state border to the southern and reaching to the western edge of CO-2,7, CO-5, and CO-4,6. CO-4,6 is another combined region including counties from the eastern side of the state reaching from the northern border to the southern border and extending to the eastern side of CO-1, CO-5, and CO-3. CO-5 is the last district it is in the central portion of the state surrounded by CO-3 on the west and south, CO-4,6 on the east, and CO-2,7 on the north.

Port closures have direct impacts on the economies of OK-1 and OK-2. The MRIO model recaptures the indirect and induced effects experienced in the remaining Oklahoma congressional districts as well as those in Arkansas, Colorado, and Kansas through feedback paths. The effects continue to reverberate until all spending rounds cease. After spending rounds stop, all purchases occur outside the region (by definition, leakage). The effects of the system's closure are recovered by downward adjusting the TIO for the industries linked with the 12-commodity classification used by Oklahoma's Department of Transportation (discussion follows).

3.3.3 Contribution and Impact Analyses

The contribution analysis determines the OK-MKARNS' contribution to Oklahoma, Arkansas, Colorado, and Kansas' economies. A contribution analysis asks a 'what if' question by removing an industry from an economy and measuring the resulting effects on TIO, value added, and jobs. We used Miller and Blair's (2009) extraction method to conduct the contribution analysis. The Regional Purchase Coefficient (RPC) of the water transportation industry was set to zero in regions OK-1 and OK-2, home to the OK-MKARNS system. The RPC is the proportion of total demand for a commodity in a region met by supply located within the same region. Fixing the RPC to zero means that no local demand for the commodity or service is met by local production. We obtain the OK-MKARN's economic contributions to the states' economies by comparing results with (actual scenario) and without (counterfactual, or impact, scenario) the water transportation industry in this region. The contribution analysis generates multipliers for an economy's relevant industries. The multiplier measures the additional value generated elsewhere in the economy for one dollar invested in the water transportation industry.

The multiplier is calculated by dividing total output effects (direct + indirect + induced) with the direct output effects. In Arkansas, Colorado, and Kansas, the multiplier effect was calculated by dividing total effects in the state and the direct effects from OK-01,02 by the direct effects from OK-01,02.

The objective of the impact analysis is to determine, for each industry, the economic loss caused by port closure in terms of direct, indirect, and induced values of TIO, value added, and employment. Disruption of the OK-MKARNS caused shipping delays. Shipping delays are costly in terms of demurrage, switching to alternative transportation modes, and overall supply chain efficiency. We examine the effects of port closures for 2-, 4-, and 6-month disruptions. The MKARNS exists in the 1st and 2nd Congressional Districts in Oklahoma so the change in output due to the closure will be applied to both of these regions as direct effects. The rest of the congressional districts in Oklahoma as well as those in Kansas, Arkansas, and Colorado were included in the model to see the impacts the closure had on the surrounding regions in terms of output, employment, and value added.

The water transportation industry's impact on the regional economy was analyzed under two assumptions on local purchases and buybacks by adjusting the regional purchasing coefficient (RPC). The RPC determines how much demand of a commodity or service is sourced within the study region. The first assumption sets the RPC to 0 percent in regions OK-1 and OK-2, home to the OK-MKARNS system. Under this assumption, the initial impact occurs locally, and all local purchases of final demand are sourced outside of these districts. The second local purchasing assumption uses the social accounting matrix (SAM) RPC in the impact analysis. This assumption implies that some portion of industry sales and employment are sourced from within these regions. The impacts calculated under the RPC equals to SAM assumption are larger (least conservative) than those from the RPC=0 assumption (more conservative). Using these assumptions will provide a lower and an upper bound resulting in a range rather than a fixed number for employment, output, and value added.

In addition to the district-by-district study, we conduct a sensitivity analysis to compare the effects of the flood event on Oklahoma metropolitan and non-metropolitan economies. Oklahoma's five Congressional Districts also correspond with the Bureau of Economic Analysis (BEA) definitions of metropolitan and rural counties (BEA 2008). This correspondence allows for an assessment of the system's closure on metropolitan (urban) and non-metropolitan (rural) economies. We expect that the impact on the agricultural economies of rural areas will exceed that of urban regions, with an opposite effect for manufacturing industries in urban locations.

Table 2 summarizes the industries in metropolitan and non-metropolitan areas of Oklahoma, and their economic data. Districts in metropolitan regions specialize in different activities compared to the non-metropolitan regions. For instance, "Services" and "Other Transportation" have much higher industry output in metro regions, whereas "Agriculture Inputs" and "Water Transportation" have higher industry output values in non-metro areas. Which industry's supply chains and output is disrupted and the severity of the disruption on sales and purchases determine whether the impact of the flood disruption is more severe in metropolitan or non-metropolitan areas. We classified Oklahoma City, Tulsa and their surrounding areas as 'metropolitan' regions (OK-1 and OK-5) with the remaining districts categorized 'non-metropolitan' (OK-2, OK-3, and

OK-4). OK-1 and OK-2 are excluded from the metropolitan/non-metropolitan comparison because they are a combined region and the origin of the shock. Since the region was combined the effects cannot be differentiated between OK-1 and OK-2.

Table 2. Baseline Total Industrial Output (TIO) ($ million)

Industry Sectors	**Metro**		**Non-Metro**		
	OK-1	OK-5	OK-2	OK-3	OK-4
Agriculture Inputs	161	494	1,072	909	417
Animal Processing	144	386	1,390	1,596	319
Animal Production, except cattle and poultry and eggs	5	10	230	663	104
Beef Cattle Ranching and Farming	54	69	1,042	1,628	535
Breweries, Wineries, Distilleries	36	69	44	54	9
Commercial Fishing and Hunting	1			1	
Construction	4,088	4,862	2,833	3,697	2,952
Cotton Farming		2	1	212	78
Dairy Cattle and Milk Production	3	6	36	43	40
Dairy Processing	102	209		152	198
Financial, Insurance, and Real Estate	14,860	17,616	5,950	8,177	7,661
Food Manufacturing	997	979	479	481	397
Fruit and Vegetable Farming	2	2	8	5	3
Government	3,425	10,477	10,092	6,115	8,768
Grain Farming	3	2	30	484	35
Greenhouse, Nursery, and Floriculture Production	25	14	79	28	18
Manufacturing	15,967	9,034	6,957	7,432	5,397
Milling	180	167	1,001	252	59
Mining	344	281	20	16	8
Miscellaneous	10,293	13,191	3,768	4,634	5,983
Natural Gas Petro	17,515	18,293	3,900	12,462	9,961
Oilseed Farming	12	1	34	97	4
Other Agriculture	192	253	161	265	140
Other Transportation	7,009	2,188	598	707	520
Poultry and Egg Production		2	835	7	1
Primary Forestry	5	12	40	11	18
Rail Transportation	372	176	395	243	104
Retail Trade	3,928	4,583	2,469	2,813	2,553
Secondary Forestry	857	454	1,755	99	326
Services	19,864	25,734	5,813	7,773	7,408
Textiles	50	68	41	21	76
Tree Nut Farming	1	1	7	1	5
Truck Transportation	1,287	1,252	569	1,129	610
Utilities	3,514	2,419	1,921	2,262	1,222
Warehousing and Storage	436	605	132	85	293
Water Transportation	1	1	4	4	2
Wholesale	5,175	6,755	1,505	3,539	1,851
Total	110,908	120,667	55,211	68,097	58,075

3.4 Data

Regional data from IMPLAN will be used for this analysis. IMPLAN collects data through four main sources: the Census of Employment and Wages (CEW) from the Bureau of Labor Statistics (BLA), Regional Economic Accounts (REA) from the Bureau of Economic Analysis (BEA), County Business Patterns (CBP) from the Census, and National Income and Product Accounts (NIPA) from the BEA. The data is updated each year, however not all data are collected yearly, such as the data obtained from the Census, is estimated. IMPLAN data is arranged in 546 industries that make up the economy in the United States.

The delay costs per tonnage by commodity and by disruption length are from Robinson et al. (2014) (Table 3). The total amount of tonnage delayed is assumed equivalent to the amount of tonnage that would normally flow through the system during the respective period. If there is a 2-month delay scenario, the cost of delay is estimated by multiplying the 2-month delay cost per ton by the tonnage delayed per month. For example, 2-month delay costs for the industry "Chemical Fertilizer" is $11.25 per ton. This number is multiplied by the 2-month tonnage of chemical fertilizers and results in the total delay cost (Table 4). The tonnage values are obtained from Oklahoma Department of Transportation's Inland Waterway Fact Sheet.

Table 3. Delay Costs by Commodity and Length of Delay ($ per tonnage)

Commodity	2- Month[a]	4-Month[b]	6-Month[a]
Chemical Fertilizers	11.25	24.82	38.39
Grain	7.41	19.17	30.92
Soybeans[c]	7.41	19.17	30.92
Food and Farm Products	6.84	18.49	30.13
Manufacturing Equipment	34	72.02	109.63
Other Chemicals	10.01	22.74	35.47
Iron and Steel	13.06	28.18	43.29
Coal and Coke	5.23	16.67	28.1
Minerals and Building Products	10.07	22.89	35.71
Sand, Gravel, and Rock	0.55	3.03	5.5
Petroleum Products	10.31	23.21	36.11

a: Source: Robison et al. (2014)
b: There are no data with respect to four months delay. Cost of 4 month delay is an average between 2 months and 6 months delay.
c: Soybean delay costs were missing in Robinson et al. (2014). We assumed soybean has the same delay costs as grain.

Table 4. Disruption Shocks by Delay Length

Industry Shocked	Port Definition	2 months	4 months	6 months
Ag Inputs	Chemical Fertilizers	-$3.67	-$16.18	-$37.53
Mining	Coal and Coke	-$0.34	-$2.14	-$5.42
Other Ag and Food Manufacturing	Food/Farm Products	-$0.27	-$1.48	-$3.62
Manufacturing and Construction	Iron and Steel	-$1.30	-$5.59	-$12.89
Manufacturing	Manuf. Equip./Mach.	-$0.02	-$0.06	-$0.15
Mining	Minerals & Bldg. Mat.	-$0.22	-$1.00	-$2.34
Manufacturing	Other Chemicals	-$0.36	-$1.65	-$3.87
Natural Gas Petro	Petroleum Products	-$0.17	-$0.77	-$1.79
Mining	Sand, Gravel and Rock	-$0.01	-$0.15	-$0.40
Grain Farming	Grain	-$1.04	-$5.38	-$13.02
Oilseed Farming	Soybean	-$1.08	-$5.63	-$13.63

CHAPTER IV

FINDINGS

4.1 Economic Contribution Analysis

The contribution of the OK-MKARNS to Oklahoma's economy is estimated to be employment of 38 jobs, $9.7 million in industry output, and $2.2 million in value added (Table 5). Compared to the state's other industries, the size of these indicators is among the smallest of the 37 industries. However, the significance of the water transportation industry's contribution to Oklahoma economy is evident in the multiplier effects of total industry output and employment. The employment multiplier measures the indirect and induced jobs created by the OK-MKARNS. One additional job on the OK-MKARNS would bring an estimated 2.94 indirect and induced jobs to other industries in the economy (Table 5). Milling (6.54) and Utilities (4.35) are the only other industries with larger employment multipliers (Appendix Table B). The TIO multiplier of 2.24 indicates that for every dollar of activity supported by the OK-MKARNS, there is an additional $1.24 generated in other industries of Oklahoma's economy. Mining is the only industry in Oklahoma that creates larger indirect and induced values for each dollar of output with a multiplier of 2.71.

Table 5. Contribution of the OK-MKARNS to OK, AR, CO, and KS

	Employment	Employment Multiplier	Output ($ millions)	Output Multiplier	Value Added ($ millions)	Value Added Multiplier
OK	37.60	3.94	9.75	2.24	2.19	-4.20
AR	1.59	1.16	0.23	1.05	0.12	1.19
CO	0.13	1.01	0.02	1.01	0.01	1.02
KS	0.42	1.05	0.09	1.02	0.04	1.07
Total	40.25	4.16	10.76	2.32	2.95	-4.47

The Oklahoma value added multiplier for the water transportation industry is negative. This occurs because the positive total value added ($2.2 million) is divided by the negative direct value added of $0.7 million (Table 5). The direct effect is negative because the OK-MKARNS has a large negative proprietor income. In years of lower prices or higher operational costs, an industry's operating surplus (profit) may be lower than operating expenses[1]. If other value added components fail to counterbalance operating losses, then the calculated multiplier will be negative. The total positive value added comes from positive indirect and induced effects in other industries resulting from OK-MKARNS activity. Although water transportation has a negative direct value added, it creates enough indirect and induced value added to have the fifth greatest multiplier behind Poultry and Egg Production, Dairy Cattle and Milk Production, Mining, and Animal Processing (Appendix B). The water transportation industry does not have the highest impact numbers by indicator compared to other industries, but it does have a notable contribution through the multiplier effect observed in the indirect and induced

[1] Negative values and multipliers are not common in most industries outside of occasional years that experienced higher losses. However in those industries that receive government support and funding, such as the MKARNS, industries may experience negative values more often that result in negative multipliers.

effects for each indicator. This is indicative of the essential transportation services the system provides as supply chain support for other industries.

The contribution of the OK-MKARNS is much smaller in the other states of the analysis. Arkansas has the greatest numbers in employment, output, and value added. However, Colorado exhibits the greatest multiplier effects in output and value added and Kansas has the greatest multiplier effect in employment. Since all the direct impacts of the contribution analysis are within Oklahoma, this makes sense as only indirect and induced impacts would be captured within Arkansas, Colorado, and Kansas.

4.2 Delay Duration and Economic Impacts

4.2.1 2-Month Delay

2-month delays resulted in losses across all districts. Employment losses were greatest in Oklahoma (Table 6), followed by Arkansas, Kansas, and Colorado. The industries that experienced the greatest losses in employment across all of the states were Services, FIRE, and Miscellaneous industries (Appendix B). Sectors that experienced losses that were unique to each state were Truck Transportation in Arkansas, Breweries, Wineries, and Distilleries in Colorado, and Grain Farming in Oklahoma and Kansas. In the district breakdown AR-3 experienced the greatest losses in Arkansas, CO-2,7 in Colorado and KS-2 in Kansas. Trends in output were similar (Table 7). Oklahoma had the greatest losses but Kansas experienced the next greatest, followed by Arkansas and Colorado. Individual districts were the same. Value added follows the trends from output (Table 8). The highest losses were in Oklahoma, followed by Kansas, Arkansas, and Colorado. AR-3, CO-2,7 and KS-2 experienced the greatest district losses in each state.

Table 6. 2-Month Delay Impact on Employment (number of jobs)

	Lower to Upper		Lower to Upper		Lower to Upper		Lower to Upper
OK-1,2	-62 to -68	**AR-1**	0 to 0	**CO-1**	0 to 0	**KS-1**	0 to 0
OK-3	-1 to -1	**AR-2**	0 to 0	**CO-2, 7**	0 to 0	**KS-2**	-1 to -1
OK-4	0 to 0	**AR-3**	-1 to -2	**CO-3**	0 to 0	**KS-3**	0 to 0
OK-5	0 to -1	**AR-4**	0 to 0	**CO-4,6**	0 to 0	**KS-4**	0 to 0
				CO-5	0 to 0		
Total	-63 to -69	**Total**	-2 to -2	**Total**	0 to 0	**Total**	-1 to -1

Table 7. 2-Month Delay Impact on Output ($ millions)

	Lower to Upper		Lower to Upper		Lower to Upper		Lower to Upper
OK-1, 2	-14.3 to -15.5	**AR-1**	-0.04 to -0.04	**CO-1**	0 to 0	**KS-1**	-0.11 to -0.11
OK-3	-0.1 to -0.2	**AR-2**	-0.01 to -0.01	**CO-2, 7**	-0.02 to -0.02	**KS-2**	-0.19 to -0.19
OK-4	-0.04 to -0.04	**AR-3**	-0.24 to -0.26	**CO-3**	-0.01 to -0.01	**KS-3**	-0.05 to -0.05
OK-5	-0.1 to -0.1	**AR-4**	-0.05 to -0.05	**CO-4, 6**	-0.01 to -0.01	**KS-4**	-0.09 to -0.09
				CO-5	0 to 0		
Total	-14.5 to -15.8	**Total**	-0.34 to -0.37	**Total**	-0.05 to -0.05	**Total**	-0.43 to -0.45

Table 8. 2-Month Delay Impact on Value Added ($ millions)

	Lower to Upper		Lower to Upper		Lower to Upper		Lower to Upper
OK-1, 2	-5.6 to -6.2	**AR-1**	-0.01 to -0.01	**CO-1**	0 to 0	**KS-1**	-0.03 to -0.04
OK-3	-0.07 to -0.07	**AR-2**	-0.01 to -0.01	**CO-2, 7**	-0.01 to -0.01	**KS-2**	-0.08 to -0.08
OK-4	-0.01 to -0.02	**AR-3**	-0.12 to -0.13	**CO-3**	0 to 0	**KS-3**	-0.02 to -0.03
OK-5	-0.05 to -0.06	**AR-4**	-0.02 to -0.02	**CO-4, 6**	-0.01 to -0.01	**KS-4**	-0.03 to -0.03
				CO-5	0 to 0		
Total	-5.73 to -6.35	**Total**	-0.16 to -0.17	**Total**	-0.02 to -0.02	**Total**	-0.17 to -0.17

4.2.2 4-Month Delay Duration

In the 4-month delay scenario all districts incurred losses in all the indicators (Table 9, Table 10, Table 11). Oklahoma incurred the greatest losses as it was the state with the direct impacts. Kansas followed except in employment where it was Arkansas. Then Arkansas and Colorado was the least impacted. All losses were greater than the 2-month delay duration as the longer products are delayed the greater losses the industries incur. However, the losses are not of a linear nature as the increase from 2-months to 4-months was more than double in each of the state totals. The same districts in each state were impacted most severely: AR-3, CO-2,7, and KS-2.

Table 9. 4-Month Delay Impact on Employment (# of jobs)

	Lower to Upper		**Lower to Upper**		**Lower to Upper**		**Lower to Upper**
OK-1,2	-287 to -312	**AR-1**	-1 to -1	**CO-1**	0 to 0	**KS-1**	-2 to -2
OK-3	-4 to -4	**AR-2**	0 to 0	**CO-2, 7**	0 to 0	**KS-2**	-3 to -3
OK-4	-1 to -1	**AR-3**	-6 to -7	**CO-3**	0 to 0	**KS-3**	-1 to -1
OK-5	-2 to -2	**AR-4**	-1 to -1	**CO-4,6**	0 to 0	**KS-4**	-1 to -1
				CO-5	0 to 0		
Total	-294 to -319	**Total**	-8 to -9	**Total**	-1 to -1	**Total**	-7 to -7

Table 10. 4-Month Delay Impact on Output ($ millions)

	Lower to Upper		**Lower to Upper**		**Lower to Upper**		**Lower to Upper**
OK-1, 2	-64.0 to -69.3	**AR-1**	-0.20 to -0.21	**CO-1**	-0.03 to -0.03	**KS-1**	-0.52 to -0.53
OK-3	-0.7 to -0.7	**AR-2**	-0.09 to -0.09	**CO-2, 7**	-0.10 to 0.11	**KS-2**	-0.88 to -0.92
OK-4	-0.2 to -0.2	**AR-3**	-1.07 to -1.16	**CO-3**	-0.03 to -0.03	**KS-3**	-0.26 to -0.28
OK-5	-0.5 to -0.5	**AR-4**	-0.25 to -0.26	**CO-4, 6**	-0.08 to -0.08	**KS-4**	-0.44 to -0.46
				CO-5	-0.02 to -0.02		
Total	-65.4 to -70.7	**Total**	-1.61 to -1.73	**Total**	-0.27 to -0.28	**Total**	-2.10 to -2.20

Table 11. 4-Month Delay Impact on Value Added ($ millions)

	Lower to Upper		Lower to Upper		Lower to Upper		Lower to Upper
OK-1, 2	-26.2 to -28.5	**AR-1**	-0.07 to -0.07	**CO-1**	-0.02 to -0.02	**KS-1**	-0.17 to -0.17
OK-3	-0.3 to -0.4	**AR-2**	-0.04 to -0.04	**CO-2, 7**	-0.05 to -0.05	**KS-2**	-0.37 to -0.39
OK-4	-0.08 to -0.09	**AR-3**	-0.55 to -0.60	**CO-3**	-0.01 to -0.02	**KS-3**	-0.12 to -0.13
OK-5	-0.3 to -0.3	**AR-4**	-0.09 to -0.09	**CO-4, 6**	-0.03 to -0.04	**KS-4**	-0.15 to -0.16
				CO-5	-0.01 to -0.01		
Total	-26.9 to -29.3	**Total**	-0.75 to -0.81	**Total**	-0.12 to -0.13	**Total**	-0.81 to -0.85

4.2.3 6-Month Delay Duration

The 6-month delay scenario followed the trends of the other two scenarios. All of the districts incurred losses, and Oklahoma incurred the greatest losses (Table 12, Table 13, Table 14). Again the nature of the loss is not linear as the losses more than double when compared to the 4-month scenario.

The industries that were most affected in Arkansas included services, miscellaneous, FIRE, wholesale, and truck transportation (Appendix B). In 2018, one of eleven jobs in Arkansas were in the trucking industry and 87% of Arkansas communities relied completely on the trucking industry to move their goods (ATRI 2020). The combined demand for port products and truck transportation within AR-3 could account for this being the region in Arkansas with the highest losses due to disruption of the OK-MKARNS.

The industries that exhibited the greatest losses in Colorado were services, FIRE, manufacturing, miscellaneous, and breweries, wineries, and distilleries (Appendix B). Further exploration of why Breweries, Wineries, and Distilleries was one of the most affected industries is needed. Grain Farming was one of the industries that experienced the greatest losses in the project, since Breweries, Wineries, and Distilleries use products from the Grain Farming industry indirect effects could have been incurred through disruption of grain supply throughout those months.

The industries in Kansas that had the greatest losses included Grain Farming, Utilities, Agriculture Inputs, FIRE, and Manufacturing (Appendix B). In 2018, 87% of Kansas' land was in farms and three of their top five agricultural commodities included corn, wheat, and sorghum. Wheat and corn were also included in their top ag exports, with wheat valuing at $572 million (4.9% of total US exports) and corn valuing at $195 million (1.7% of total US exports) in 2018 (USCB 2020). In the 6-month delay scenario Kansas Grain Farming exhibited losses over $900,000 in output and $200,000 in value added.

Table 12. 6-Month Delay Impact on Employment (# of jobs)

	Lower to Upper		Lower to Upper		Lower to Upper		Lower to Upper
OK-1,2	-676 to -733	**AR-1**	-2 to -2	**CO-1**	0 to 0	**KS-1**	-4 to -4
OK-3	-9 to -9	**AR-2**	-1 to -1	**CO-2, 7**	-1 to -1	**KS-2**	-7 to -7
OK-4	-2 to -3	**AR-3**	-15 to -16	**CO-3**	0 to 0	**KS-3**	-2 to -3
OK-5	-5 to -6	**AR-4**	-3 to -3	**CO-4,6**	-1 to -1	**KS-4**	-3 to -4
				CO-5	0 to 0		
Total	-692 to -750	**Total**	-20 to -21	**Total**	-3 to -3	**Total**	-17 to -17

Table 13. 6-Month Delay Impact on Output ($ millions)

	Lower to Upper		Lower to Upper		Lower to Upper		Lower to Upper
OK-1, 2	-64.0 to -69.3	**AR-1**	-0.20 to -0.21	**CO-1**	-0.03 to -0.03	**KS-1**	-0.52 to -0.53
OK-3	-0.7 to -0.7	**AR-2**	-0.09 to -0.09	**CO-2, 7**	-0.10 to 0.11	**KS-2**	-0.88 to -0.92
OK-4	-0.2 to -0.2	**AR-3**	-1.07 to -1.16	**CO-3**	-0.03 to -0.03	**KS-3**	-0.26 to -0.28
OK-5	-0.5 to -0.5	**AR-4**	-0.25 to -0.26	**CO-4, 6**	-0.08 to -0.08	**KS-4**	-0.44 to -0.46
				CO-5	-0.02 to -0.02		
Total	-65.4 to -70.7	**Total**	-1.61 to -1.73	**Total**	-0.27 to -0.28	**Total**	-2.10 to -2.20

Table 14. 6-Month Delay Impact on Value Added ($ millions)

	Lower to Upper		Lower to Upper		Lower to Upper		Lower to Upper
OK-1, 2	-149.1 to -161.5	**AR-1**	-0.49 to -0.51	**CO-1**	-0.09 to -0.10	**KS-1**	-1.23 to -1.27
OK-3	-1.6 to -1.7	**AR-2**	-0.22 to -0.24	**CO-2, 7**	-0.25 to -0.27	**KS-2**	-2.08 to -2.18
OK-4	-0.4 to -0.5	**AR-3**	-2.51 to -2.72	**CO-3**	-0.08 to -0.09	**KS-3**	-0.63 to -0.67
OK-5	-1.2 to -1.3	**AR-4**	-0.60 to -0.63	**CO-4, 6**	-0.21 to -0.22	**KS-4**	-1.04 to -1.09
				CO-5	-0.05 to -0.06		
Total	-152.3 to -165.0	**Total**	-3.82 to -4.10	**Total**	-0.69 to -0.73	**Total**	-4.99 to -5.21

4.3 Economic Impacts on Oklahoma Metropolitan and Non-Metropolitan Regions

We summarize the economic impacts for metropolitan and non-metropolitan regions in Table 15. All direct impacts occur in OK-1 and OK-2 because these districts were combined for the analysis. All effects for metropolitan and non-metropolitan results are therefore reported as indirect or induced effects. There was greater overall economic loss in the non-metropolitan regions of the state, but there are some notable differences in the industries that were affected. In the metropolitan region, Utilities and Services incurred the greatest losses compared with other industries. In more densely populated areas, demand for Utilities and Services is higher, exacerbating losses to these industries. Alberini et al. (2011) found that when energy prices increased in metropolitan areas, households substitute inputs for energy and choose less energy intensive options. In the non-metropolitan regions, the Wholesale industry incurred the highest losses.

Table 15. Economic impact on OK Metro vs. Non-Metro Regions by Length of Delay

Length of Delay	Regions	Employment	Value Added ($ millions)	Output ($ millions)
2-Month	Metropolitan	-0.5	-0.05	-0.11
	Non-Metropolitan	-1	-0.09	-0.19
4-Month	Metropolitan	-2	-0.27	-0.53
	Non-Metropolitan	-5	-0.42	-0.91
6-Month	Metropolitan	-5	-0.63	-1.26
	Non-Metropolitan	-12	-0.99	-2.16

CHAPTER V

CONCLUSION

The disruption of the OK-MKARNS could have regional economic impacts on industries and regions that depend either directly or indirectly on OK-MKARNS waterborne transportation services. There has been a need to understand the value of the economic impact and determine which industries may be affected and by how much. Findings of the contribution analysis indicate that while the total effects from the OK-MKARNS are not massive when compared to a state economy, the multiplier effects are substantial. This indicates the OK-MKARNS provides a valuable service as supply chain support to other industries in the state. The total impact of the closure of the OK-MKARNS is dependent on the duration of the closure. Each of the delay scenarios analyzed, 2-Month, 4-Month, and 6-Month resulted in substantial losses to the state of Oklahoma with greater losses as the duration increased. Findings indicate closure of the OK-MKARNS had a greater impact on the productivity of non-metropolitan regions than metropolitan regions in Oklahoma. It also had a greater impact on those regions with a greater geographic proximity to the OK-MKARNS with less severe effects further from the waterway.

Arkansas, Colorado, and Kansas also exhibited losses in each of their districts as a result of delay disruptions. In many of the districts, service and FIRE industries exhibited the highest losses as reduction in business to business transactions or loss of spending of labor income. However, each state also exhibited losses unique to that state's economy. Arkansas experienced losses in the trucking industry, an industry that much of the state is reliant on. Colorado has a large craft brew industry and one of its most affected industries was Breweries, Wineries, and Distilleries. Kansas is a large wheat export state and saw losses in grain farming.

Myles (2000) defines an 'impure' public good as one that simultaneously provides a number of users but is subject to congestion. Defined this way, the OK-MKARNS, and other transportation infrastructure, are impure public goods. The benefits individuals receive from impure public goods diminish as congestion increases. The causes of congestion vary from the obvious case of many users accessing the good to more subtle causes related to maintenance and repair. The 2019 disruption of the OK-MKARNS caused by a historically unprecedented flooding event revealed the importance of its transportation services to the region's economy. The waterway remained closed well after waters subsided as repairs to the channel and banks continued into 2020. The flood's magnitude caused the extended closure, but so did the condition of the waterway's channels and locks. What remains unknown is if increasing the waterway's resiliency to extreme flooding events through continued maintenance would have shortened the closure period. More frequent maintenance and repair of the waterway would require fiscal budgeting through legislation, or increased use of the waterway by agricultural, mining, and manufacturing industries. An obstacle a government faces in maintaining a public good and sustaining a level of service provided is household and other stakeholder's willingness-to-pay for the good. Toward this end, future analyses could collect primary data on beneficiaries' knowledge of the OK-MKARNS use and existence value.

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APPENDICES

APPENDIX A

Table A.1 Aggregation of economic sectors

Aggregated Economic Sectors	**Economic Sectors in Aggregation**
Oilseed farming	Oilseed farming
Grain farming	Grain farming
Fruit and vegetable farming	Vegetable and melon, and other fruit farming
Tree nut farming	Tree nut farming
Greenhouse, nursery, and floriculture production	Greenhouse, nursery, and floriculture production
Cotton farming	Cotton farming
Beef cattle ranching and farming	Beef cattle ranching and farming, including feedlots and dual-purpose ranching and farming
Dairy cattle and milk production	Dairy cattle and milk production
Poultry and egg production	Poultry and egg production
Animal production	Animal production, except cattle and poultry and eggs
Primary forestry	Forestry, forest products, and timber tract production; Commercial logging
Commercial fishing and hunting	Commercial fishing, hunting, and trapping
Natural gas petro	Oil and gas extraction; drilling oil and gas wells; support activities for oil and gas operations; petroleum refineries; industrial gas manufacturing
Mining	All commercial mining and other nonmetallic minerals; drilling oil and gas wells; supportive activities for oil and gas operation
Services	All services
Utilities	Electric power generation, transmission and distribution; natural gas distribution; water, sewage, and other systems

Table A.1 Aggregation of economic sectors (continues)

Aggregated Economic Sectors	**Economic Sectors in Aggregation**
Construction	All constructions, maintenance and repair
Textiles	All textiles
Milling	Flour and rice milling, malt manufacturing; wet corn milling; soybean and other oilseed processing; fats and oils refining and blending; sugar cane mills and refining
Food manufacturing	All food manufacturing
Dairy processing	Cheese and dairy production
Animal processing	Poultry processing; animal, except poultry, slaughtering; meat processed from carcasses; rendering and meat byproduct processing; seafood product preparation and packaging; leather and hide tanning and finishing
Breweries, wineries, distilleries	Breweries; wineries; distilleries
Secondary forestry	Furniture, wood work manufacturing; and all other converted paper product manufacturing
Agriculture inputs	Support activities for agriculture and forestry; other animal food, fertilizer, pesticide and other agricultural chemical manufacturing; farm machinery and equipment, lawn and garden equipment manufacturing
Other agriculture	Tobacco, sugarcane, and sugar beet farming; all other crop farming; Landscape and horticultural services
Wholesale	Wholesale
Retail trade	Dealers; retail stores
Rail transportation	Rail transportation
Water transportation	Water transportation
Truck transportation	Truck transportation
Other transportation	Air transportation; transit, ground passenger, pipeline, scenic and sightseeing transportation; support activities for transportation; couriers and messengers; warehousing and storage
Warehousing	Warehousing
Financial, Insurance, Real Estate	Depository and non-depository credit intermediation; brokerage; financial vehicles; insurance carriers, agencies, brokerage, and related activities; Real estate and owner-occupied dwellings
Miscellaneous	All other sectors (used goods, scrap, religious, business, and social organizations)

Table A.1 Aggregation of economic sectors (continues)

Aggregated Economic Sectors	Economic Sectors in Aggregation
Government	Schools, local and federal electric utilities; transit, state and local government enterprises; local and federal employment and payroll of state and federal government, rest of the world adjustment
Manufacturing	Non-food manufacturing (not including agricultural and forestry input- or output-related manufacturing)

Table A.2 Counties included in each Congressional District

District	Counties
AR-01	Phillips, Independence, Prairie, Chicot, Fulton, Cleburne, Cross, St. Francis, Mississippi, Woodruff, Jackson, Izard, Monroe, Craighead, Lee, Stone, Arkansas, Greene, Lonoke, Desha, Searcy, Poinsett, Baxter, Clay, Crittenden, Lincoln, Sharp, Lawrence, Randolph
AR-02	White, Conway, Faulkner, Saline, Van Buren, Pulaski, Perry
AR-03	Pope, Carroll, Boone, Sebastian, Marion, Benton, Crawford, Washington
AR-04	Howard, Garland, Hempstead, Pike, Ashley, Bradley, Scott, Lafayette, Miller, Grant, Montgomery, Newton, Nevada, Union, Franklin, Columbia, Yell, Cleveland, Madison, Jefferson, Polk, Sevier, Calhoun, Ouachita, Clark, Logan, Hot Spring, Little River, Johnson, Drew, Dallas
CO-01	Denver
CO-02,07	Grand, Broomfield, Summit, Clear Creek, Larimer, Boulder, Gilpin, Jefferson
CO-03	San Juan, Jackson, Dolores, Huerfano, San Miguel, Lake, Rio Blanco, Gunnison, Archuleta, La Plata, Routt, Ouray, Mineral, Rio Grande, Custer, Mesa, Pitkin, Delta, Montezuma, Conejos, Costilla, Saguache, Moffat, Alamosa, Garfield, Hinsdale, Pueblo, Eagle, Montrose
CO-04,06	Elbert, Sedgwick, Kiowa, Cheyenne, Crowley, Phillips, Las Animas, Weld, Bent, Lincoln, Otero, Washington, Morgan, Logan, Baca, Adams, Yuma, Arapahoe, Prowers, Kit Carson, Douglas
CO-05	Chaffee, Fremont, Teller, El Paso, Park
KS-01	Mitchell, Gove, Stanton, Rice, Norton, Lane, Ford, Kearny, Ellsworth, Chase, Scott, Riley, Geary, Clay, Barton, Gray, Ellis, Wichita, McPherson, Morris, Hodgeman Stevens, Sheridan, Logan, Jewell, Russell, Grant, Lincoln, Decatur, Washington, Haskell, Sherman, Meade, Smith, Finney, Lyon, Rush, Wallace, Rooks, Morton, Rawlins, Ness, Pawnee, Osborne, Marion, Pottawatomie, Ottawa, Graham, Clark, Cheyenne, Phillips, Dickinson, Cloud, Greeley, Seward, Trego, Thomas, Saline, Wabaunsee, Hamilton, Republic, Reno

Table A.2 Counties included in each Congressional District

District	Counties
KS-02	Shawnee, Jackson, Miami, Woodson, Montgomery, Neosho, Anderson, Jefferson, Brown, Wilson, Douglas, Franklin, Marshall, Bourbon, Nemaha, Crawford, Cherokee, Linn, Leavenworth, Coffey, Atchison, Allen, Labette, Doniphan, Osage
KS-03	Wyandotte, Johnson
KS-04	Sumner, Cowley, Chautauqua, Barber, Kiowa, Harvey, Stafford, Edwards, Sedgwick, Pratt, Butler, Kingman, Harper, Comanche, Greenwood, Elk
OK-01,02	Mayes, Rogers, Tulsa, Pittsburg, Delaware, Ottawa, Coal, Craig, Atoka, Okmulgee, Hughes, Nowata, McCurtain, Johnston, Le Flore, McIntosh, Adair, Haskell, Bryan, Cherokee, Marshall, Pushmataha, Muskogee, Washington, Choctaw, Latimer, Okfuskee, Wagoner, Sequoyah
OK-03	Caddo, Roger Mills, Washita, Kiowa, Ellis, Osage, Canadian, Grant, Payne, Major, Woods, Blaine, Kingfisher, Dewey, Alfalfa, Custer, Kay, Beckham, Garfield, Logan, Greer, Harmon, Woodward, Texas, Jackson, Lincoln, Pawnee, Noble, Cimarron, Creek, Harper, Beaver
OK-04	Comanche, Murray, Stephens, Tillman, Love, Carter, Jefferson, Pontotoc, Grady, Cotton, McClain, Garvin, Cleveland
OK-05	Seminole, Pottawatomie, Oklahoma

APPENDIX B

Table B.1 Oklahoma Industry Multipliers

Industry	**Output Multiplier**	**Employment Multiplier**	**Value Added Multiplier**
Oilseed Farming	1.62	3.10	1.47
Grain Farming	1.84	2.32	2.12
Fruit and Vegetable	1.59	1.36	1.95
Tree Nut Farming	1.61	1.16	1.68
Greenhouse, Nursery,	1.59	1.44	1.89
Cotton Farming	1.51	1.43	1.67
Beef Cattle Ranching	1.54	1.25	1.95
Dairy Cattle and Milk	1.68	2.64	3.72
Poultry and Egg	1.53	2.35	5.07
Animal Production,	1.42	1.21	1.29
Primary Forestry	1.56	1.20	1.65
Commercial Fishing	1.41	1.09	1.38
Natural Gas Petro	1.48	2.68	1.64
Mining	2.71	3.27	3.48
Services	1.45	1.31	1.43
Utilities	1.56	4.35	1.96
Construction	1.69	1.62	1.82
Textiles	1.48	1.44	1.84
Milling	1.38	6.54	2.63
Food Manufacturing	1.46	1.93	1.91
Dairy Processing	1.59	3.11	2.76
Animal Processing	1.71	3.44	3.37
Breweries, Wineries,	1.48	2.18	1.82
Secondary Forestry	1.50	2.35	1.79
Agriculture Inputs	1.66	1.99	2.20
Other Agriculture	1.73	1.16	1.78
Wholesale	1.59	2.23	1.56
Retail Trade	1.73	1.38	1.69
Rail Transportation	1.48	3.13	1.38
Water Transportation	2.10	3.88	-3.31
Truck Transportation	1.89	1.92	2.03

Table B.1 Oklahoma Industry Multipliers (Continued)

Industry	Output Multiplier	Employment Multiplier	Value Added Multiplier
Other Transportation	1.70	3.00	1.45
Warehousing and Storage	1.81	1.51	1.96
Financial, Insurance, and Real Estate	1.30	1.64	1.32
Miscellaneous	1.53	1.37	1.57
Government	1.59	1.42	1.38
Manufacturing	1.45	2.14	1.85

Table B.2 Oklahoma Impacts by Industry (6-month disruption upper bound)

	Employment	Output ($ millions)	Value Added ($ millions)
Oilseed Farming	-42.52	-13.92	-9.30
Grain Farming	-130.49	-13.67	-5.06
Fruit and Vegetable Farming	-0.05	-0.01	
Tree Nut Farming	-0.08		
Greenhouse, Nursery, and Floriculture Production	-0.17	-0.02	-0.01
Other Agriculture	-17.54	-0.62	-0.32
Cotton Farming	-0.03		
Beef Cattle Ranching and Farming	-0.67	-0.05	-0.01
Dairy Cattle and Milk Production	-0.02	-0.01	
Poultry and Egg Production	-0.06	-0.03	
Animal Production, except cattle and poultry and eggs	-0.58	-0.03	-0.03
Primary Forestry	-0.44	-0.03	-0.01
Commercial Fishing and Hunting	-0.02		
Agriculture Inputs	-93.01	-39.23	-9.80
Natural Gas Petro	-7.73	-5.89	-2.37

Table B.2 Oklahoma Impacts by Industry (6-month disruption upper bound) (continued)

	Employment	Output ($ millions)	Value Added ($ millions)
Mining	-37.53	-9.06	-2.90
Services	-104.75	-12.29	-7.04
Utilities	-4.53	-4.49	-1.65
Construction	-37.06	-4.98	-2.21
Manufacturing	-35.54	-14.97	-4.41
Milling	-0.27	-1.07	-0.12
Food Manufacturing	-11.07	-3.58	-1.05
Dairy Processing	-0.06	-0.04	-0.01
Animal Processing	-0.30	-0.13	-0.02
Breweries, Wineries, Distilleries	-0.09	-0.04	-0.01
Textiles	-0.01		
Secondary Forestry	-0.30	-0.16	-0.05
Wholesale	-24.26	-7.52	-4.39
Retail Trade	-40.26	-3.41	-1.95
Other Transportation	-2.79	-1.96	-1.76
Rail Transportation	-1.50	-1.16	-0.78
Water Transportation	-4.65	-2.23	0.32
Truck Transportation	-11.24	-2.18	-1.14
Warehousing and Storage	-5.57	-0.57	-0.23
Miscellaneous	-48.81	-5.90	-2.93
Financial, Insurance, and Real Estate	-51.12	-14.50	-7.51
Government	-35.29	-4.18	-3.06
Total	-750.42	-167.95	-69.82

Table B.3 Arkansas Impacts by Industry (6-month disruption upper bound)

	Employment	Output ($ millions)	Value Added ($ millions)
Oilseed Farming	-0.26	-0.08	-0.05
Grain Farming	-0.31	-0.05	-0.02
Fruit and Vegetable Farming			
Tree Nut Farming			
Greenhouse, Nursery, and Floriculture Production	-0.01		
Other Agriculture	-0.27	-0.01	-0.01
Cotton Farming	-0.02		
Beef Cattle Ranching and Farming	-0.02		
Dairy Cattle and Milk Production			
Poultry and Egg Production	-0.19	-0.08	
Animal Production, except cattle and poultry and eggs	-0.01		
Primary Forestry	-0.12	-0.01	-0.01
Commercial Fishing and Hunting	-0.01		
Agriculture Inputs	-0.72	-0.19	-0.05
Natural Gas Petro	-0.05	-0.03	-0.01
Mining	-0.33	-0.07	-0.03
Services	-8.41	-1.04	-0.64
Utilities	-0.08	-0.08	-0.03
Construction	-0.24	-0.03	-0.01
Manufacturing	-0.68	-0.30	-0.09
Milling	-0.16	-0.23	-0.02
Food Manufacturing	-0.15	-0.05	-0.01
Dairy Processing	-0.01	-0.01	

Table B.3 Arkansas Impacts by Industry (6-month disruption upper bound) (continued)

	Employment	Output ($ millions)	Value Added ($ millions)
Animal Processing	-0.52	-0.17	-0.03
Breweries, Wineries, Distilleries	-0.02	-0.02	-0.01
Textiles			
Secondary Forestry	-0.27	-0.12	-0.04
Wholesale	-1.24	-0.40	-0.24
Retail Trade	-1.05	-0.09	-0.05
Other Transportation	-0.28	-0.04	-0.02
Rail Transportation	-0.05	-0.03	-0.01
Water Transportation			
Truck Transportation	-1.13	-0.20	-0.09
Warehousing and Storage	-0.48	-0.06	-0.03
Miscellaneous	-2.29	-0.23	-0.12
Financial, Insurance, and Real Estate	-1.41	-0.42	-0.23
Government	-0.65	-0.06	-0.05
Total	-21.43	-4.10	-1.91

Table B.4 Colorado Impacts by Industry (6-month disruption upper bound)

	Employment	Output ($ millions)	Value Added ($ millions)
Oilseed Farming			
Grain Farming	-0.05	-0.01	-0.01
Fruit and Vegetable Farming			
Tree Nut Farming			
Greenhouse, Nursery, and Floriculture Production			
Other Agriculture	-0.02		
Cotton Farming			
Beef Cattle Ranching and Farming	-0.02		
Dairy Cattle and Milk Production			
Poultry and Egg Production			
Animal Production, except cattle and poultry and eggs			
Primary Forestry			
Commercial Fishing and Hunting			
Agriculture Inputs	-0.13	-0.05	-0.01
Natural Gas Petro	-0.01		
Mining	-0.12	-0.05	-0.03
Services	-0.74	-0.10	-0.06
Utilities	-0.01	-0.01	
Construction	-0.03		
Manufacturing	-0.25	-0.11	-0.04
Milling	-0.01	-0.02	
Food Manufacturing	-0.03	-0.01	
Dairy Processing			

Table B.4 Colorado Impacts by Industry (6-month disruption upper bound) (continued)

	Employment	Output ($ millions)	Value Added ($ millions)
Animal Processing	-0.01	-0.01	
Breweries, Wineries, Distilleries	-0.14	-0.08	-0.03
Textiles			
Secondary Forestry	-0.01		
Wholesale	-0.13	-0.05	-0.03
Retail Trade	-0.14	-0.01	-0.01
Other Transportation	-0.04	-0.01	-0.01
Rail Transportation			
Water Transportation			
Truck Transportation	-0.04	-0.01	
Warehousing and Storage	-0.01		
Miscellaneous	-0.63	-0.09	-0.05
Financial, Insurance, and Real Estate	-0.31	-0.09	-0.05
Government	-0.09	-0.01	-0.01
Total	-2.97	-0.73	-0.35

Table B.5 Kansas Impacts by Industry (6-month disruption upper bound)

	Employment	Output ($ millions)	Value Added ($ millions)
Oilseed Farming	-0.23	-0.24	-0.10
Grain Farming	-2.63	-0.93	-0.23
Fruit and Vegetable Farming			
Tree Nut Farming			
Greenhouse, Nursery, and Floriculture Production			
Other Agriculture	-0.17	-0.01	
Cotton Farming	-0.01		
Beef Cattle Ranching and Farming	-0.18	-0.04	-0.01
Dairy Cattle and Milk Production			
Poultry and Egg Production			
Animal Production, except cattle and poultry and eggs	-0.04	-0.01	
Primary Forestry	-0.01		
Commercial Fishing and Hunting	-0.02		
Agriculture Inputs	-1.22	-0.49	-0.12
Natural Gas Petro	-0.16	-0.11	-0.02
Mining	-0.10	-0.02	-0.01
Services	-3.40	-0.40	-0.23
Utilities	-0.67	-0.75	-0.31
Construction	-0.20	-0.03	-0.01
Manufacturing	-0.85	-0.46	-0.13
Milling	-0.12	-0.21	-0.03
Food Manufacturing	-0.07	-0.04	-0.01
Dairy Processing			

Table B.5 Kansas Impacts by Industry (6-month disruption upper bound) (continued)

	Employment	**Output ($ millions)**	**Value Added ($ millions)**
Animal Processing	-0.14	-0.09	-0.01
Breweries, Wineries, Distilleries	-0.01		
Textiles			
Secondary Forestry	-0.08	-0.02	-0.01
Wholesale	-0.83	-0.26	-0.14
Retail Trade	-0.92	-0.08	-0.05
Other Transportation	-0.23	-0.04	-0.02
Rail Transportation	-0.10	-0.06	-0.04
Water Transportation			
Truck Transportation	-0.27	-0.05	-0.02
Warehousing and Storage	-0.10	-0.01	-0.01
Miscellaneous	-1.58	-0.20	-0.11
Financial, Insurance, and Real Estate	-1.80	-0.54	-0.28
Government	-1.28	-0.12	-0.11
Total	-17.44	-5.21	-2.02

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