Resilience Assessment of Freight Transport Optimization Programs for the Philippine Greater Capital Region

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Abstract: Critical to sustaining economic growth, logistics sprawl is a problem that needs to be addressed effectively and immediately, especially in developing countries. With the surplus of development programs but limited resources, there is a need to identify the optimum and sustainable direction to be taken, especially as the Philippines' exposure to the strongest typhoons makes it imperative to consider resilience. In this paper, resilience is measured and quantified using an Inoperability Input-Output model, where a disruption in freight transport operations (e.g. flooding) is taken as the initial perturbation. Using resilience as the primary metric, three freight development programs: a) Freight consolidation centers; b) Freight volume shift to outer ports; and c) Rail freight, and its various combinations were assessed. With the policy evaluation procedure undertaken, the interests of both the stakeholders and the community were covered.

Keywords: Logistics sprawl, Urban freight, Input-Output, Policy Evaluation

1. INTRODUCTION

In a survey conducted on shippers operating in the Philippine Greater Capital Region (GCR), 16 out of 17 are in the manufacturing business. Within this region, comprised of the National Capital Region (NCR), Region 3 (R3), and Region 4A (R4A), 74% of manufacturing companies operate inside Special Economic Zones (SEZs), which attract manufacturing companies through offering fiscal incentives such as a reduction in taxes. SEZs have sprung outwards from the metropolitan region, evidencing the logistics sprawl phenomenon in the Philippine GCR. Logistics sprawl, defined as the relocation of logistics and transport companies from inner urban areas towards the periphery of the cities (Gupta and Garima, 2017), is critical to sustaining economic growth, especially for developing countries. Aljohani and Thompson (2016) listed the mismatch on truck activity level and local road suitability, extension of urban area boundaries, increased distances travelled by trucks as some of its effects. With its potential to hamper economic growth, it should be addressed effectively and immediately.

Under the Philippine Institute for Development Studies (PIDS), Patalinghug et al. (2015) conducted a system-wide study of the logistics industry in the Philippine GCR, where assessment of the freight transport modeling scenarios was limited to basic transport metrics (e.g. average travel speed, vehicle-kilometers, vehicle-hours, etc.). However, as the Philippines sits in the western rim of the Pacific Ocean, it is the country most exposed to tropical storms, where 19 of the 80 typhoons that annually develop above tropical waters enter the Philippine region (Wingard and Brandlin, 2013). The impact has been projected to get worse, as noted in the decrease in the number of smaller cyclones and an increase in the frequency of more hazardous tropical cyclones (Cinco et al., 2016). Thus, in the assessment of the optimum development program, the freight transport infrastructure’s resilience against flooding is also a significant aspect to be examined. Tierney and Bruneau (2007), Rose and Krausmann (2013), and Gilbert et al. (2015) quantified resilience using the economic loss reduction metric. In Hasegawa et al. (2009), Okuyama and Santos (2014), and Roquel et al. (2017), economic loss is estimated using an inoperability input-output model (IIM).

The IIM is a tool used to assess the direct and indirect economic impacts of disruptive events throughout the various sectors in a nation’s economy (Jung et al., 2009). Its numerous applications include modeling of infrastructure interdependencies and risks of terrorism (Santos and Haimes, 2004; Santos, 2006), electric power blackouts (Anderson et al., 2007), extreme weather events (Crowther et al., 2007, Haggerty et al., 2008; Baghersad and Zobel, 2015; Aviso et al., 2015), and other scenarios with supply chain disturbances (Pant et al., 2011; Blos and Miyagi, 2015). In this paper, a disruption in the road freight sector (e.g. flooding), which in turn leads to operation delays and decreased industry production, was modeled using the IIM to estimate the subsequent economic losses. By incorporating the resilience metric, quantified as economic loss savings, the assessment approach undertaken made for a more sustainable approach as it considers the development programs’ ability to withstand the impacts of disasters.

The next section introduces the development programs modeled. Section 3 provides a discussion on the Input-Output (IO) framework. Section 4 contains the modeling methodology and results, while Section 5 presents the conclusions and recommendations for future research.

2. LOGISTICS DEVELOPMENT PROGRAMS

Various measures to address logistics sprawl have been proposed in literature. For one, an increase in average shipment load and efficient spatial distribution of logistics facilities can offset the negative effects of logistics sprawl (Sakai et al., 2017). This proposes to combine goods at freight consolidation centers (FCCs), where goods having the same target destinations are combined into one large delivery using high-load vehicles (Olsson and Woxenius, 2014). For the Philippine GCR, locations of these facilities can be aligned with the proposed development of regional and sub-regional centers as part of the spatial reorganization recommended by the Japan International Cooperation Agency (JICA) (2014).

In this approach, shippers only pay for the space taken up, which results to operational cost savings. However, the additional steps (e.g. consolidation and deconsolidation) correspond to additional travel time and other sources of delays. With the limited time frame for trucks to ply Metro Manila roads as per the existing truck ban, time is a critical factor to be considered, on top of the additional costs for infrastructure and processes involved. Furthermore, there is a risk of increasing truck distances as truck trips are split into three: 1) Origin-to-FCC; 2) FCC-to-FCC; and 3) FCC-to-Destination, which would also result to an increase in the consequent emissions. Thus, the authors recognize that the viability of this development program strongly depends on the efficient spatial distribution of the FCCs and a substantial volume of freight cargo to be consolidated, to offset the additional costs with the projected overall savings.

Another freight operation optimization program encourages the use of ports outside the metropolitan region. In the Philippine GCR, two ports located around 100 km from the capital have utilization rates of only 6% and 8% of port capacity (NEDA, 2014). Despite approximately 47% of truck trips coming from and going to areas outside Metro Manila

(JICA, 2014), around 76% of the shippers still use the Manila ports, reportedly operating at almost 78% utilization (NEDA, 2014). The availability of shipping lines, accessibility with less costs and cheaper rates, and location of port with respect to the consignee, importers, and warehouses were identified as some of the reasons for shippers' patronage of the Manila ports (Patalinghug et al., 2015).

To decongest the Manila ports while also improving the utilization of the outside ports (i.e. port volume shift (PVS)), a combination of fines and price discounts policy and volume restriction policy can be employed (Patalinghug et al., 2015). If the pricing incentives do not compensate for the non-price service attributes of the Manila ports, diversion of freight traffic is unlikely to materialize. On the other hand, an extensive quantity restriction may pose congestion problems on the outer ports. Thus, the authors acknowledge that the effectivity of PVS heavily relies on a systematic incentive framework, grounded on projected diverted demand and capacity enhancement policies.

Still another direction for development is the utilization of the Philippine National Railway (PNR) network and transformation of some its existing stations into rail freight stations (RFS). With PNR currently operating as a commuter transit service, rail freight operations can be limited at night, at least at the onset of railway use for freight transport. By plying on its own designated space, the impacts of freight vehicles to both private vehicle and public transit users can be minimized. Furthermore, it can serve as an alternative for shippers to transport their goods while bypassing the brunt of Metro Manila traffic.

This approach, however, will require the rehabilitation of the PNR lines and the development of inland container yards or depots at the RFSs. Furthermore, like the FCC scenario, the splitting of truck trips could also pose an increase in truck travel distances. Despite these, with the PNR network stretching further both to the North and South of the GCR, its potential to stimulate economic growth in the outer regions merits its inclusion in the list of development options. It is within these confines that the authors choose to move forward with the study with three development programs summarized in Table 1, and assess the various combinations.

Table 1. Summary of Development Programs

Scenario	Description
FCC	Facility location setup based on the spatial reorganization proposed by JICA, where truck trips with both origin and destination zones within 5 kilometers from an FCC are consolidated into larger deliveries
PVS	Shifting of truck traffic volume based on how the Bangkok Port was limited to 1 million twenty-foot equivalent units (TEUs) while diverting the rest of truck traffic to the Laem Chabang Port, located over 110 km to the South
RFS	Rehabilitation of existing railway for use in carrying freight traffic and development of selected PNR stations into intermodal freight facilities with freight cargo handling capabilities and inland container yards or depots

3. INPUT-OUTPUT FRAMEWORK

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 and Blair, 2009). An extension of the IO model, the IIM focuses on the spread of operability degradation in a networked infrastructure system, 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 (Haimes and Jiang, 2001). The inability (i.e. as a percentage) of a certain infrastructure to produce and meet the final demand, referred to as inoperability, is expressed as a ratio with which a sector's production is degraded relative to some ideal production level (Santos, n.d.).

In the IO model, 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 nth commodity. As each sector's output is ultimately produced to satisfy consumers' demand, a sector's total output is, henceforth, the sum of intermediate demand and final demand,

$$x_1 = a_{11}x_1 + a_{21}x_2 + ... + a_{n1}x_n + f_1 \tag{1}$$

where,

x_1 : total production output needed from industry 1,
f_1 : final demand for its output, and
$a_{1j}x_j$: input demand of the *j*th industry.

For the entire economy, the system can be written as a matrix equation,

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

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

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

where,

x : total output matrix,
A : technical coefficient matrix,
f : final demand vector, and
L : Leontief inverse or the total requirements matrix.

With matrix $\boldsymbol{A}$ 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.

The IIM has a similar structure to the Leontief IO model,

$$\mathbf{q} = \mathbf{A}^*\mathbf{q} + \mathbf{c}^* \tag{5}$$

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

$$\mathbf{A}^* = \hat{\mathbf{x}}^{-1}\mathbf{A}\hat{\mathbf{x}} \tag{7}$$

where,

q : sector inoperability,
c* : initial perturbation, and
A* : interdependency matrix.

The interdependency matrix, is a transformation of the Leontief technical coefficient matrix. The demand perturbation, is a vector comprised of the final demand disruptions to each sector, consisting of elements also normalized between 0 and 1, where 0 represents a fully-functioning system and 1 corresponds to a system with total failure (Tan *et al.*, 2014).

Economic loss is then computed as the product of inoperability and the average daily ideal production output of each sector,

$$EL_i = q_i * x_i \tag{8}$$

where,

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

For this paper, the total output values used were from the year 2015, the latest available data.

3.1. Regionalization of National Coefficients

For this study, the 2012 IO Account of the Philippines was calibrated using 2015 GDP values to come up with more realistic estimates. As the focus is on the economic loss stemming from an initial perturbation specifically in the road freight sector, the IO table was aggregated as shown in Table 2, where transportation subsectors were kept disaggregated.

Table 2. IO Table Aggregation

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

Moreover, as the IO tables published by the Philippine Statistics Authority (PSA) are national accounts, introduction of the initial perturbation only to the road freight sector in NCR, R3, and R4A required the regionalization of national coefficients. To do this, non-survey techniques discussed by Miller and Blair (2009) were employed, specifically the two-region logic with more than two regions approach, which uses location quotients to regionalize the IO table, and then later balanced using the cross-entropy technique discussed in Fofana *et al.* (2005). Table 3 shows the final regional disaggregation used in this paper.

Table 3. Regional Disaggregation

Region	Description
1	National Capital Region (NCR)

2	R3
3	R4A
4	Rest of Luzon
5	Visayas
6	Mindanao

4. POLICY SCENARIO MODELING

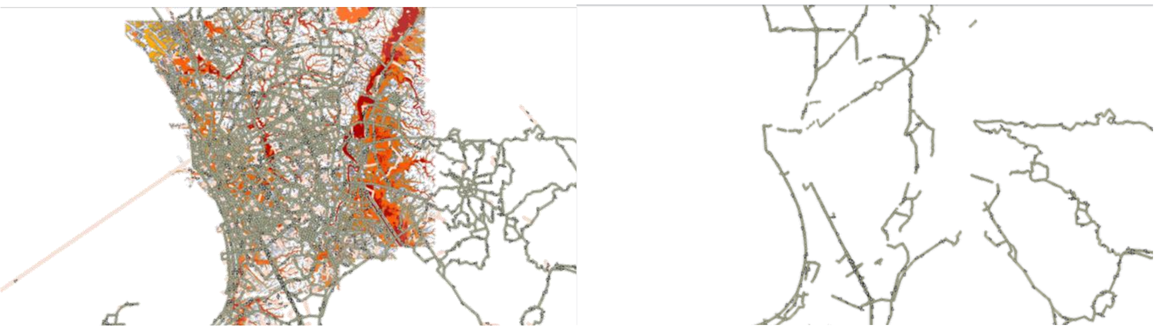
This paper uses the 2012 truck origin-destination (OD) matrix from the Metro Manila Urban Transportation Integration Study Update and Capacity Enhancement Project (MUCEP) of JICA (2014). This matrix was estimated using OD interview surveys of freight vehicle drivers conducted at 20 survey stations along the outer cordon line setup at the boundaries of the GCR. Standard traffic assignment was performed using the EMME4 transport modeling software to establish base conditions. Peak hour truck trips were assigned on top of off-peak public and private trips as trucks can only ply Metro Manila roads during off-peak periods due to the current truck ban. The OD matrix used in the BASE scenario was calibrated with 2017 truck counts at 7 locations where freight traffic passes through. Table 4 summarizes the combinations of development programs modeled as scenarios, where Scenario A involves the use of FCCs, Scenario B includes the PVS, Scenario C covers both the FCC and PVS, and so on.

Table 4. Modeling Scenario Combination

	BASE	A	B	C	D	E	F	G
FCC		🟥		🟥		🟥		🟥
PVS			🟥	🟥			🟥	🟥
RFS					🟥	🟥	🟥	🟥
*Legend:		🟥	- Included					

In the FCC scenario, a total of 8 consolidation centers were setup at the proposed regional and sub-regional centers specified in the JICA (2014) study while another 7 consolidation centers were setup at the periphery of the metropolitan area. As for the PVS scenario, to limit the Manila ports to only 1 million TEUs, 73% of the trips to and from Manila ports were diverted to Subic or Batangas ports, whichever is nearer. Lastly, a total of 11 stations along the PNR line were setup with supposed freight cargo handling facilities for the RFS scenario.

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



C) Mounted on 5-year Flood Hazard Map D) Non-flooded Road Network

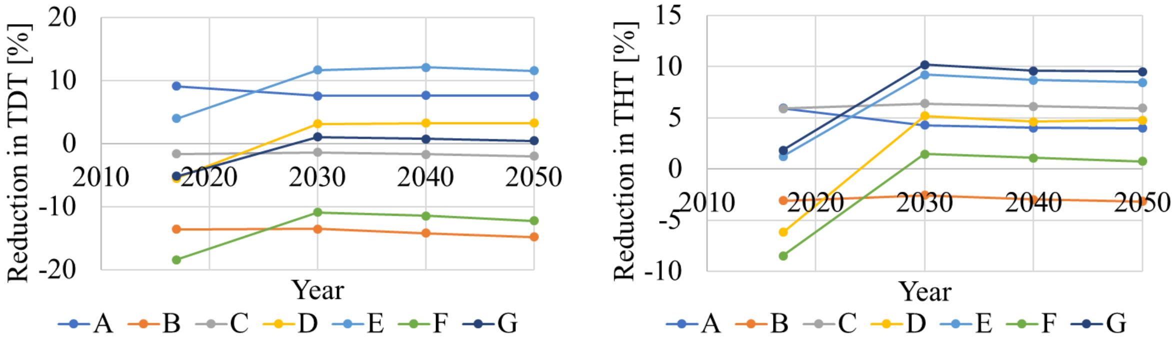
Figure 1. Truck Traffic Modeling

For the flooded condition, the transport network was overlain onto a 5-year flood hazard map and the flooded links (i.e. 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 supposedly reduces transport network capacity. For this study, the operation disruption was modeled as a 24-hour flood. Thus, the characteristics of the modeled flooded condition were 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.

Table 5 shows a summary of the truck distance travelled (TDT), truck vehicle hours travelled (THT), average speed, and rail distance travelled (RDT) and rail hours travelled (RHT) for the RFS scenarios, for base year 2017 and for the 2030, 2040, and 2050 projections. Looking at the values, the behavior of the results of all scenarios are quite similar. However, when looking at the percentage change of TDT and THT against the BASE scenario, Scenarios E, A, and D can be identified to show greater reduction in TDT while Scenarios G, E, and C are those for THT. Additionally, applying the FCC and PVS scenarios on top of the RFS scenario correspond to reductions in RDT and RHT.

Table 5. Traffic Modeling Results

		BASE	A	B	C	D	E	F	G
2017	TDT (thousand km)	1473.78	1339.68	1655.48	1500.60	1555.92	1411.58	1733.46	1563.63
	THT (thousand hr)	292.98	275.60	302.01	275.70	311.14	289.38	317.76	287.65
	SPEED (km/hr)	34.67	34.75	34.67	34.80	34.59	34.61	34.54	34.77
	RDT (thousand km)	-	-	-	-	3.99	3.83	3.42	3.19
	RHT (thousand hr)	-	-	-	-	0.07	0.06	0.06	0.05
2030	TDT (thousand km)	1846.52	1706.80	2077.62	1875.83	1788.46	1637.92	2025.00	1825.34
	THT (thousand hr)	757.81	725.27	777.15	709.42	718.66	688.09	746.72	680.62
	SPEED (km/hr)	29.93	29.96	29.96	30.15	30.15	30.14	30.11	30.29
	RDT (thousand km)	-	-	-	-	4.66	4.45	4.00	3.69
	RHT (thousand hr)	-	-	-	-	0.08	0.07	0.07	0.06
2040	TDT (thousand km)	2022.47	1868.28	2288.12	2060.84	1955.76	1786.36	2226.92	2006.47
	THT (thousand hr)	1345.89	1292.07	1386.05	1263.59	1283.87	1229.03	1331.53	1217.09
	SPEED (km/hr)	27.33	27.36	27.31	27.50	27.45	27.49	27.42	27.59
	RDT (thousand km)	-	-	-	-	5.09	4.85	4.25	3.91
	RHT (thousand hr)	-	-	-	-	0.08	0.08	0.07	0.07
2050	TDT (thousand km)	2094.16	1935.97	2380.46	2141.51	2025.08	1860.19	2321.75	2083.98
	THT (thousand hr)	1896.21	1820.85	1956.33	1783.56	1805.77	1735.88	1882.01	1715.67
	SPEED (km/hr)	25.77	25.72	25.65	25.87	26.60	25.95	25.83	26.03
	RDT (thousand km)	-	-	-	-	5.23	4.99	4.40	4.05
	RHT (thousand hr)	-	-	-	-	0.09	0.08	0.07	0.07



A) Reduction in Truck Distance Travelled B) Reduction in Truck Hours Travelled

Figure 2. Traffic Modeling Results

For the flooded scenario modeling, the number of assigned trips was recorded and the percentage decrease was quantified as the operation disruption. For this paper, operation disruption was limited to only trips that were made impossible in the flooded scenario. Table 6 shows the summary of the truck traffic assignment results for both the normal and flooded conditions, while Table 7 shows the summary of *c**, to be introduced into the IO model.

Table 6. Flooded Scenario Modeling Results

Scenario			BASE		A		B		C		D		E		F		G	
Flooding			No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Assigned Truck Trips	2017	NCR	18,088	8,411	19,349	9,094	17,112	7,735	16,104	7,327	18,022	6,740	19,296	7,410	16,910	6,358	15,936	6,024
		R3	6,617	5,883	6,475	5,802	7,079	6,201	6,929	6,118	6,294	5,558	6,158	5,487	6,816	5,937	6,682	5,867
		R4A	8,910	6,469	8,644	6,189	9,428	6,835	9,153	6,544	8,622	6,182	8,346	5,892	9,186	6,596	8,901	6,293
	2030	NCR	20,511	9,497	21,968	10,281	19,406	8,733	18,254	8,269	20,465	7,613	21,936	8,401	19,196	7,179	18,083	6,799
		R3	8,386	7,455	8,208	7,354	8,977	7,855	8,768	7,742	7,974	7,041	7,802	6,952	8,643	7,528	8,453	7,422
		R4A	11,406	8,281	11,073	7,928	2,079	8,745	1,703	8,368	11,036	7,913	10,690	7,547	11,769	8,438	11,380	8,046
	2040	NCR	21,641	9,998	23,183	10,826	20,507	9,208	19,279	8,714	21,618	8,020	23,180	8,855	20,288	7,567	19,103	7,164
		R3	9,606	8,540	9,423	8,443	10,286	9,011	10,046	8,871	9,134	8,248	8,959	7,982	9,904	8,626	9,687	8,505
		R4A	13,138	9,525	12,790	9,145	13,916	10,061	13,477	9,623	12,711	9,088	2,348	8,705	13,561	9,710	13,107	9,254
	2050	NCR	22,363	10,309	23,967	11,169	21,220	9,528	19,955	9,020	22,369	8,277	23,996	9,142	21,006	7,814	19,785	7,400
		R3	10,392	9,238	10,217	9,154	11,136	9,755	10,878	9,605	9,877	8,721	9,711	8,653	10,721	9,338	0,488	9,208
		R4A	14,238	10,308	13,887	9,915	15,093	10,912	14,610	10,417	13,773	9,834	13,406	9,438	14,710	10,518	14,211	10,019

Table 7. Initial Perturbation Values

Flooding			BASE	A	B	C	D	E	F	G
Assigned Truck Trips	2017	NCR	0.535	0.530	0.548	0.545	0.626	0.616	0.624	0.622
		R3	0.111	0.104	0.124	0.117	0.117	0.109	0.129	0.122
		R4A	0.274	0.284	0.275	0.285	0.283	0.294	0.282	0.293
	2030	NCR	0.537	0.532	0.550	0.547	0.628	0.617	0.626	0.624
		R3	0.111	0.104	0.125	0.117	0.117	0.109	0.129	0.122
		R4A	0.274	0.284	0.276	0.285	0.283	0.294	0.283	0.293
	2040	NCR	0.538	0.533	0.551	0.548	0.629	0.618	0.627	0.625
		R3	0.111	0.104	0.124	0.117	0.097	0.109	0.129	0.122
		R4A	0.275	0.285	0.277	0.286	0.285	0.295	0.284	0.294
	2050	NCR	0.539	0.534	0.551	0.548	0.630	0.619	0.628	0.626
		R3	0.111	0.104	0.124	0.117	0.117	0.109	0.129	0.122
		R4A	0.276	0.286	0.277	0.287	0.286	0.296	0.285	0.295

4.1 Economic Loss Savings Estimation

By introducing the initial perturbation values into the IIM, the spread of inoperability across the network is estimated. Figure 3 shows that of the BASE scenario in 2017, where disruptions in the road freight sectors in NCR, R3, and R4A have corresponding impacts onto all other sectors, even on those in other regions where no initial perturbation was introduced. This demonstrates the interconnected network of the economy. Looking at the distribution, NCR sectors were found to be most affected. This can be attributed to the notably higher initial operation disruption modeled for the region. On the other hand, with regard to the sectors, 9, 10, and 14 can be identified to have relatively higher values. This exemplifies the strong interdependence between the transportation subsectors, as well as with the communications and storage sector.

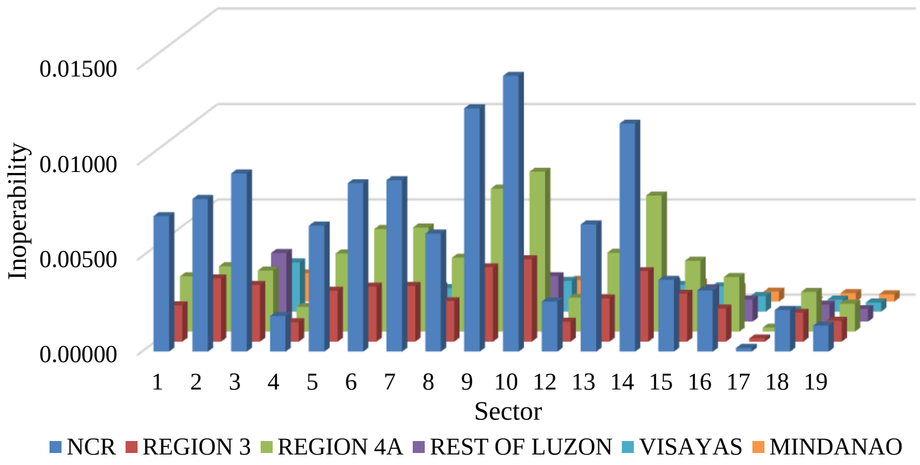


Figure 3. Spread of Inoperability (BASE/2017)

By multiplying inoperability with the average daily ideal production output (total output divided by 360 days), the economic losses are estimated in terms of losses in production output. Figure 4 shows the distribution of losses across the economy for the BASE scenario in 2017, where a different set of most affected sectors can be identified. This is attributed to the fact that different sectors produce outputs having its own monetary value. In this case, the manufacturing sector was found to incur the biggest loss at around PhP 88 billion, followed by the trade sector at over PhP 46 billion. Despite having inoperability values around 0.009 and 0.004, respectively, as compared with 0.013 and 0.014 for sectors 9 and 10, respectively, the monetary value of the production outputs of manufacturing and trade sectors simply dwarfs those of public utility cars and taxicab operations and tourist buses and cars, and thus, sustaining greater losses. With additional losses of PhP 296 billion from the rest of the economy, the overall loss when a 5-year flood disrupts the road freight sector amounts to over PhP 430 billion, or around 2.8% of the GDP.

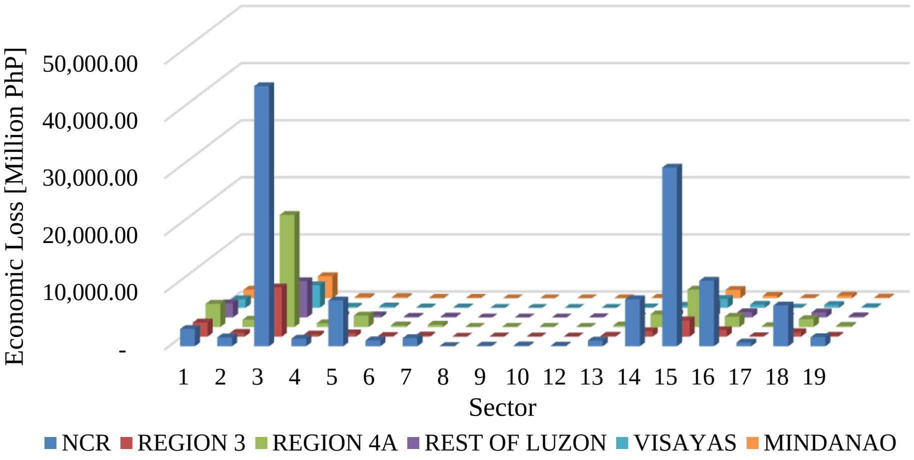


Figure 4. Spread of Economic Loss (BASE/2017)

Consequently, looking at the regional losses, NCR was found to incur around PhP 285 billion for the BASE scenario in 2017, while approximately PhP 81 billion and PhP 30 billion are suffered by regions 3 and 4A, respectively. With NCR accounting for around 38% of the GDP and having the highest initial perturbation to begin with, sustaining over 66% of the overall estimated losses was expected. It is also important to mention how the Rest of Luzon, Visayas, and Mindanao were estimated to lose around PhP 16 billion, PhP 10 billion, and PhP 9 billion, respectively, despite having no initial perturbation introduced to any of its sectors. This shows that any operation disruption to any sector in any region will ripple throughout the entire economy and result to economic losses, on account of production output that should have otherwise been produced.

Table 8. Sector Economic Losses at 2017 Prices [Billion PhP]

Sector	Description	BASE	A	B	C	D	E	F	G
1	Agriculture, Fishery and Forestry	15.04	14.99	15.42	15.41	17.13	16.97	17.16	17.18
2	Mining and Quarrying	4.75	4.74	4.87	4.87	5.41	5.36	5.42	5.43
3	Manufacturing	87.91	87.61	90.12	90.06	100.11	99.20	100.28	100.41
4	Construction	3.19	3.18	3.27	3.26	3.63	3.60	3.64	3.64
5	Electricity, Gas and Water	11.43	11.39	11.71	11.71	13.01	12.89	13.03	13.05
6	Bus line operation	1.69	1.68	1.73	1.73	1.92	1.90	1.92	1.93
7	Jeepney and other land transport services	2.33	2.32	2.38	2.38	2.65	2.62	2.65	2.66
8	Railway transport	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09
9	Public utility cars and taxicab operation	0.22	0.22	0.23	0.23	0.25	0.25	0.25	0.25
10	Tourist buses and cars including chartered and rent-a-car	0.24	0.24	0.25	0.25	0.28	0.27	0.28	0.28
11	Road freight transport	211.95	211.21	217.26	217.13	241.36	239.15	241.75	242.06
12	Water Transport	0.22	0.22	0.23	0.23	0.25	0.25	0.26	0.26
13	Air Transport	1.69	1.69	1.74	1.74	1.93	1.91	1.93	1.94
14	Communications and Storage	12.78	12.74	13.10	13.10	14.56	14.42	14.58	14.60
15	Trade	46.04	45.88	47.20	47.17	52.43	51.95	52.52	52.58
16	Finance	16.24	16.19	16.65	16.64	18.50	18.33	18.53	18.55
17	Real Estate and Ownership of Dwellings	0.97	0.97	1.00	1.00	1.11	1.10	1.11	1.11
18	Private Services	11.16	11.12	11.44	11.43	12.71	12.59	12.73	12.75
19	Government Services	2.38	2.38	2.44	2.44	2.72	2.69	2.72	2.72
	Grand Total	430.34	428.83	441.13	440.86	490.05	485.58	490.85	491.48

Table 9. Regional Economic Losses at 2017 Prices [Billion PhP]

Region	Description	BASE	A	B	C	D	E	F	G
1	NCR	285.18	282.56	292.10	290.55	333.46	328.19	332.42	331.40
2	Region 3	29.83	28.55	32.36	31.12	32.40	30.87	34.50	33.28
3	Region 4A	80.61	83.13	81.12	83.67	84.45	87.15	84.19	87.01
4	Rest of Luzon	15.84	15.78	16.22	16.21	18.12	17.95	18.12	18.14
5	Visayas	9.66	9.62	9.89	9.88	11.06	10.95	11.06	11.07
6	Mindanao	9.22	9.18	9.44	9.43	10.57	10.46	10.56	10.57
	Grand Total	430.34	428.83	441.13	440.86	490.05	485.58	490.85	491.48

Table 11 shows a summary of the overall economic loss reduction versus the BASE scenario, where only Scenario A was found to reduce the estimated economic losses. Scenario B was estimated to result to an additional loss of approximately PhP 11 billion. This shows that the PVS scenario not only increases the truck travel distances and times, it also forces the trucks to take different routes, which may be situated in flood prone areas. With this, the authors would like to note that for the PVS scenario to be a viable option, a comprehensive route plan that covers transport economy, road infrastructure suitability, and robust accessibility is an absolute necessity, on top of the fines and price discounts, volume restriction, and capacity enhancement policies.

On the other hand, the RFS scenario resulted to an additional loss of almost PhP 60 billion. Though essentially similar to the FCC scenario (i.e. Consolidating truck trips at specified locations), a significant volume of truck trips were found to be impossible during the flooded condition. This highlights the critical role of spatial distribution, for both FCC and RFS scenarios, as trucks were not able to reach their destinations simply because some of the RFSs became inaccessible. This entails that in the identification of RFSs to be developed, aside from the catchment area and relative distances between stations, road conditions in the vicinity, both during normal and irregular circumstances, are also of indispensable importance.

It also puts the current spatial distribution of FCCs into question as it may not necessarily be the most economical and resilient setup just yet. Some sites may prove to be more viable locations for the FCCs in terms of efficient coverage of the demand, while others may be accessible to more areas, especially during the flooded condition. This opens the possibility for a greater reduction in overall economic loss, currently estimated at PhP 1.5 billion every time a 5-year flood occurs. Moreover, an exploration of the setting of RFS locations could even overturn the current findings and result to a positive value for economic loss reduction.

Table 11. Overall Economic Loss Reduction VS BASE in 2017 Prices [Billion PhP]

Year	A	B	C	D	E	F	G
2017	1.51	(10.79)	(10.52)	(59.71)	(55.24)	(60.51)	(61.14)
2030	3.83	(28.78)	(26.84)	(152.32)	(139.34)	(155.11)	(155.97)
2040	7.88	(58.12)	(55.15)	(294.29)	(286.33)	(318.74)	(320.53)
2050	16.20	(109.66)	(106.71)	(646.42)	(588.42)	(655.03)	(658.69)

6. CONCLUSIONS AND RECOMMENDATIONS

This paper employed the IO framework to evaluate various logistics optimization programs and assess its resilience against flooding. By incorporating how it is impacted by a disruption, its overall effect to the economy is considered. Moving forward into the future, the transport infrastructure’s sustainability is critical and the approach taken in this paper has proven to be mathematically sound in quantifying the apparent losses as the initial perturbation propagates.

As found in the economic losses estimated using the IIM, the current specifications of the rail freight scenario resulted to even bigger losses. Thus, the authors recommend exploring the various combinations of existing stations to be developed into RFSs to determine the most efficient and resilient setup. As it could possibly reinforce or weaken rail freight’s merit as a development option, the authors recognize this as an avenue for future research.

Moreover, as spatial distribution was found to be a critical factor, the authors recommend conducting a study on optimizing the locations of the FCCs to determine the optimum configuration of this development program. By maximizing the potential benefit of consolidating truck trips (i.e. more truck trips combined into large deliveries) while minimizing the vehicle distances (i.e. less total truck trip distances travelled), the most suitable locations of FCCs can be determined based on overall operation efficiency, to improve the program's economic viability as well as resilience to disasters. The optimized configuration can then be used to guide policy makers in pursuing this development direction.

Also, the authors acknowledge that while three freight development policies and its various combinations were assessed in this paper, there may still be other options that could be more effective in optimizing logistics operations. It is, therefore, recommended to continue exploring other freight development policies employed elsewhere to test its suitability in the local setting.

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