Transport Infrastructure Development Assessment Using a Multi-Regional Inoperability Input-Output Model

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Abstract: Traffic congestion in Metro Manila had been forecasted to cost Php 6 billion per day by 2030. In response, the city of Manila implemented a truck ban. It eventually cost the economy an estimate of Php 43.85 billion from the resulting port congestion. Numerous freight transport development plans were proposed shortly thereafter. However, due to limited resources, an optimum development roadmap is needed. Being exposed to the strongest typhoons, the transportation infrastructure's overall effect when operation disruptions occur (e.g. flooding) should also be considered. Thus, this paper proposes to include the resulting total economic losses caused by inoperability in the transportation sector in the assessment of freight transport development programs. The researches used an Inoperability Input-Output model to estimate losses as inoperability propagates across the economy. Two infrastructure development scenarios were assessed in this paper, resulting to approximately Php 122 million and Php 5 million, respectively, in economic loss savings.

Keywords: freight transport, multi-regional, inoperability; input-output; flooding

1.INTRODUCTION

Last February 2014, a truck ban was introduced in Manila, Philippines. The decision was based mostly on the perception that trucks contribute significantly to road congestion in Metro Manila. At that point, it was forecasted that traffic problems would escalate if adequate solutions were not implemented. From daily congestion costs of Php 2.4 billion reported in 2012, the Japan International Cooperation Agency (JICA) estimated an increase to Php 6 billion per day by 2030 (JICA, 1999). The truck ban, however, eventually cost the economy an estimate of Php 43.85 billion throughout its seven-month duration from the resulting port congestion (Philippine Institute for Development Studies, 2015).

Changes in truck operations had been implemented in the past as well, all in lieu of decongesting city roads. However, Figure 1 shows how the 1978 truck ban ultimately failed in achieving its intended purpose of decongesting city roads. As shown, there is a sudden increase in utility vehicle registration just before and after the truck ban. This shows that trucking companies effectively shifted to using smaller trucks not covered by the ban (Castro et al., 2003). In the end, trucking companies are rendered unable to take advantage of the economies of scale accorded by larger vehicles or the technology provided by detachable trailers and load consolidation. The truck ban resulted in an increase in both operational costs of trucking companies and volume of vehicles, thereby defeating the primary purpose of decongesting traffic. Other researchers have also noted how the truck ban may have negative impacts on retailer distribution costs (Quak & De Koster, 2007), travel time and emissions (Nakamura et al., 2008), and congestion and kilometers traveled (Lyons et al., 2017).

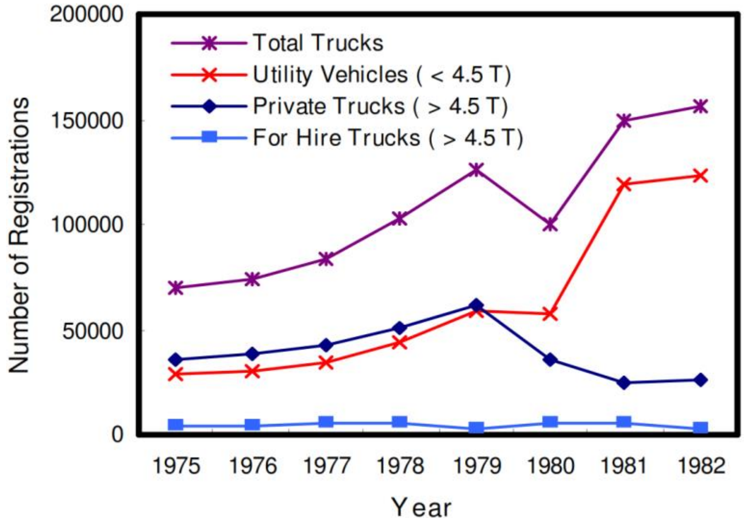


Figure 1. Truck Type Distribution (Castro et al., 2003)

On a positive note, the latest truck ban stirred up activity at the underutilized Subic and Batangas ports, shown as points A and B, respectively in Figure 2. This happened as shippers looked for a way to ship their cargoes without going through the Manila port (Almonte, 2014). Payumo (2014) discussed how these nearby ports are similar to Laem Chambang port in Thailand that was built primarily to decongest the Bangkok river port. He suggested that the Bangkok-Laem Chambang ports can be used as a baseline model, where Manila port can be limited to handling 1 million 20-foot equivalent units (TEUs), and the rest be diverted to Subic and Batangas ports. To do this, however, accessibility of both Subic and Batangas ports should be improved. If those other ports can be made more attractive, freight traffic going to and from Manila port can be seamlessly diverted. Compared to Manila port's 2014 throughput of 3.7 million TEUs ("Good results", 2015), capping it to just 1 million TEUs can certainly alleviate the traffic congestion in Metro Manila attributed to trucks.

Figure 2. Locations of Subic and Batangas Ports
Source: Google Images

Currently, the only way to connect the Subic and Batangas ports is to pass through the National Capital Region (NCR). To bypass any delay incurred due to traffic congestion in the metropolis, the North Luzon Expressway (NLEX) and South Luzon Expressway (SLEX) is currently being connected as shown in Figure 3. The network involves Metro Manila Skyway Stage 3 (MMSS-3), a 14.8-km elevated expressway from Buendia in Makati City to Balintawak in Quezon City. The NLEX-SLEX Connector Road Project (NSCRP), on the other hand, is an 8-km highway extending the NLEX southward from the end at C3 Road in Caloocan City to Sta. Mesa connecting to the common alignment of MMSS-3. These are expected to finish by 2018 and 2022, respectively.

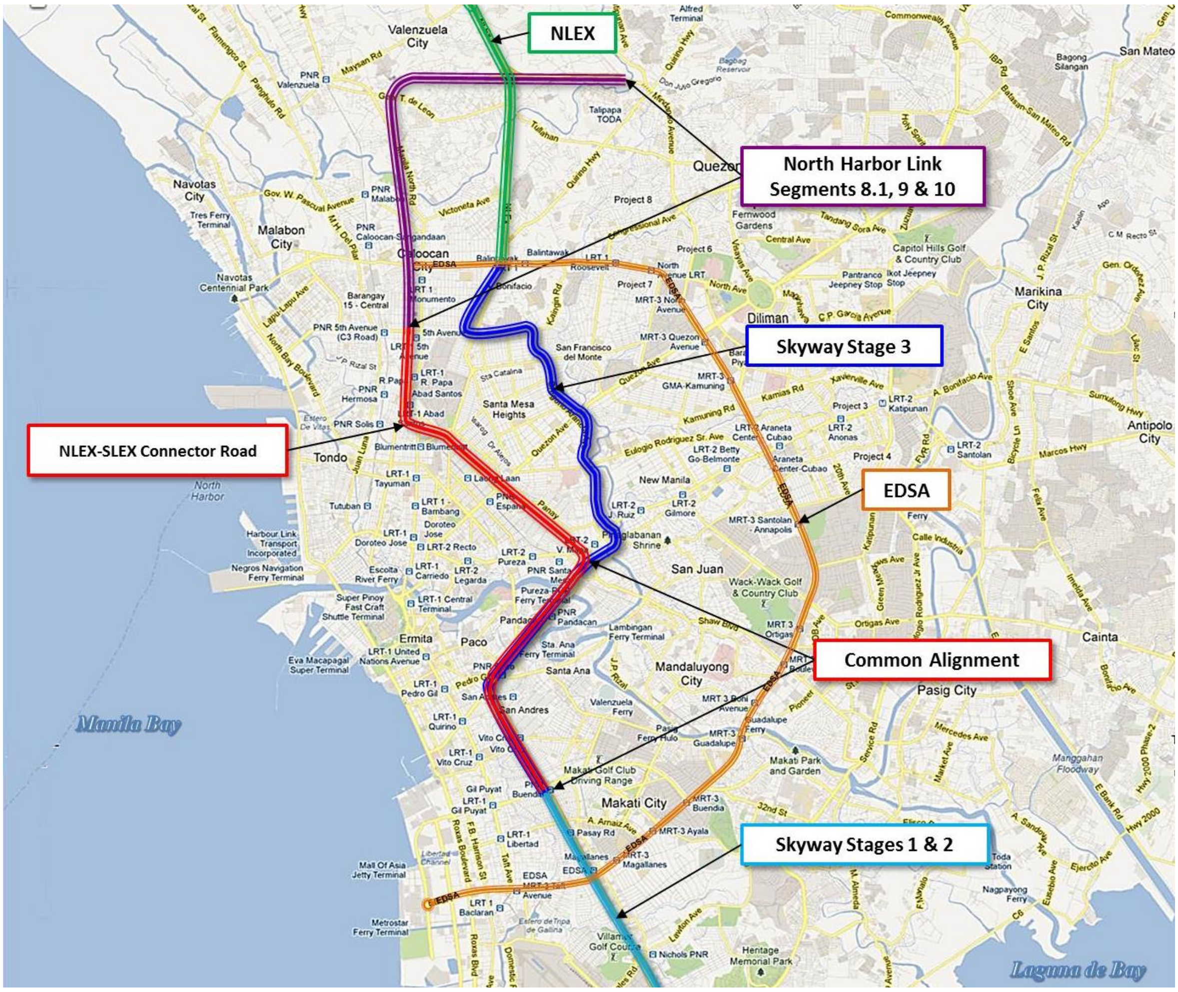


Figure 3. NLEX-SLEX Connection Projects
Source: DPWH

In addition to these, there are other development options by which freight operations can be improved. However, due to limited resources, there is a need to define an optimum development roadmap that not only facilitates economic growth, but also addresses the vulnerabilities of freight operations. With the Philippines being at the forefront of the strongest typhoons as shown in Figure 4, the transportation infrastructure's overall effect throughout the economy when operation disruptions occur due to natural disasters (e.g. flooding) should also be considered. Thus, this paper proposes to include the resulting total economic losses caused by inoperability in the transportation sector in the assessment of different freight transport infrastructure development scenarios.

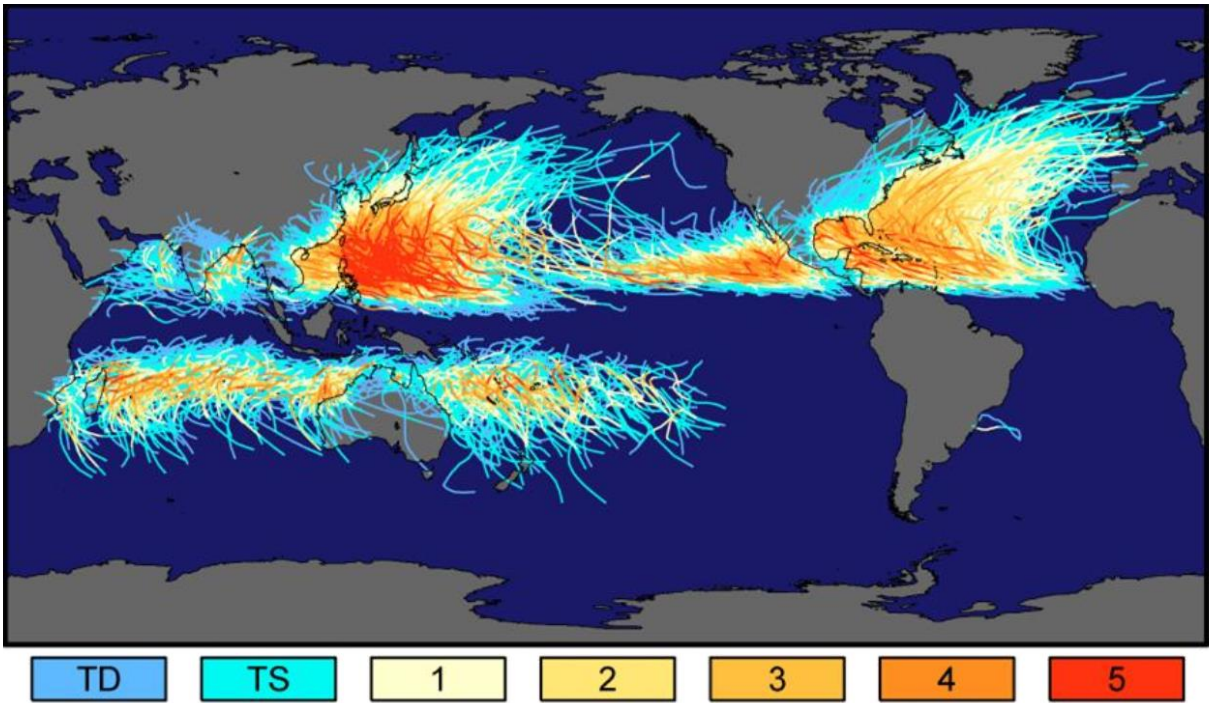


Figure 4. Tracks and Intensity of all Tropical Storms
Source: earthobservatory.nasa.gov

2.INPUT-OUTPUT MODEL

This paper makes use of the Input-Output (IO) framework in quantifying the total economic loss from operation disruption in one sector. The Leontief IO Model provides a view of the interaction between different sectors of the economy, with the goal of estimating the input requirement for each type of goods or service (Leontief, 1936; Miller & Blair, 2009). The rationale is that the output of any industry is needed as an input in many other industries, or even for that industry itself. Therefore, the "correct" (i.e. shortage- and surplus-free) level of output from any industry must be one that is consistent with all the input requirements in the economy, so that no bottlenecks will arise anywhere. The IO model assumes that (1) each industry produces only one homogenous commodity; (2) each industry uses a fixed input ratio for the production of its output; and (3) production in every industry is subject to constant return to scale, in effect that a k-fold change in every input will result in an exactly k-fold change in the output.

In order to produce each unit of the *j*th commodity, the input need for the *i*th commodity must be a fixed amount, which can be denoted as a_{ij}. Specifically, the production of each unit of the *j*th commodity requires a_{1j} of the first commodity, a_{2j} of the second, …, and a_{nj} of the *n*th commodity. This system constitutes the requirements for the economy to function and meet the production demand. However, each sector's output is ultimately produced with a goal to satisfy consumers' demand. Hence, a sector's total output is the sum of intermediate demand and final demand, as shown in the following:

$$x_1 = a_{11}x_1 + a_{12}x_2 + ... + a_{1n}x_n + f_1 \quad (1)$$

where,

x_1 : the total production output needed from industry 1,

f_1 : denotes the final demand for its output, and

$a_{1j}x_j$: the input demand of the *j*th industry.

Thus, for the entire economy, the system can be written as a matrix equation as follows:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f} \tag{2}$$

where,

x : the total output matrix,
A : the technical coefficient matrix, and
f : the final demand vector,

with n x 1, n x n, and n x 1 dimensions, respectively, where n stands for the number of sectors. The product, **AX**, represents the portion of the total production used for internal consumption. Given the final demand, **f**, the total production matrix x can be computed from:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{f} = \mathbf{L}\,\mathbf{f} \tag{3}$$

where,

L : Leontief inverse or the total requirements matrix.

This captures the multiplier effect that ripples throughout the different sectors. This equation gives the production output needed from every sector to satisfy both the demands from internal and consumer utilization.

With matrix **A** consisting of elements a_{ij}, denoting input requirements of sector j from sector i, normalized with respect to the total input requirement of sector j, the model encapsulates the interdependence of different economic sectors. Furthermore, following the linear relationship of matrix equations, the model allows for the analysis of changes in final demands due to external causes, and its system-wide effects on the interconnected network of the economy. This characteristic, used to calculate the effects of a change in demand for a certain type of commodity to the entire system, is shown in the following equation:

$$\Delta x = \mathbf{L}\,\Delta f \tag{4}$$

One extension of the IO models focuses on the spread of operability degradation in a networked infrastructure system (Haimes and Jiang, 2001). It can be used to focus on the contraction of final demand as a consequence of an exogenous shock, which propagates throughout the production of interdependent economic infrastructures (Santos and Haimes, 2004). This extension of the IO model is called the inoperability input-output model (IIM), where a change in production can be taken as the difference between the planned production and the degraded production, and a change in demand can be taken as the difference between the planned final demand and the degraded final demand.

The inability (as a percentage) of a certain infrastructure to produce and meet the final demand is referred to as inoperability. This is expressed as a ratio with which a sector's production is degraded relative to some ideal or "as-planned" production level (Santos, n.d.). For example, when a sector with an ideal production output of 100 units is hit by a natural disaster, reducing its production to 90 units, the production loss of 10 units, which is 10% of the ideal production output, translates to a sector inoperability value of 0.10. Values range from 0 to 1, where 0 represents a fully functioning system and 1 corresponds to a system with total failure (Tan et al., 2014). The inoperability input-output model has a similar structure to the Leontief IO model, as shown in the following equations,

$$\mathbf{q} = \mathbf{A}^*\mathbf{q} + \mathbf{c}^* \quad (5)$$

$$\mathbf{q} = (\mathbf{I} - \mathbf{A}^*)^{-1}\, \mathbf{c}^* \quad (6)$$

$$\mathbf{A}^* = \hat{\mathbf{x}}^{-1} * (\mathbf{A} * \hat{\mathbf{x}}) \quad (7)$$

where,

$\mathbf{q}$	: sector inoperability,
$\mathbf{c}^*$	: initial perturbation, and
$\mathbf{A}^*$	: the interdependency matrix.

$\mathbf{A}^*$ is a transformation of the Leontief technical coefficient matrix $\mathbf{A}$, which tells how much additional inoperability is contributed by a column sector to the row sector. The demand perturbation, $\mathbf{c}^*$, is a vector comprised of the final demand disruptions to each sector, consisting of elements also normalized between 0 and 1. Finally, economic loss is then computed as the product of inoperability and total output of each sector, as shown in the following equation

$$\mathrm{EL_i} = \mathrm{q_i} * \mathrm{x_i} \quad (8)$$

where,

EL_i	: economic loss estimate for sector i,
q_i	: sector inoperability, and
x_i	: the total output of sector i.

3.MULTI-REGIONAL INOPERABILITY INPUT-OUTPUT MODEL

The 2000 IO Account of the Philippines (National Statistical Coordination Board, 2006) was used in this study as the latest published 2006 IO Account of the Philippines contains some questionable elements in the IO tables (e.g. Construction industry having zero input to all other sectors). Despite containing data from almost two decades ago, its use still has merit, as shown in Magtibay-Ramos et al. (2010) where both forward and backward linkages between different Philippine economic sectors did not significantly change from 1979 to 2000. Nonetheless, the 2000 IO tables were recalibrated using 2015 GDP values to come up with more realistic estimates.

The published IO tables were disaggregated into 11, 60 and 240 sectors. As this paper focuses on the economic loss from an initial perturbation specifically in the road freight sector, the 240-sector table was used. However, researchers can also tailor the IO table to a certain dimension depending on the focus of their study. Thus, other subsectors not of much importance were aggregated. Table 1 shows the final aggregation re-specification of the IO table used in this study, where transportation sectors were kept disaggregated. Table 2, on the other hand, shows the final regional disaggregation. The regions part of the Greater Capital Region (NCR, Region 3, and Region4-A) were kept disaggregated while the rest are aggregated by island group.

Table 1 Disaggregation of Sectors

Sector	Description
1	Agriculture, Fishery and Forestry
2	Mining and Quarrying
3	Manufacturing
4	Construction
5	Electricity, Gas and Water
6	Bus line operation
7	Jeepney and other land transport services
8	Railway transport
9	Public utility cars and taxicab operation
10	Tourist buses and cars including chartered and rent-a-car
11	Road freight transport
12	Water Transport
13	Air Transport
14	Communications and Storage
15	Trade
16	Finance
17	Real Estate and Ownership of Dwellings
18	Private Services
19	Government Services

Table 2 Regional Disaggregation

Region	Description
1	NCR
2	Region 3
3	Region 4-A
4	Region 5
5	Rest of Luzon
6	Visayas
7	Mindanao

The 2000 IO Account of the Philippines contains values for the entire country. However, the rate of participation across different regions is not homogenous. Thus, the IO table should be further disaggregated with respect to regions to allow the appropriate introduction of the initial perturbation. To do this, non-survey techniques in regionalization of national coefficients (Miller & Blair, 2009) were employed, specifically, the two-region logic with more than two regions approach. First, location quotients were calculated as follows

$$LQ_i^r = \left(\frac{x_i^r/x^r}{x_i^n/x^n}\right) \tag{9}$$

where,

LQ_i^r : location quotient of sector *i* in region *r*,
x_i^r : gross output of sector *i* in region *r,*
x^r : total output of all sectors in region *r*,
x_i^n : gross output of sector *i,* and
x^n : total output of all sectors at the national level.

The intra-regional coefficients are then calculated as follows

$$a_{ij}^{rr} = \begin{cases} (LQ_i^r)a_{ij}^n & \text{if } LQ_i^r < 1 \\ a_{ij}^n & \text{if } LQ_i^r \geq 1 \end{cases} \quad (10)$$

where,

a_{ij}^{rr} : input coefficient of sector *i* to sector *j* in region *r,* and
a_{ij}^{n} : input coefficient of sector *i* to sector *j* at the national level

The off-diagonal coefficients are then calculated as follows

$$a_{ij}^{\tilde{r}r} = a_{ij}^{n} - a_{ij}^{rr} \quad (11)$$

$$a_{ij}^{r\tilde{r}} = a_{ij}^{n} - a_{ij}^{\tilde{r}\tilde{r}} \quad (12)$$

where,

$a_{ij}^{\tilde{r}r}$: import coefficient from the rest of the economy to region *r,* and
$a_{ij}^{r\tilde{r}}$: import coefficient from region *r* to the rest of the economy

The coefficients are then converted to flows shown as follows

$$\begin{bmatrix} \boldsymbol{A}^{rr} & \boldsymbol{A}^{r\tilde{r}} \\ \boldsymbol{A}^{\tilde{r}r} & \boldsymbol{A}^{\tilde{r}\tilde{r}} \end{bmatrix} \begin{bmatrix} \hat{x}^{r} & 0 \\ 0 & \hat{x}^{\tilde{r}} \end{bmatrix} = \begin{bmatrix} \boldsymbol{Z}^{rr} & \boldsymbol{Z}^{r\tilde{r}} \\ \boldsymbol{Z}^{\tilde{r}r} & \boldsymbol{Z}^{\tilde{r}\tilde{r}} \end{bmatrix} \quad (13)$$

These are calculated for every region *r*, to produce the following summary.

Table 3 Summary of Two-Region Logic with More than Two Regions Approach

$\boldsymbol{Z}^{11}$							$\boldsymbol{Z}^{1\tilde{1}}$
	$\boldsymbol{Z}^{22}$						$\boldsymbol{Z}^{2\tilde{2}}$
		$\boldsymbol{Z}^{33}$					$\boldsymbol{Z}^{3\tilde{3}}$
			$\boldsymbol{Z}^{44}$				$\boldsymbol{Z}^{4\tilde{4}}$
				$\boldsymbol{Z}^{55}$			$\boldsymbol{Z}^{5\tilde{5}}$
					$\boldsymbol{Z}^{66}$		$\boldsymbol{Z}^{6\tilde{6}}$
						$\boldsymbol{Z}^{77}$	$\boldsymbol{Z}^{7\tilde{7}}$
$\boldsymbol{Z}^{\tilde{1}1}$	$\boldsymbol{Z}^{\tilde{2}2}$	$\boldsymbol{Z}^{\tilde{3}3}$	$\boldsymbol{Z}^{\tilde{4}4}$	$\boldsymbol{Z}^{\tilde{5}5}$	$\boldsymbol{Z}^{\tilde{6}6}$	$\boldsymbol{Z}^{\tilde{7}7}$	

According to Miller & Blair (2009), the off-diagonal flow matrices can be assumed to come equally from all other regions (e.g. $Z^{21} = Z^{31} = Z^{41} = Z^{51} = Z^{61} = Z^{71} = (1/6)\boldsymbol{Z}^{\tilde{1}1}$). For this paper, however, the distribution of import flows was based on regional GDP weights. The resulting table was then balanced through the RAS procedure, an iterative process to update matrices, using the GAMS software. Balanced flow values were then divided by sector total inputs to get the final technical coefficient matrix **A**, with an IO structure shown in Table 4. The interdependence matrix **A*** is then calculated using equation (7).

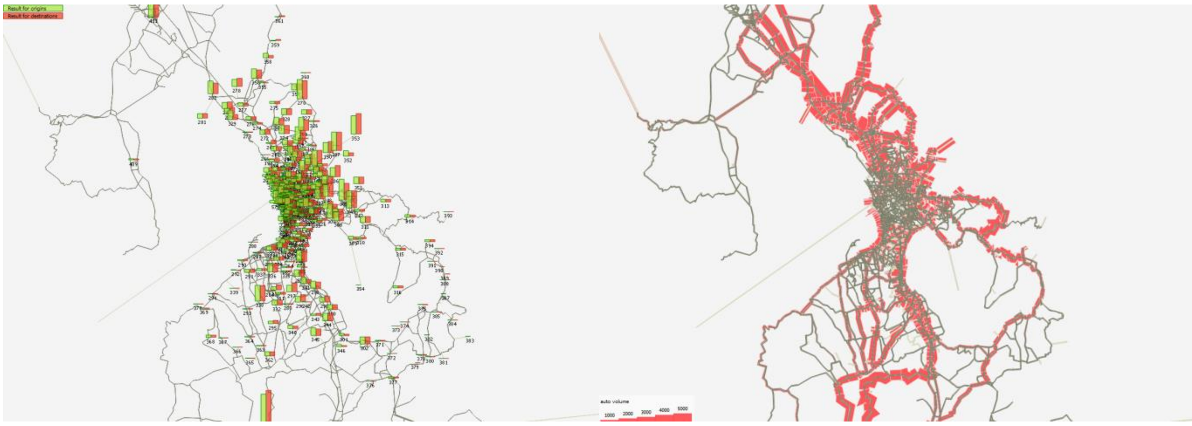
Table 4 Multi-Regional IO Table Structure

MRIO	Region	NCR				Region 3				…	Mindanao			
Region	Sector	1	2	…	19	1	2	…	19	…	1	2	…	19
NCR	1													
	2													
	⋮													
	19													
Region 3	1													
	2													
	⋮													
	19													
⋮	⋮													
Mindanao	1													
	2													
	⋮													
	19													

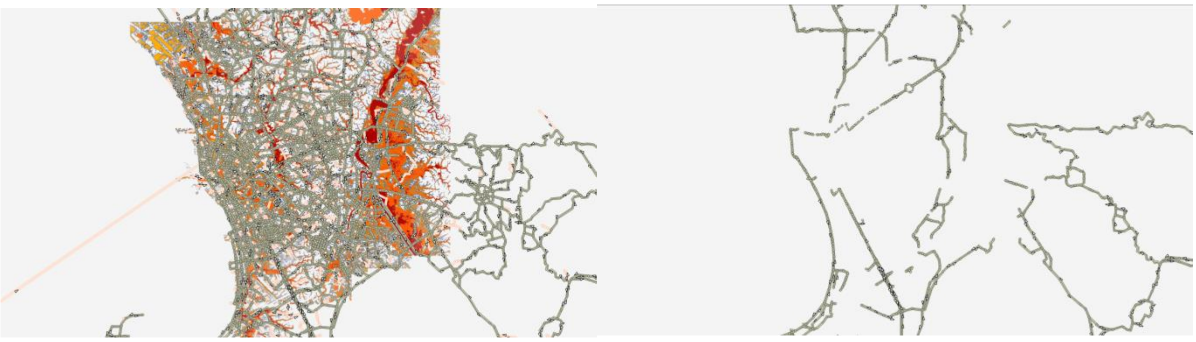
4.TRANSPORTATION MODELING

This paper uses the truck origin-destination matrix from the Metro Manila Urban Transportation Integration Study Update and Capacity Enhancement Project (MUCEP). Standard traffic assignment was performed to establish base conditions. For the flooded condition, the transport network was mounted onto a five-year flood hazard map and the flooded links (positioned in orange- and red-colored areas, corresponding to 0.5m – 1.5m and over 1m flood heights, respectively) were identified and coded accordingly. Traffic assignment was performed again to show operation disruption when flooding is introduced into the network. For this study, the operation disruption was modeled as a 24-hour flood. Thus, the characteristics of the modeled flooded condition was assumed to hold throughout the day. Considering that the flood scenario modeled (flood height of over 0.5m) is the kind that persists throughout the day, the authors find this a sound assumption.

Transport modeling was performed on three scenarios: (1) Present condition; (2) with MMSS-3; and (3) with NSCRP. The traffic characteristics of both non-flooded and flooded conditions, and the corresponding operation degradation in the latter, are shown in Table 5. From this, it can be seen that there is a significant reduction in assigned trips when comparing the non-flooded and flooded conditions. There is also a reduction in vehicle distance traveled (VDT) and vehicle hours traveled (VHT). However, there is an increase in the average speeds. This means that under the flooded condition, trips that were made impossible due to unavailability of possible routes resulted to less congested passable roads, hence, the higher average speeds. Consequently, the reductions in VDT and VHT cover the decrease from trips not made and the increase from using longer available routes. For this paper, despite incurring losses from delays as well, the values for the initial perturbation, c^*, will be limited to the ratio of trips not assigned due to flooding.



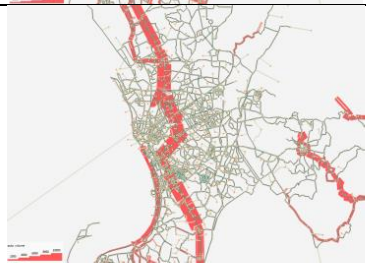
A) Truck O-D B) Standard Truck Traffic Assignment



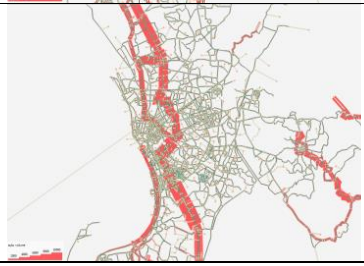
C) Mounted on five-year Flood Hazard Map D) Non-flooded Road Network

Figure 5. Truck Traffic Modeling

Table 5 Transport Modeling Results

Scenario	Modeling Result							Operation Degradation	
	Condition	Traffic Assignment	Region	Ave. Spd [kph]	VDT [km]	VHT [hr]	Assigned Trips	Region	c*
1) Present	Without Flood		NCR	14.42	2,558,328	177,365	54,308	NCR	0.738
			REG3	8.96	3,693,876	412,303	61,118	REG3	0.381
			REG4A	11.91	3,770,728	316,568	68,892	REG4A	0.542
	With Flood		NCR	27.22	449,563	16,514	14,226		
			REG3	18.26	1,406,231	77,011	37,842		
			REG4A	10.99	1,801,791	163,884	31,580		
2) W/ MMSS-3	Without Flood		NCR	20.73	2,553,708	123,174	54,308	NCR	0.587
			REG3	10.79	3,610,118	334,447	61,118	REG3	0.099
			REG4A	13.34	3,741,311	280,372	68,892	REG4A	0.390
	With Flood		NCR	20.82	1,262,811	60,660	22,443		
			REG3	6.05	3,753,886	620,948	55,090		
			REG4A	6.87	3,457,010	503,429	42,058		

cont. Table 5. Transport Modeling Results

3) W/ NSCRP	Without Flood		NCR	20.96	2,368,757	113,035	54,308	NCR	0.577
			REG3	10.34	3,646,622	352,632	61,118		
			REG4A	13.37	3,743,093	280,021	68,892	REG3	0.096
	With Flood		NCR	21.73	1,348,973	62,084	22,919		
			REG3	8.18	3,791,327	463,595	55,265	REG4A	0.388
			REG4A	7.25	3,570,743	492,286	42,152		

5.INOPERABILITY AND ECONOMIC LOSS

Estimation of economic loss starts from the introduction of the initial perturbation. In this paper, the c* matrix contains the percentage reduction in assigned trips. Using this quantity, however, does not account for the apparent losses coming from delays incurred in those assigned trips. Also, this does not cover the compounding effects of the kind of flood modeled in this study, which usually persists over a couple of days. Thus, the authors would like to note that the use of such values would result to an under-estimation. Table 6 shows the initial perturbation in the road freight sectors in various regions and its corresponding row numbers in the MRIIM table. Figure 6, on the other hand, shows a sample of the resulting spread of inoperability, q, across the economy.

Table 6 Initial Perturbation in Road Freight Sectors

Scenario	Region	Description	c*	Row
Present	1	NCR	0.738	11
	2	Region 3	0.381	30
	3	Region 4-A	0.542	49
W/ MMSS-1	1	NCR	0.587	11
	2	Region 3	0.099	30
	3	Region 4-A	0.390	49
W/ NSCRP	1	NCR	0.578	11
	2	Region 3	0.096	30
	3	Region 4-A	0.388	49

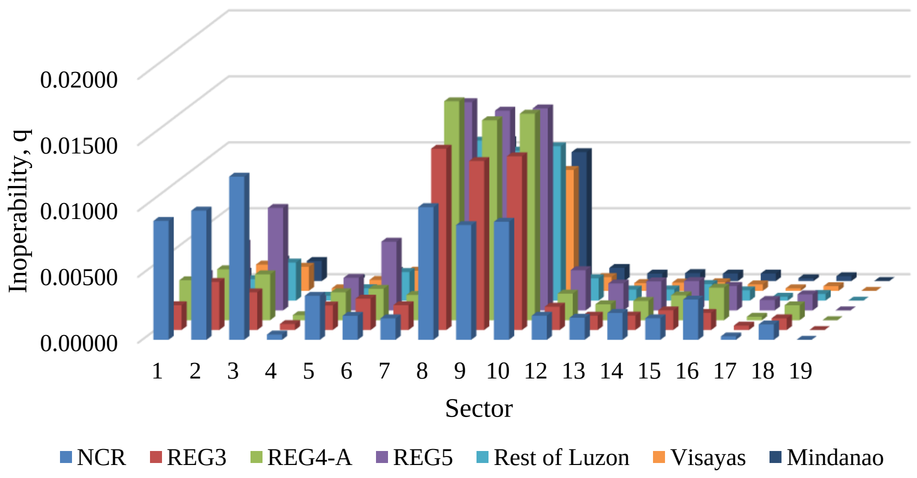


Figure 6 Spread of Inoperability, q (Base Scenario)

As shown in Figure 6, there is, indeed, an effect on other sectors when one sector (in this case, road freight sector) incurs operation disruptions. This shows the interdependence of the different sectors of the economy. The introduction of inoperability in the road freight sector resulted to a spread of inoperability across the economy. Based on the inoperability metric, the top 5 most affected sectors are the following: (1) Railway transport, (2) Tourist buses and cars including chartered and rent-a-car, (3) Public utility cars and taxicab operation, (4) Manufacturing, and (5) Mining and Quarrying. From this, the interdependence between subsectors in the transportation sector is highly emphasized.

It is also meaningful to express the resulting impact in terms of monetary values.

These may result to a separate set of most affected sectors. To estimate the economic loss, inoperability values are multiplied with the average daily ideal production output (total output divided by 360 days) of each respective sector, where the product can be taken as a loss in terms of production output. For this paper, the total output values used were that of the year 2015. Tables 7, 8, and 9 show the estimated economic loss in each sector within each region for the three development scenarios, respectively, calculated using equation (8). Figure 7, on the other hand, shows a sample of the corresponding economic losses as inoperability spread across the economy.

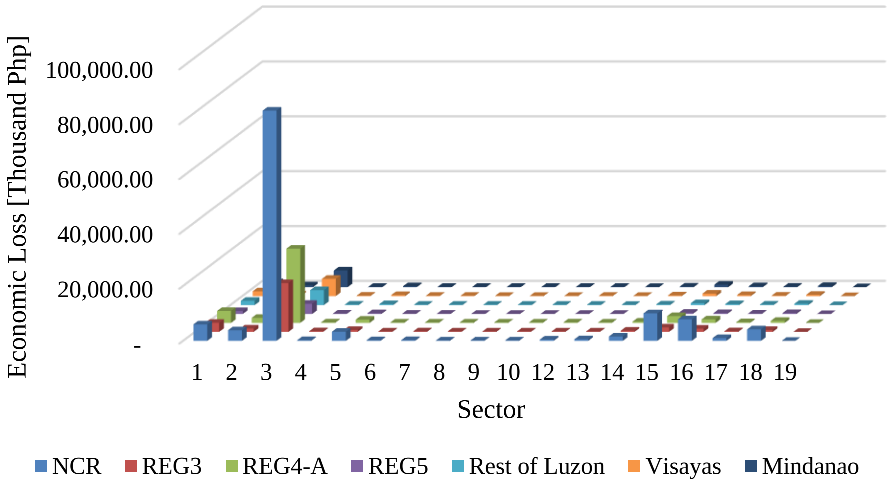


Figure 7 Economic Loss (Present) [Thousand Php]

Comparing Figures 6 and 7, the set of most affected sectors are shown to be not necessarily the same when basing on different metrics. As shown in Figure 6, sectors 2, 3, 8, 9, and 10 were found to be significantly impacted in terms of inoperability. However, when looking at the computed economic losses shown in Figure 7, sectors 1, 2, 3, 15, and 16 appear to be those that were most significantly affected. This shows that higher inoperability values do not directly translate to bigger economic losses. As shown in Tables 7, 8, and 9, the top 5 most affected sectors are the following: (1) Manufacturing, (2) Trade, (3) Finance, (4) Agriculture, and (5) Private Services for NCR and Mining and Quarrying for Region 4-A, Region 5, Rest of Luzon, Visayas, and Mindanao.

Table 10 shows a summary of the total economic losses for each sector for the three development scenarios while Table 11 shows the overall economic loss under each modeling scenario and its respective savings and project cost. As shown in the latter, operation disruption in the road freight sector due to flooding costs the economy over Php 458 million. However, under the scenario with MMSS-3, the impact is dampened as the unassigned trip are lessened, and thus, decreasing the estimated economic loss to approximately Php 336 million. Construction of the NSCRP would further decrease the estimated economic loss to a little over Php 331 million.

These translate to a corresponding value of savings in the form of economic loss avoided. The MMSS-3 and NSCRP result to approximately Php 122 million and Php 5 million, respectively. However, looking at the project costs of Php 26.5 billion and Php 15.74 billion, with the corresponding savings-to-cost ratios of 0.00462 and 0.00030, respectively, the two projects do not seem to have the same viability.

Table 7 Economic Loss (Present) [Thousand Php]

Sector	Description	NCR	REG3	REG4-A	REG5	R.o.Luzon	Visayas	Mindanao	Subtotal
1	Agriculture, Fishery and Forestry	5,991.55	3,329.45	4,368.49	1,083.97	1,556.52	1,744.24	1,793.54	19,867.76
2	Mining and Quarrying	3,859.19	1,226.41	1,856.21	384.72	574.87	626.23	628.01	9,155.65
3	Manufacturing	83,938.43	17,792.72	27,072.73	3,713.15	5,413.49	6,287.65	6,080.24	150,298.41
4	Construction	274.62	209.76	185.77	133.55	142.01	141.72	140.35	1,227.79
5	Electricity, Gas and Water	3,318.76	723.28	1,211.17	267.44	351.83	379.24	361.90	6,613.63
6	Bus line operation	233.59	161.82	141.26	98.74	110.61	110.46	113.15	969.63
7	Jeepney and other land transport services	279.95	171.52	151.37	102.77	114.61	115.43	117.30	1,052.94
8	Railway transport	129.89	147.78	143.19	84.29	99.33	93.94	109.65	808.06
9	Public utility cars and taxicab operation	139.72	148.57	144.60	84.30	99.57	94.58	109.25	820.60
10	Tourist buses and cars including chartered and rent-a-car	142.12	149.09	146.22	84.14	99.51	94.44	109.44	824.96
11	Road freight transport	163,671.24	21,520.69	37,068.33	101.06	121.72	129.15	130.13	222,742.32
12	Water Transport	487.36	139.12	173.25	84.12	107.44	118.86	119.28	1,229.43
13	Air Transport	567.29	155.80	127.55	64.21	75.73	81.80	77.99	1,150.37
14	Communications and Storage	1,575.67	441.96	475.95	176.45	212.36	231.14	227.94	3,341.45
15	Trade	10,010.93	1,626.58	2,483.68	472.70	670.44	915.89	905.97	17,086.18
16	Finance	7,850.17	1,202.28	1,301.44	308.43	346.36	399.22	359.35	11,767.24
17	Real Estate and Ownership of Dwellings	1,008.89	209.17	262.36	132.39	148.04	157.68	147.79	2,066.32
18	Private Services	4,177.19	721.41	763.31	342.08	451.45	483.56	435.22	7,374.22
19	Government Services	-	-	-	-	-	-	-	-
	Subtotal	287,656.55	50,077.42	78,076.86	7,718.49	10,695.89	12,205.24	11,966.51	458,396.96

Table 8 Economic Loss (W/ MMSS-3) [Thousand Php]

Sector	Description	NCR	REG3	REG4-A	REG5	R.o.Luzon	Visayas	Mindanao	Subtotal
1	Agriculture, Fishery and Forestry	4,749.55	1,903.13	3,290.45	851.00	1,218.81	1,365.25	1,403.79	14,781.98
2	Mining and Quarrying	3,035.52	643.22	1,365.34	288.55	431.77	472.23	472.91	6,709.54
3	Manufacturing	66,652.54	7,820.11	19,843.88	,910.62	4,215.00	4,890.89	4,724.72	111,057.77
4	Construction	214.43	125.29	139.93	102.01	108.57	108.41	107.33	905.97
5	Electricity, Gas and Water	2,603.47	340.02	864.96	185.21	245.99	267.17	253.23	4,760.05
6	Bus line operation	181.97	98.69	106.79	75.12	84.26	84.20	86.24	717.27
7	Jeepney and other land transport services	218.62	103.00	114.05	78.13	87.21	87.89	89.31	778.21
8	Railway transport	99.58	94.64	109.49	64.26	75.91	71.84	83.84	599.56
9	Public utility cars and taxicab operation	107.42	94.66	110.44	64.26	76.07	72.30	83.50	608.65
10	Tourist buses and cars including chartered and rent-a-car	109.31	94.91	111.66	64.13	76.01	72.19	83.65	611.86
11	Road freight transport	130,156.75	5,634.35	26,654.49	61.03	73.03	78.72	78.94	162,737.31
12	Water Transport	361.92	73.88	106.64	50.34	62.64	71.72	71.08	798.20
13	Air Transport	444.10	76.82	91.16	45.83	53.85	58.43	55.53	825.73
14	Communications and Storage	1,242.50	225.80	349.05	132.18	158.77	173.13	170.64	2,452.06
15	Trade	7,874.22	789.05	1,747.69	316.06	450.27	637.67	629.85	12,444.81
16	Finance	6,190.92	459.55	913.55	202.96	227.56	265.81	235.63	8,495.96
17	Real Estate and Ownership of Dwellings	770.89	105.76	171.46	79.54	89.21	95.70	88.68	1,401.23
18	Private Services	3,254.05	342.84	520.41	223.55	298.51	321.88	286.92	5,248.17
19	Government Services	-	-	-	-	-	-	-	-
	Subtotal	228,267.75	19,025.71	56,611.45	5,794.76	8,033.44	9,195.41	9,005.79	335,934.31

Table 9 Economic Loss (W/ NSCRP) [Thousand Php]

Sector	Description	NCR	REG3	REG4-A	REG5	R.o.Luzon	Visayas	Mindanao	Subtotal
1	Agriculture, Fishery and Forestry	4,677.46	1,869.53	3,256.34	838.36	1,200.76	1,345.03	1,383.01	14,570.50
2	Mining and Quarrying	2,988.92	631.15	1,352.46	284.11	425.17	465.02	465.69	6,612.51
3	Manufacturing	65,632.96	7,657.39	19,693.33	2,866.90	4,152.25	4,818.22	4,654.59	109,475.63
4	Construction	211.46	123.40	138.45	100.73	107.21	107.05	105.99	894.29
5	Electricity, Gas and Water	2,563.52	333.29	857.58	182.33	242.19	263.06	249.31	4,691.28
6	Bus line operation	179.49	97.28	105.63	74.22	83.26	83.19	85.22	708.29
7	Jeepney and other land transport services	215.59	101.50	112.84	77.19	86.17	86.84	88.24	768.36
8	Railway transport	98.39	93.35	108.22	63.50	75.02	70.99	82.85	592.32
9	Public utility cars and taxicab operation	106.11	93.37	109.16	63.49	75.17	71.45	82.52	601.27
10	Tourist buses and cars including chartered and rent-a-car	107.97	93.61	110.37	63.36	75.11	71.34	82.66	604.44
11	Road freight transport	128,161.44	5,464.99	26,517.25	60.30	72.15	77.76	77.98	160,431.88
12	Water Transport	356.62	72.86	105.55	49.72	61.88	70.84	70.21	787.68
13	Air Transport	437.68	75.70	90.51	45.41	53.37	57.88	55.03	815.59
14	Communications and Storage	1,223.92	221.96	346.01	130.53	156.78	170.93	168.48	2,418.61
15	Trade	7,754.60	775.23	1,732.99	311.91	444.34	629.02	621.31	12,269.40
16	Finance	6,097.16	450.31	907.62	200.84	225.12	262.89	233.12	8,377.06
17	Real Estate and Ownership of Dwellings	759.41	104.19	169.92	78.58	88.13	94.54	87.61	1,382.39
18	Private Services	3,205.18	337.14	516.05	220.87	294.85	317.90	283.40	5,175.39
19	Government Services	-	-	-	-	-	-	-	-
	Subtotal	224,777.88	18,596.25	56,230.27	5,712.36	7,918.93	9,063.96	8,877.22	331,176.87

Table 10 Summary of Economic Loss Estimates [Thousand Php]

Sector	Description	Development Scenario		
		PRESENT	W/MMSS-3	W/ NSCRP
1	Agriculture, Fishery and Forestry	19,867.76	14,781.98	14,570.50
2	Mining and Quarrying	9,155.65	6,709.54	6,612.51
3	Manufacturing	150,298.41	111,057.77	109,475.63
4	Construction	1,227.79	905.97	894.29
5	Electricity, Gas and Water	6,613.63	4,760.05	4,691.28
6	Bus line operation	969.63	717.27	708.29
7	Jeepney and other land transport services	1,052.94	778.21	768.36
8	Railway transport	808.06	599.56	592.32
9	Public utility cars and taxicab operation	820.60	608.65	601.27
10	Tourist buses and cars including chartered and rent-a-car	824.96	611.86	604.44
11	Road freight transport	222,742.32	162,737.31	160,431.88
12	Water Transport	1,229.43	798.20	787.68
13	Air Transport	1,150.37	825.73	815.59
14	Communications and Storage	3,341.45	2,452.06	2,418.61
15	Trade	17,086.18	12,444.81	12,269.40
16	Finance	11,767.24	8,495.96	8,377.06
17	Real Estate and Ownership of Dwellings	2,066.32	1,401.23	1,382.39
18	Private Services	7,374.22	5,248.17	5,175.39
19	Government Services	-	-	-
	Subtotal	458,396.96	335,934.31	331,176.87

Table 11 Comparison of Costs

Scenario	Economic Loss [Thousand Php]	Savings [Thousand Php]	Project Cost [Million Php]	Ratio
1) Present	458,396.96	-	-	-
2) W/ MMSS-3	335,934.31	122,462.65	26,500.00	0.00462
3) W/ NSCRP	331,176.87	4,757.44	15,740.00	0.00030

If the evaluation of these infrastructure projects were to be limited to the estimated economic loss savings, the MMSS-3 would be much more viable compared with the NSCRP, where the former is more than 15 times more cost-effective. From the assessment approach employed in this paper, the project cost of Php 15.74 billion simply cannot be covered by the estimated additional savings of almost Php 5 million. In other words, it would take over 3,300 flooding instances to pay back the original project cost.

6.CONCLUSIONS AND RECOMMENDATIONS

This paper shows that the IO framework can be employed in the assessment of different transport infrastructure development scenarios and their impact on the entire economy when hit by operation disruptions. As presented, the total economic loss originating from an initial demand perturbation can be isolated and calculated as it propagates throughout the economy. With this, various scenarios can be assessed. As this study strictly models the effect of freight operation disruption due to flooding, the resulting estimates are strictly those that originated from freight transport inoperability.

This means that cars, utility vehicles, buses, etc., though probably affected by flooding as well, were not yet considered. This entails a larger initial demand perturbation, larger inoperability values, larger total economic losses, and ultimately, larger savings. Moreover, as previously mentioned, the initial perturbation was based solely on unassigned trips and does not account for economic losses stemming from delays. Also, the compounding losses as the flood persists over a couple of days were not covered in this study. All these ultimately result to under-estimation of economic losses computed. When these are considered, it may overturn the finding that the construction of the NSCRP is not a viable option.

Other factors that may also be taken into consideration are the calculation of vehicle operating costs and environmental costs as different scenarios would have different average speeds, VDTs, and VHTs. In doing so, the transportation modeling component should be repeated while considering other vehicle classes. This would reasonably affect the traffic characteristics used in the computation of operating and environmental costs.

On a side note, as the effects of operation disruptions caused by flooding usually persist even after the day of impact, it is also recommended to consider the application of the dynamic extension of the IIM. This would account for a more realistic total economic loss throughout the duration of the operation disruption. This would also allow for the assessment of recovery measures available to each development scenario.

Ultimately, this paper shows how the MRIIM can be employed to demonstrate the interdependence of different sectors in different regions of the economy, and how a change in one sector in one region can propagate across the economic network. The researchers, however, acknowledge that the model does not give accurate economic loss values, but rather estimate how and where these losses are incurred. This allows for policy development and evaluation. Lastly, the paper also shows how the MRIIM, primarily due to its simple structure and transparent inter-industry linkages, can quantify both intra- and inter-regional effects, and moreover, can be easily modified and integrated with other models.

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