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Evaluating Regional Freight Corridors in the Mid-America States: A Step towards Regional Prioritization for Freight Operations and Investments

--Manuscript Draft--

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ABSTRACT

This research investigates the regional connections and operational features of freight corridors identified in the National Highway Freight Network across the MAASTO region. Using the Freight Analysis Framework 4 (FAF4) data, detailed Geographic Information System (GIS) and statistical analysis are conducted to evaluate the value of these multistate corridors. This case study defines the value of a corridor as the overall monetary value of shipments on the corridor as captured in the FAF4 database. This network is verified by the distribution of truck volume, particularly long-distance truck volume. A simple yet effective method to estimate corridor value is also proposed. This method is applied to the freight corridors in the MAASTO region, revealing principal corridors with relatively large values for each state. Analysis for multi-state corridors also shows the relative value of the corridors across the states involved. The corridor value elucidates the physical and operational features of the corridors as well as characteristics of the areas where the corridors extend.

Keywords: Freight Transportation, Corridor Value, National Highway Freight Network (NHFN), Freight Analisys Framework (FAF), Regional Freight Corridors.

1. INTRODUCTION

Freight transporation has a huge impact on the national and regional economies. The report from the Federal Highway Administration (FHWA) *(1)* presents that the industry of freight transporation employed 4.6 million workers, contributed 9.5% of U.S. economic activity in terms of gross domestic product (GDP) in 2015, and moved approximately 55 million tons (valued at $49.5 billion) per day. The report also forecasts that the total value of freight in U.S. will be nearly double in 2045 from 2012. Trucks on the highway network represent the largest mode of freight transportation, carrying 64% of the weight and 69% of the value *(1)*.

To improve the performance of freight transportation on the nation's highways, the FHWA established the National Highway Freight Network (NHFN) under the Fixing America's Surface Transportation (FAST) ACT *(2)*. Since 2002, the Freight Analysis Framework (FAF) has been produced to describe specific freight volumes and values for each state by all modes. Other data related to freight transportation, such as Commodity Flow Survey (CFS) data *(3)*, are incorporated in the FAF and widely developed on national and regional levels to support policy decisions and research analysis. The CFS data is collected every five years, in years that end in 2 or 7. Research for the economic value of freight transportation is widely conducted with an array of approaches. On the national level, researchers found close relationships between freight transporation and economic growth using various indicators such as GDP or GVA (Gross Value Added) *(4–6)*. They also suggested more detailed data and disaggregated models are desired to better describe the relationships. Similarly, studies at the state and county levels have also been conducted to analyze the regional impact of freight transporation and to support regional planning *(7–10)*. However, there have been few efforts to derive the value of corridors that span multiple states despite the fact that freight trucks are the largest mode of traffic across the nation's highway network. Thus, understanding the value of multistate freight corridors will lead to a more systematic analysis of their economic impact beyond county and state boundaries. This can better support regional planning by helping prioritize corridors for regional development and demonstrating to policy makers the importance of these corriodors to the economic well-being of a region or state.

This research aims to (i) investigate physical and operational features of corridors to identify the principal freight network, and (ii) develop a framework to estimate the value of freight corridors based on these features. To this end, we conduct both geographic information system (GIS) and statistical analysis on the MAASTO (Mid America Association of State Transportation Officials) region as a case study. The MAASTO region consists of ten states in the Midwestern United States: Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.

The remaining paper is organized as follows. Section 2 presents an extensive literature review for the national-level database including NHFN and FAF, and studies for economic analysis related to freight transportation. As a case study, Section 3 shows detailed physical and operational features of the freight network in the MAASTO region and Section 4 presents a method to estimate the corridor value and the results of GIS and statistical analysis. Conclusions and a discussion for future research are provided in Section 5.

2. LITERATURE REVIEW

2.1 National Highway Freight Network (NHFN)

National Highway Freight Network (NHFN) includes the major corridors for freight transporation established under the FAST Act. NHFN consists of the following components *(1)*:

- The Primary Highway Freight System (PHFS)
- Other Interstate portions not on the PHFS
- Critical Rural Freight Corridors (CRFCs)
- Critical Urban Freight Corridors (CUFCs)

The PHFS is the most critical highway system for freight transportation and consists of 41,518 miles. This includes 37,436 miles of Interstate and 4,082 miles of non-Interstate highways. To provide continuity and access to freight transportation facilities, some remaining portions of Interstates are also included in the NHFN. The additional Interstate length is estimated to be 9,511 miles nationwide, though the mileage fluctuates based on changes in the Interstate system. CRFCs (rural areas) and CUFCs (urbanized area) are public roads that provide access to the PHFS and the Interstates with important freight transportation facilities, such as ports or public transportation facilities. States and Metropolitan Planning Organizations (MPOs) are responsible for designating CRFCs and CUFCs. These roads have a maximum of 150 miles (or 20% of the PHFS mileage in the state, whichever is greater) for CRFCs and 75 miles (or 10% of the PHFS mileage in the state, whichever is greater) of CUFCs.

In Section 3, we investigate the physical features of NHFN in the MAASTO region in detail using GIS. Note that FHWA provides a Shapefile of NHFN for GIS with periodic updating, and in this research, we use the latest version as of October 2016 *(11)*.

2.2 Freight Analysis Framework (FAF)

To describe national and state freight movement, the Freight Analysis Framework (FAF) is produced by FHWA in cooperation with other departments, such as the Bureau of Transportation Statistics (BTS) *(12)*. FAF integrates various data sources, such as the CFS and international trade data from the Census Bureau, to estimate regional freight flow distribution. The latest FAF is the fourth generation of FAF (FAF4 hereafter) with the base year of 2012. It has 132 domestic and 8 international zones. FAF4 provides estimation for tonnage and value by the zone of origin and destination for each mode (e.g., truck, rail or water) with forecasting through 2045 *(13–15)*. In addition, FAF4 provides various traffic data on a predefined road network (FAF4 network hereafter). The traffic data of FAF4 is mainly from the Highway Performance Monitoring System (HPMS) including AADT (annual average daily traffic) and AADTT (annual average daily truck traffic) for each road section. For freight traffic assignment *(16)*, FAF4 provides long-distance truck freight flow (typically greater than 50 miles *(17)*) based on the FAF4 freight origin-destination distribution. FAF4 also provides detailed attributes for the FAF4 network, which includes the following roadways *(16)*:

- Interstate highways
- Other FHWA designated NHS routes

- National Network (NN) routes that are not part of NHS
- Other rural and urban principal arterials
- Intermodal connectors
- Rural minor arterials for those counties that are not served by either NN or NHS routes
- Urban bypass and streets as appropriate for network connectivity.

Since NHFN in section 2.1 is included in the FAF4 network, FAF4 can provide the operational features of NHFN such as long-distance truck volume for each corridor, and the volume and value of freight. Thus, in Section 3, we will investigate the operational features of NHFN in the MAASTO region, as well as the physical characteristics (i.e., length), to verify the role of NHFN in freight movement. FAF4 also provides the economic value of freight for each zone that includes multiple corridors. Thus, in Section 4, we will develop a framework to estimate the corridor value using the freight value for each zone and assigned truck volume for each corridor.

2.3 Economic Analysis for Freight Transportation Corridors

The contribution of freight transportation to the economy has been widely investigated *(4, 7, 10, 18–20)*. For example, Wang et al. *(18)* proposed a method to estimate direct freight benefits from transportation projects. The benefits included improvements in travel-time and operating-cost savings and reductions in environmental impact. Based on these benefits, researchers derived regional economic impacts in terms of employment, wages and GDP. The case study of a widening project on a major Interstate in Washington showed that the freight investment has resulted in significant benefits stemming from improved transportation performance. The benefits transfer to economic impacts via job creation and the improvement of regional economic activity. On the other hand, Peng and Yu *(7)* developed an economic analysis framework for freight transportation by integrating the Freight Supply chain Intermodal Model (FreightSIM) and a regional economic model (input-output model). Two case studies in Florida demonstrate that this model can derive impacts from freight transportation projects (e.g., highway expansion) for each sector (e.g., transportation, construction, or finance) at both county and state levels. Nonetheless, efforts to identify the economic value at the corridor level are largely missing in the current literature.

3. IDENTIFICATION OF FREIGHT NETWORK IN MAASTO REGION

This section investigates the physical features of the road network in the MAASTO region and identifies a principal freight network along with its operational features such as truck volume distribution.

Firstly, we investigate the FAF4 network in the MAASTO region, which includes NHFN and other corridors as presented in Fig. 1(a). The total length of the FAF4 network in the MAASTO region is 110,844 miles with 11,932 miles (10.8%) of NHFN and 98,912 miles (89.2%) of non-NHFN corridors. The length by state is presented in Table 1. Fig. 1(c) presents the proportion of the road length for each state in the FAF4 network. The results show that the 10 states have similar proportions of road lengh in the FAF4 network ranging from 7.2% (Kentucky) to 12.3% (Illinois). In contrast, Fig. 1(b) presents NHFN in the MAASTO region, and Fig. 1(d) shows the proportion of road length in the NHFN by state. By comparing two pie charts in Fig. 1(c) and 1(d), we found that the distribution of NHFN across the 10 states is more disproportionate. Specifically, five states have larger proportions of NHFN than the FAF4 network (Illinois △6.8%, Ohio △3.8%, Indiana △2.5%, Michigan △0.4%, and Missouri △0.4%), but other five states have smaller proportions of NHFN (Minnesota ▽4.4%, Wisconsin ▽3.5%, Kansas ▽2.7%, Iowa ▽2.4%, and Kentucky ▽0.7%)[1].

TABLE 1 Length of FAF Network for Each Road Type

(Unit: mile)

STATE	Sum	IL	IN	IA	KS	KY	MI	MN	MO	OH	WI
Sum	110,844	13,596	8,454	10,206	11,167	8,006	11,516	13,308	10,826	11,420	12,347
NHFN	11,932	2,271	1,204	804	893	778	1,280	912	1,209	1,672	909
%	10.8	16.7	14.2	7.9	8.0	9.7	11.1	6.9	11.2	14.6	7.4
PHFS	8,834	1,686	971	549	740	616	630	547	1,023	1,418	654
%	8.0	12.4	11.5	5.4	6.6	7.7	5.5	4.1	9.5	12.4	5.3
non-PHFS	3,098	586	233	255	153	161	650	365	185	254	256
%	2.8	4.3	2.8	2.5	1.4	2.0	5.6	2.7	1.7	2.2	2.1
other	98,912	11,325	7,250	9,402	10,274	7,228	10,236	12,396	9,617	9,748	11,437
%	89.2	83.3	85.8	92.1	92.0	90.3	88.9	93.1	88.8	85.4	92.6

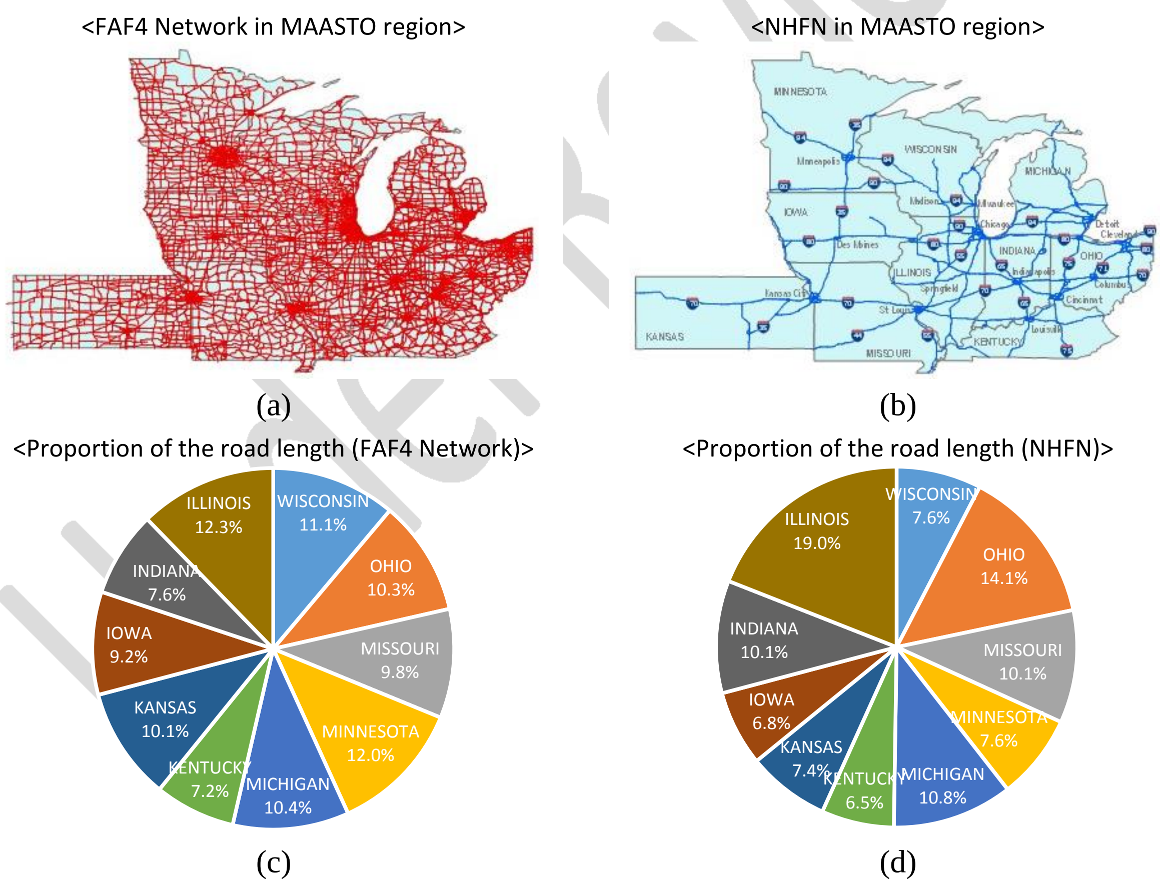


FIGURE 1. GIS Map of (a) FAF4 Network and (b) NHFN; Proportion of the Road Length for Each State in the MASSTO Region for (c) the FAF4 Network and (d) NHFN.

[1] Some numbers in manuscript may not match exactly to corresponding numbers in Figures due to rounding.

Fig. 2 shows the proportion of road length and truck volume by road type for each state. The first pie chart for each state presents the proportion of road length by road type. (Note that NHFN is divided into PHFS and non-PHFS as described in Section 2.1.) The second and third pie charts respectively show the distributions of all truck volumes and long-distance truck volumes. The figure shows that NHFN comprises a small proportion of the FAF4 network in terms of length, ranging from 6.9% (Minnesota) to 16.7% (Illinois). Yet, it carries the majority of truck volumes, particularly long-distance truck volumes. For example, in Illinois, 73% of all truck volumes and 94.6% of long-distrance truck volumes are distributed on NHFN.

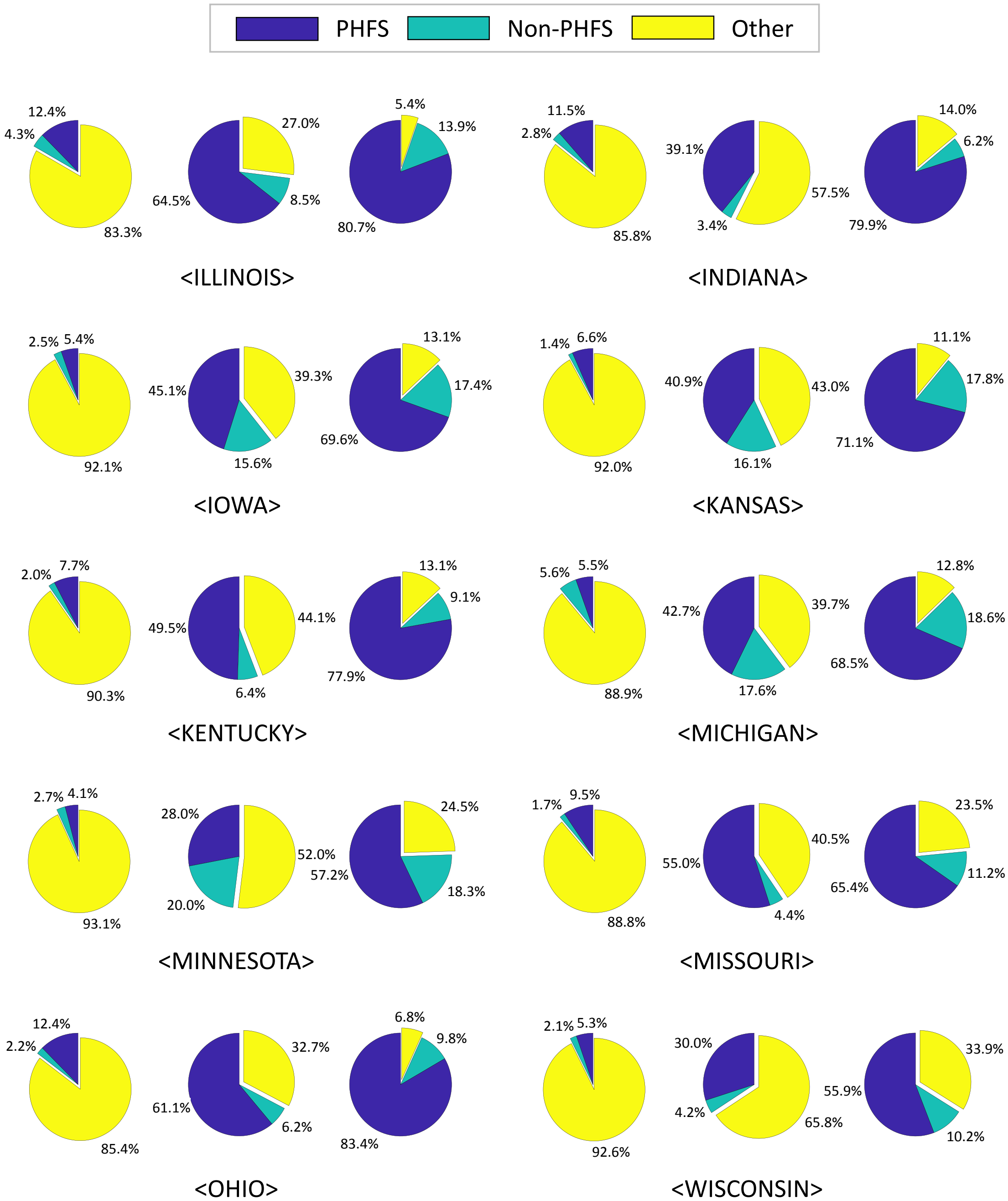
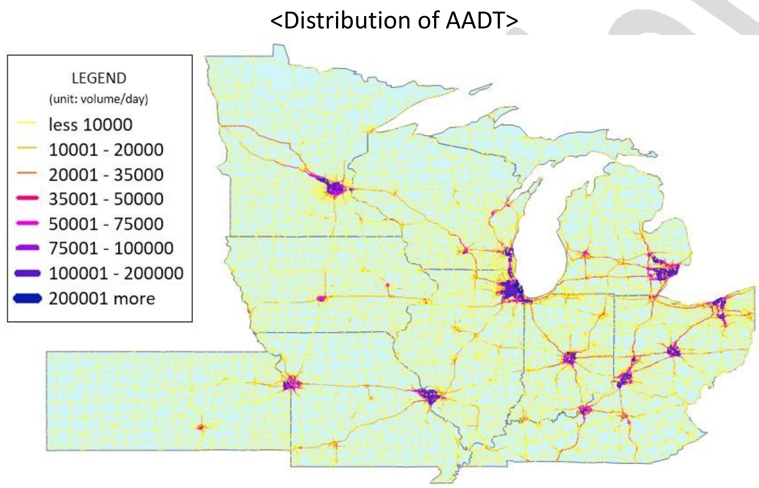
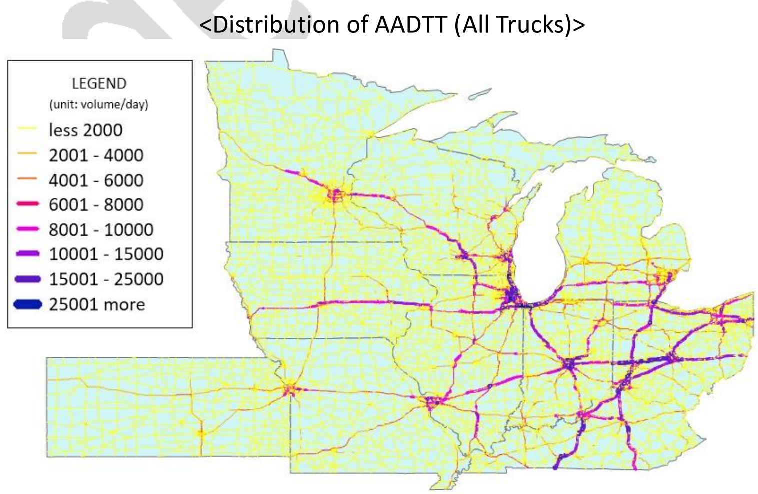


FIGURE 2. Proportion of Road Length, All Truck Volume, and Long-Distance Truck Volume by Road Type for Each State.

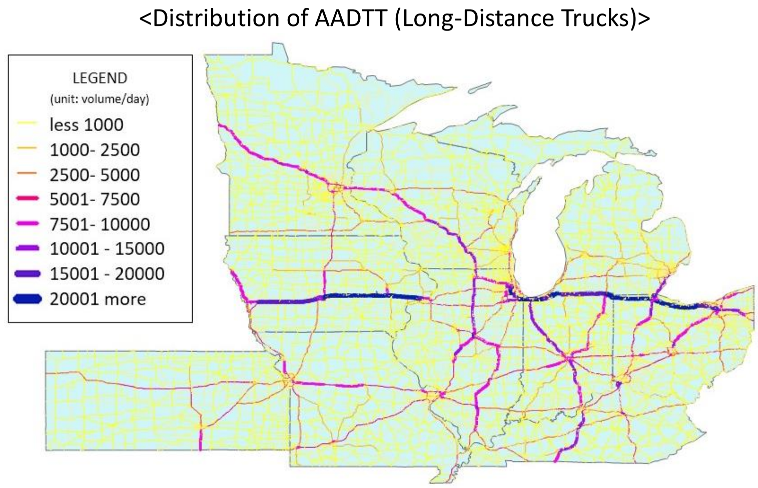
These features are also investigated through a GIS analysis. In the FAF4 network, average annual daily traffic (AADT) is quantified, including both passenger vehicles and trucks, for each road section, as presented in Fig. 3(a). As expected, the corridors near metropolitan areas (e.g., Minneapolis, Chicago, and Detroit) have large AADT values, and the distribution of AADT is not clearly related to NHFN. To see the distribution of truck volume, we quantify average annual daily truck traffic (AADTT) using all truck volumes for each road section as illustrated in Fig. 3(b). Unlike the distribution of AADT, the corridors with large truck volumes largely correspond to NHFN (Fig. 1(b)). Specifically, I-94 (in Minnesota, Wisconsin, Illinois, Indiana and Michigan), I-90 (in Minnesota, Wisconsin, Illinois, Indiana and Ohio), I-80 (in Iowa, Illinois, Indiana, and Ohio), I-70 (in Kansas, Missouri, Illinois, Indiana, and Ohio), I-75 (in Kentucky, Ohio and Michigan), I-65 (in Kentucky, Indiana) and I-55 (in Illinois) are all well-represented in Fig. 3(b). The similarity with NHFN is even more noticeable with the distribution of long-distance truck volumes in the FAF4 network as presented in Fig. 3(c). Thus, we can verify that NHFN accurately represents the major freight corridors and network in the MAASTO region.



(a)



(b)



(c)

FIGURE 3. NHFN and Truck Volume Distribution: (a) AADT; (b) AADTT (All Trucks); (c) AADTT (Long-Distance Trucks)

The length of Interstates on NHFN in the MAASTO region is presented in detail below. Fig. 4(a) shows the top ten longest corridors, and the sum of their length comprises nearly 60% of the total length. Note that some corridors have multiple road names in certain areas, and in this analysis, we identify the road name following the definition of FAF4 network (and the NHFN system, which is the same). Fig. 4(b)–4(f) show the top five longest corridors and the proportion in each state. The results show that most major corridors are multistate corridors.

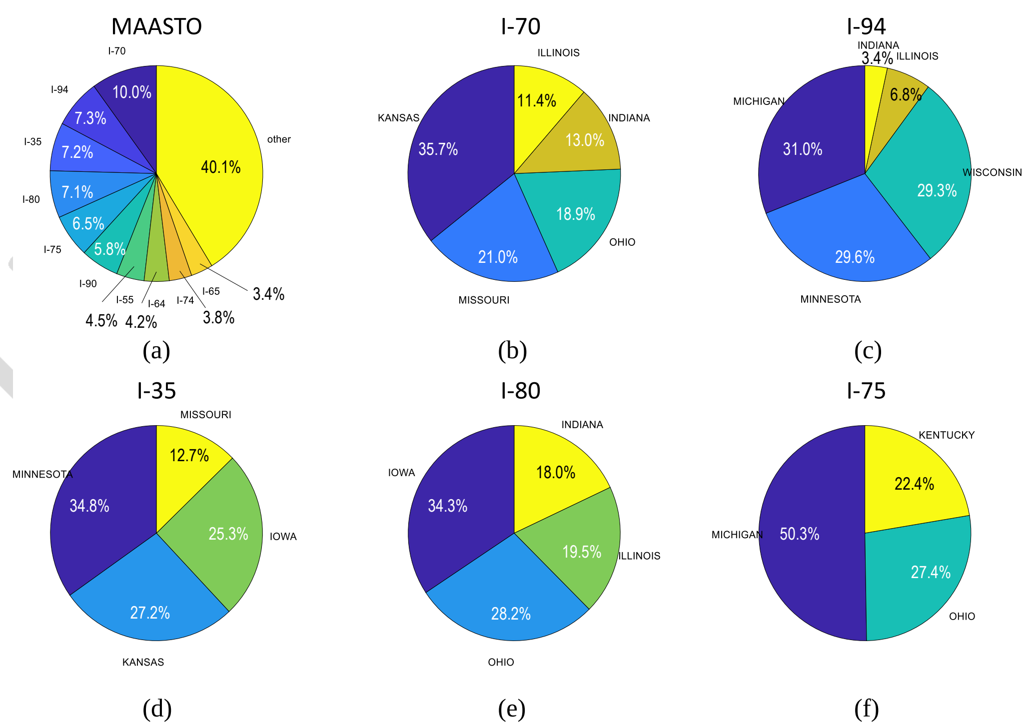


FIGURE 4. (a) The Top Ten Longest Corridors in MAASTO Region; (b)–(f) Proportion of States for the Top Five Longest Corridors.

4. ECONOMIC VALUE OF FREIGHT CORRIDOR

In the previous section, we verified that NHFN accurately represents the major freight corridors based on truck volume distribution and investigated the physical features of the corridors. Importantly, we found that the major freight corridors in the MAASTO region are multistate corridors. This underscores the need to look at freight corridors regionally and consider multistate collaboration on the investments and operations of economically important, multistate corridors. In this section, we propose a simple method to estimate the economic value for corridors and apply the method to freight corridors in the MAASTO region with a GIS analysis.

4.1 Method to Estimate Economic Value of Corridor

As stated in Section 2.2, FAF4 provides an aggregated origin-destination (OD) table of tonnage and value for each mode at a level of state or CFS zone. Thus, deriving a corridor value from large-scale FAF4 data directly is quite challenging. Thus, to estimate the economic value of a corridor, we assume that:

(i) The corridor value is propotional to the corridor's truck volume.
(ii) The value of each truck is propotional to the total value of freight in the travel area.

The first assumption simply indicates that a corridor with larger truck volumes has a higher value. The second assumption suggests that a freight truck has a higher value if it travels in an area with higher value. These assumptions are obviously not accurate as freight trucks traveling in the same area can have different values depending on its origin, destination, or commodity. However, these simplifying assumption are made due to the lack of disaggregate freight economic data beyond the level of state and major urban regions in the FAF4 dataset.

Since one corridor is composed of multiple road sections with different truck volumes, we first derive the road section value, as:

$$V_s^{i,k} = V_a \times \frac{q_s^{i,k}}{\sum_{i=1}^{I} \sum_{k=1}^{K^i} q_s^{i,k}} \qquad (1)$$

where, $V_s^{i,k}$ is the value for road section k (=1,… K^i) of corridor i, V_a is the total freight value of the area where corridor i extends, $q_s^{i,k}$ is the truck volume for road section k of corridor i, K^i is a number of road sections of corridor i (=1,… I), and I is the number of corridors in the area. Note that, for the case study in the MAASTO region, the area is defined as 29 CFS zones including metropolitan areas and the remainder of each state for consistency with FAF4 data. But, to derive more sophisticated results, disaggregating FAF data to smaller zones would be feasible using existing methods *(8, 9, 21, 22)*. We also define the total freight value of area, V_a, is the sum of all values from/to the area in FAF4 data, and use long-distance truck volumes since freight transportation in FAF4 is mostly long-distance travel rather than local activity. These road section values, $V_s^{i,k}$, are used for GIS analysis in the following subsection. To estimate the corridor value, the length of road sections within the corridor should be considered. Thus, we define the corridor total value (in dollar-miles) as:

$$V_c^i = \sum_{k=1}^{K^i} \left(V_s^{i,k} \times l_s^{i,k} \right) \qquad (2)$$

where, V_c^i is the total value of corridor i, and $l_s^{i,k}$ is the length of road section k in corridor i. Equation (2) shows that a corridor will have a relatively large value when (i) the length of the corridor is long, or (ii) the value of road sections is large. Thus, V_c^i presents physical (by $l_s^{i,k}$), operational (by $q_s^{i,k}$ in (1)), and area-specific economic (V_a in (1)) characteristics. We also derive the average value of corridor (in dollars) as:

$$\bar{V}_c^i = \frac{V_c^i}{\sum_{k=1}^{K^i} l_s^{i,k}} \qquad (3)$$

4.2 Economic Value of Freight Corridors in MAASTO Region

Using the method presented in the previous subsection, we estimate corridor values for NHFN in the MAASTO region. First, we derive the value of each road section on NHFN and then quantify the value in a GIS map as presented in Fig. 5. The result shows that I-94 (in Minnesota and Wisconsin) and I-80 (in Iowa, Illinois, Indiana, and Ohio) have relatively large values. Other major Interstates of east-west direction, I-90 (in Illinois, Indiana and Ohio) and I-70 (in Kansas, Missouri, Illinois, Indiana, and Ohio), and north-south direction, I-75 (in Kentucky, Ohio, and Michigan), I-65 (in Kentucky and Indiana) and I-55 (in Missouri and Illinois) also have large values.

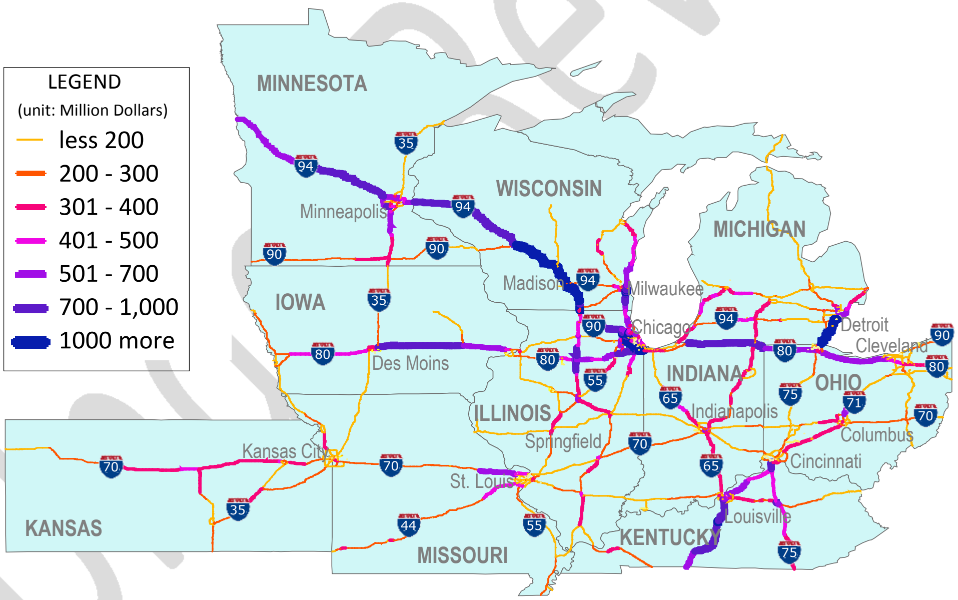


FIGURE 5. Distribution of Road Section Value in MAASTO Region.

The corridor values are investigated at the state and interstate levels in more detail. Fig. 6(a) shows the value of each state, which is the sum of the truck freight values from/to the state in the FAF4 data. The proportion of the total value in each state ranges from 5.7% (Kansas) to 20.2% (Illinois). We also investigate the value distribution as presented in Fig. 6(b)–6(k). The results show that the area value is distributed widely to multiple corridors in some corridors (e.g, Illinois or Indiana) or concentrated on several major corridors in others (e.g., Iowa, Kansas, Minnesota or Wisconsin).

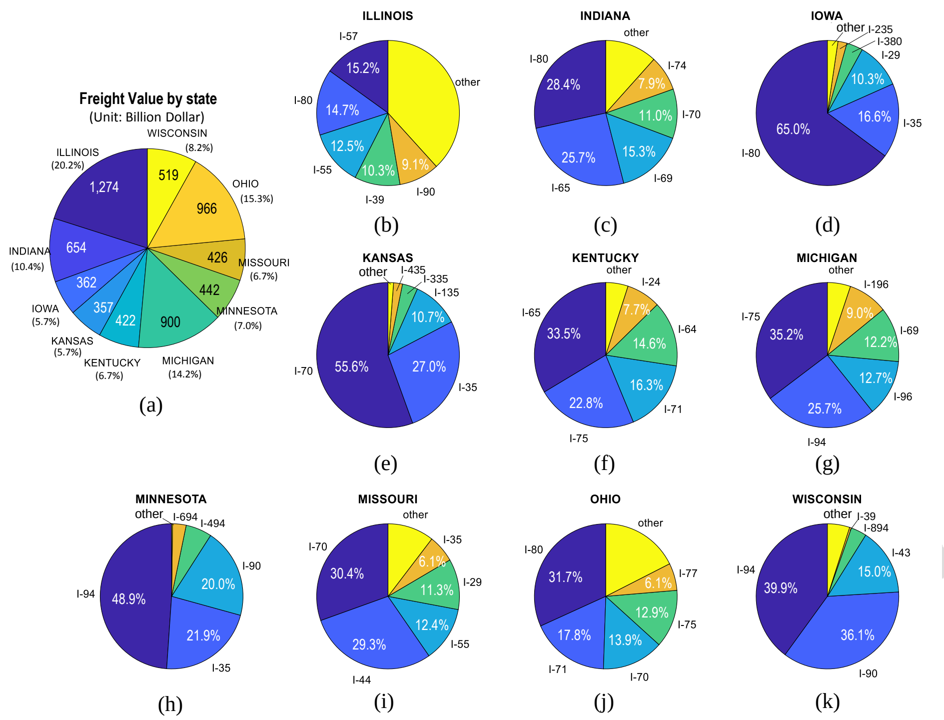


FIGURE 6. Corridor Values at the State Level, and Distributions for Major Freight Corridors.

This research also investigates the value distribution at the regional (spanning multiple states) level. Fig. 7(a) shows the value distribution in the MAASTO region for each Interstate. Similar to the result of the GIS analysis in Fig. 5, I-80, I-94, I-70, I-90 and I-75 have a large portion of the total value. Interestingly, the value distribution has a different order (and portion) comparing to the length distribution (see Fig. 4(a)). In Fig. 4(a), I-70 has the largest portion for length, but it is third highest in terms of corridor total value in Fig. 7(a). This indicates that I-70 is the longest corridor in the MAASTO region, but its overall value is relatively small compared to other major corridors. Note that the GIS analysis in Fig. 5 also shows that the value of I-70 is not as significant as the other Interstates in general. On the other hand, I-80 has 13.3% of the value (in Fig. 7(a)) though the length portion is only 7.1% (in Fig. 5(a)). The changes of proportions from the length to value for major corridors are presented as: increasing (I-80: △6.2%, I-94: △5.6%, I-90 △3.1%, I-65: △2.1%, and I-75: △0.1%) and decreasing (I-35: ▽1.7%, I-55: ▽1.3%, and I-70: ▽0.9%). In addition, the proportion of "other" corridors (except the top ten corridors) decrease from 40.1% (length) to 28.9% (value), which shows that the value of the major corridors is more significant than other corridors.

Fig. 7(b)–7(f) shows the proportion by state for major freight corridors. This distribution is also different when comparing the proportion of corridor length in Fig. 4(b)-4(f) since the corridor total value is affected by the total value of the area (e.g., CFS zone) and the truck volume as well as the corridor length. For example, the breakdown of the total value of I-80 is: Iowa (35.2%), Ohio (24.2%), Indiana (20.4%), and Illinois (20.3%) respectively. In comparison, the breakdown of the length is: Iowa (34.3%, ▽0.9%), Ohio (28.2%, △4.0%), Indiana (18.0%, ▽2.4%), and Illinois (19.5%, ▽0.8%). Thus, the derived corridor values provide a different perspective for the characteristics of corridors than physical (e.g., length) and operational (e.g., volume) features.

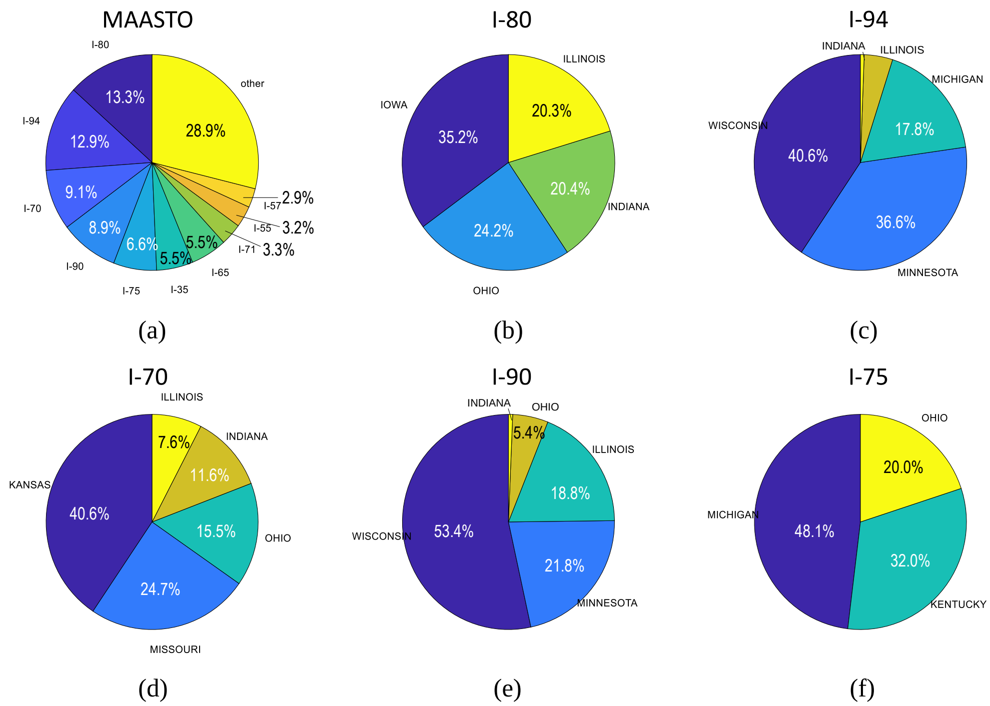


FIGURE 7. (a) The Top Ten Value Corridors in MAASTO Region; (b)–(f) Proportion of States for the Top Five Value Corridors.

Finally, Fig. 8 presents top 20 corridors in terms of the average value derived in equation (3). The corridors of large value in Fig. 7(a) are also presented in this result though the rankings are different (e.g., I-80: 1st → 3rd, I-94: 2nd → 5th, and I-70: 3rd → 17th). Fig. 9 shows the top seven corridors of average value for each state. These results include some corridors that have relatively short length, but large average corridor value. For example, the length of I-190, which extends near Chicago O'Hare airport in Illinois, is 1.8 miles, but it has the largest average corridor value of 1,065 million dollars. Thus, for prioritization of freight corridors, we should consider both "total value" and "average value" of corridors.

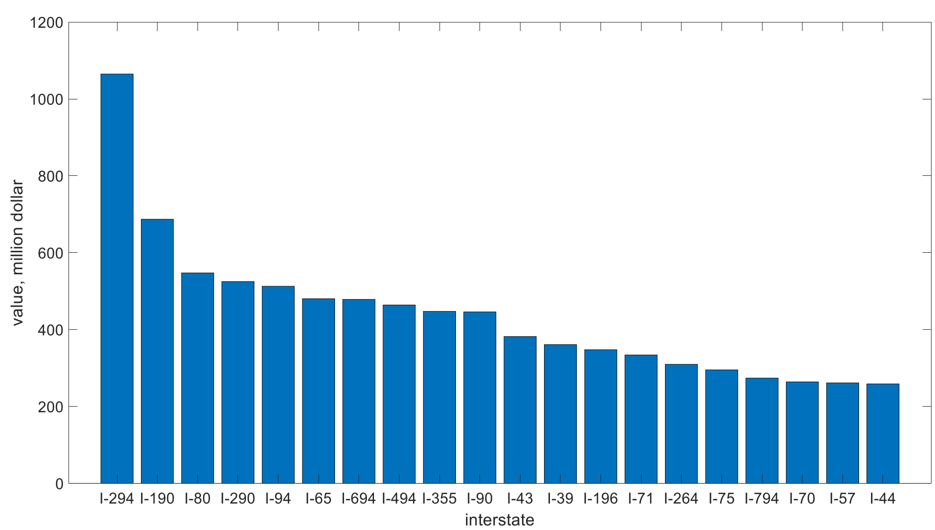


FIGURE 8. Top Twenty Corridors That Have Largest Average Corridor Value in MAASTO Region.

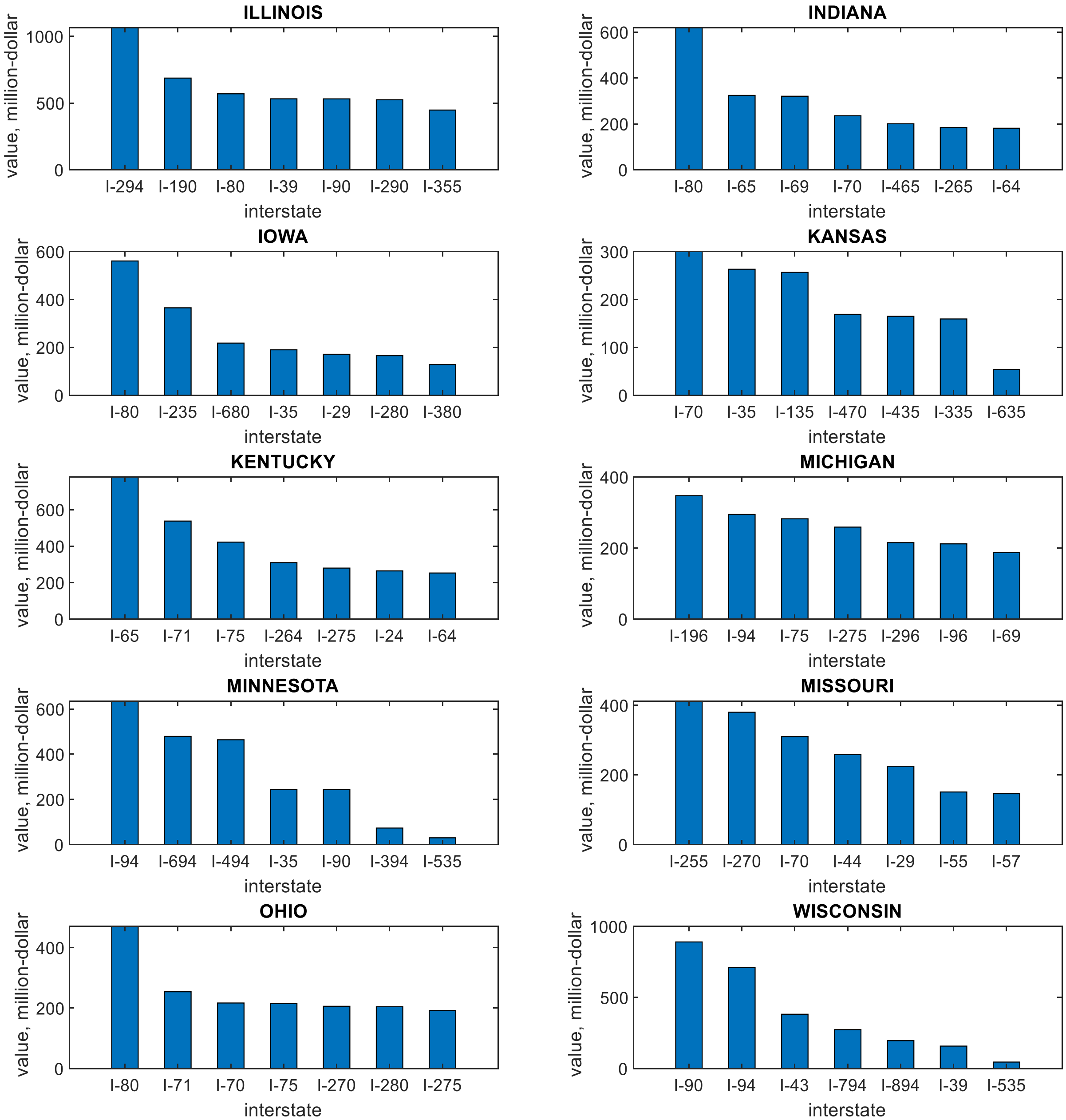


FIGURE 9. Top Seven Corridors That Have the Largest Average Corridor Value in Each State.

5. CONCLUSION

This research investigated the physical and operational features of corridors to verify and rank the freight network using the FAF4 data. The network in the MAASTO region was verified by the truck volume distribution (particularly the distribution of long-distance truck volume) using a GIS analysis. These results verified its close relationship with the freight network from NHFN. A simple yet effective method to estimate corridor value was proposed, and a statistical analysis in the MAASTO region was conducted as a case study. Results presented the principal corridors that have relatively large economic values for each state. The analysis for multi-state corridors also showed the relative values of states for each corridor. The corridor value accommodates physical and operational features of the corridors as well as characteristics of the areas where the corridors extend.

There are several issues that merit future research. To identify a major freight network, we used the truck volume distribution as a quantitative index for highway freight transportation. However, qualitive factors, such as connectivity to freight facilities or other modes, should be considered to complete the assessment of the multimodal freight transportation network. To estimate the corridor value, we assumed that the value of each truck is related to the total value of the travel area. However, some trucks may just pass through the area, and their values likely depend more on their origins and destinations. Thus, to derive more accurate corridor values, more information related to passing freight trucks should be considered.

Further, as our transportation regions have realized the importance of freight corridors and especially multistate corridors, this analysis is a step towards prioritization of multistate freight corridors. Based on this information, multistate corridors can be selected for regional projects or synchronized for state-by-state improvements. Indeed, freight knows no borders and the multistate approach can ensure efficiency in investments by departments of transportation and freight operations.

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AUTHOR CONTRIBUTION STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: Y. Han, E. Perry, S. Ahn; data collection: Y. Han, G.Vorhes; analysis and interpretation of results: Y. Han, E. Perry, S. Ahn; draft manuscript preparation: Y. Han, E. Perry, S. Ahn. All authors reviewed the results and approved the final version of the manuscript.

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