E09

Estimating Lifeline Resilience Factors Using Post-Disaster Business Recovery Data

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Abstract: Recent studies have provided reference for the lifeline resilience factors of industrial sectors. However, those results are derived from business surveys based on hypothetical disasters or expert-opinion-based estimations due to a lack of data from businesses that experienced the lifeline disruptions after a disaster. Therefore, this paper estimates the remaining production capacity after lifeline disruptions due to a disaster, called lifeline resilience factors, in different business sectors. Lifeline resilience factors are estimated using a production function based on post-disaster business survey data in the areas affected by the 2011 Great East Japan Earthquake. A comparative study between manufacturing and non-manufacturing sectors is conducted to understand the resilience and vulnerability characteristics of the analyzed sectors. The results show distinct lifeline importance between these sectors and are consistent with those of extant studies. These findings contribute significantly to confirming the stability of lifeline resilience factors for disaster impact analysis.

1. Introduction

Businesses and their economic functions are vulnerable to disasters, which vulnerability has increased with urban agglomeration development (Webb et al. 2002). Lifelines are critical and necessary resources for the optimal functioning of human life and urban areas, without which urban regions cannot operate (Corey C M, Deitch E A.,2011). Resilient systems could help decrease failure probabilities and lead to speedy recovery (Tierney and Bruneau 2007). Identifying the resilience of crucial lifelines is important for assessing the economic impact of disasters and reducing indirect business losses caused by post-disaster lifeline interruptions.

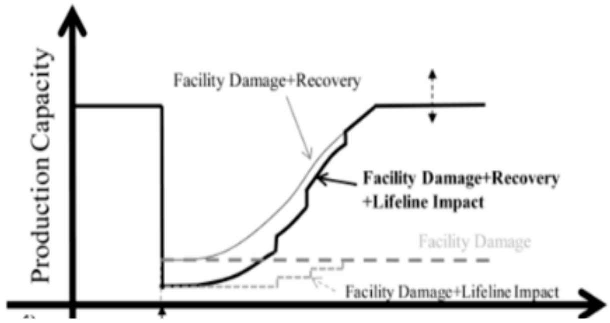


Figure.1 Business recovery scenarios with and without lifeline disruptions impact

Several studies estimate the impacts of lifeline disruptions on the economy, mostly focusing on single lifeline disruption impacts, such as electricity (Rose et al. 2010), water (Chang et al. 2002), and transportation disruptions (Boarnet 1998). Additionally, studies mostly derive results from survey data based on hypothetical disasters (Kajitani and Tatano 2009) or expert-opinions estimations (ATC-13,1985; ATC-25,1991) due to a lack of post-disaster business recovery data. As such, the estimation of lifeline resilience factors based on real disaster data is still necessary for achieving effective and efficient post-disaster recovery.

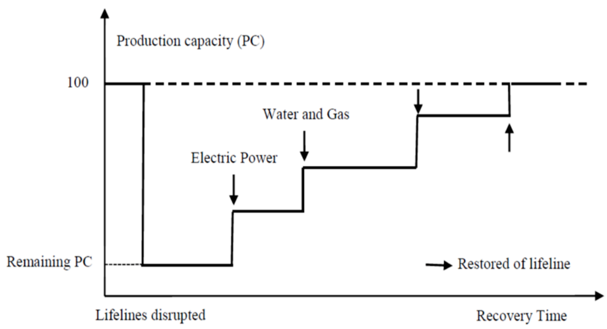


Figure.2 Examples of the relationships between production capacities and lifelines

Therefore, this study contributes to the literature by estimating the lifeline resilience factors to quantitatively describe the economic impacts of lifeline disruptions on business recovery by taking the 2011 Great East Japan Earthquake as a case study. Lifeline resilience factor is defined as the remaining percentage output the industry could still produce in the event of lifeline disruptions (Chang et al. 2002; Kajitani Y, Tatano H., 2014), and is a critical input indicator in the model for addressing the importance of each lifeline service and estimating economic losses due to lifeline disruptions (Rose et al. 1997; Chang et al. 2002).

2. Model design

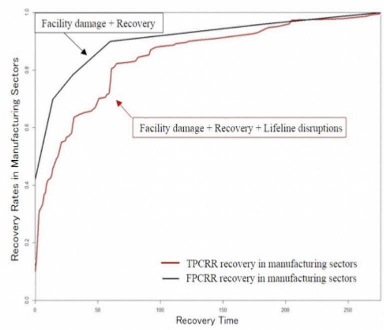


Figure 2. Recovery processes with and without lifeline disruptions

- Production Function:

$f(U, L, K) = g(U)\, l(L, K)$

- Lifeline Utility:

$g(U_i) = \theta e^{\beta_e E_i}\, e^{\beta_w W_i}\, e^{\beta_G G_i}$

- Before disaster:

$f(U_0, L_0, K_0)$

- After disaster:

$f(U_1, L_1, K_1)$

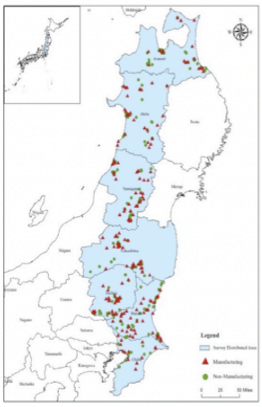
$$\boldsymbol{FPCRR} = f(U_0, L_0, K_1)/f(U_0, L_0, K_0) = h(K_1)/h(K_0)$$

$$\boldsymbol{TPCRR} = f(U_1, L_0, K_1)/f(U_0, L_0, K_0) = g(U_1)\, h(K_1)/g(U_0) h(K_0)$$

$$\boldsymbol{LPCDR} = \frac{TPCRR}{FPCRR} = \frac{f(U_1, L, K_1)}{f(U_0, L, K_0)} \Big/ \frac{f(U, L, K_1)}{f(U, L, K_0)} = \frac{g(U_1) h(K_1)}{g(U_0) h(K_0)} \Big/ \frac{h(K_1)}{h(K_0)} = \frac{g(U_1)}{g(U_0)}$$

$$\boldsymbol{LRF_E = 1 - LPCDR_E = 1 - \frac{1}{e^{\beta_E}} = 1 - e^{-\beta_E}}$$

3. Case Study and Data Descriptions



Database: Post-disaster survey data after the 2011 Great Japan Earthquake

◆ **Two Recovery Scenarios**

FPCRR: Recovery scenario assumes production capacity under impact of facility damage, and being defined as the production capacity recovery rate under facility damage.

TPCRR: Recovery scenario assumes production capacity is impacted by both lifeline system disruptions and facility damage, being defined as the total production capacity recovery rate under facility damage and lifeline disruption.

Figure.3 Study area

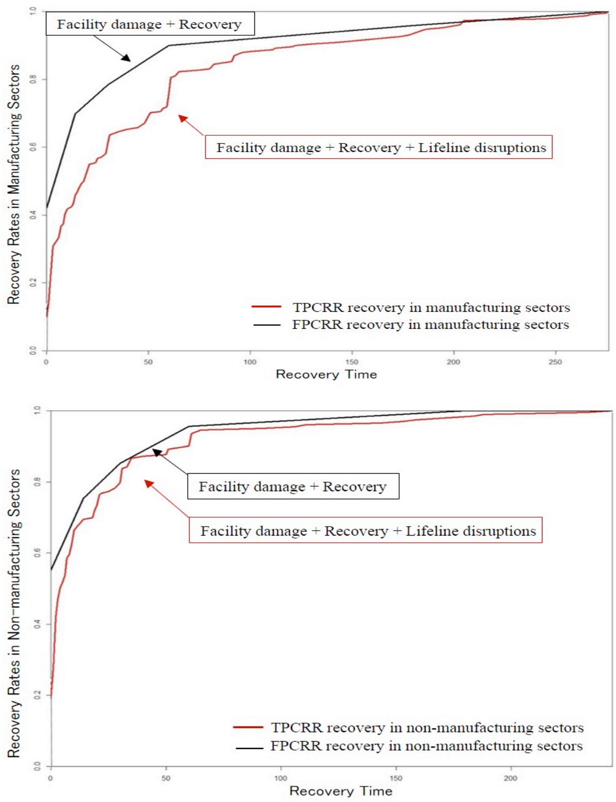


Figure.4 Observed recovery processes with and without lifeline disruptions after the 2011 Great East Japan Earthquake

4. Estimation Results

	Manufacturing sectors		Non-manufacturing sectors	
	Coefficient β_i	Lifeline Resilience factor ($\mathbf{LRF_i}$)	Coefficient β_i	Lifeline Resilience factor ($\mathbf{LRF_i}$)
(Intercept)	-1.599***		-2.11***	
Electricity	0.0234***	0.0231	0.012***	0.0121
Water	0.7817***	0.5424	1.053***	0.6511
Gas	0.8025***	0.5518	0.889***	0.5891
N	137		297	
F-stat	924.356****		991.703****	

	Sector	**Lifeline Resilience factor (LRF_i)**			**Sample Size**
		Electricity	**Water**	**Gas**	
Manufacturing Sector	Materials	0.023 (0.02***)	0.510 (0.713***)	0.352 (0.434***)	59
	Processing and assembly	0.024 (0.024)	0.423 (0.550***)	0.968 (3.448***)	22
	Life-related	0.032 (0.032***)	0.815 (1.686***)	0.813 (1.685***)	56
Non-manufacturing Sector	Construction	0.016 (0.016***)	0.809 (1.655***)	0.122 (0.130)	71
	Transportation	0.018 (0.018***)	0.538 (0.773**)	0.888 (2.190***)	53
	Wholesale/retail	0.015 (0.015***)	0.515 (0.724***)	0.533 (0.762***)	73
	Finance, insurance and real estate	0.015 (0.015***)	0.634 (1.006***)	0.249 (0.286)	26
	Service	0.054 (0.055***)	0.434 (0.570***)	0.751 (1.391***)	74

(Coefficients and the significance levels are shown in the parentheses; ****, ***, **, and * denote significance at the 0.1%, 1%, 5%, and 10% evels, respectively)