COMPARATIVE ANALYSIS OF THE RECONSTRUCTION PROCESS OF URBAN FACILITIES IN INDONESIA BASED ON RECOVERY CURVES AFTER THE 2004 INDIAN OCEAN TSUNAMI

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Abstract: Aceh in Indonesia was the most seriously damaged area due to 2004 Indian Ocean Tsunami, where more than 240,000 people were lost or killed. Following the event, Government devised a blueprint of urban recovery master plan, and lots of urban infrastructures related to the projects had been constructed in Aceh as of April 2009. The gap between the plan and reality that has some problems of recovery matter shows future challenge for post-disaster urban recovery and sustainable urban management. The authors conducted field survey in the damaged area to understand the recovery condition and obtained sets of data collected for 47 months since January 2005 by Badan Rehabilitasi dan Redonstruksi NAD-Nias (BRR), a recovery and rehabilitation agency. In this paper, recovery process in Aceh is analyzed using recovery curves for 14 indicators: department of housing (temporary and permanent housing), infrastructure (road, bridge, airport, and seaport), education (school and training of teacher), medical (hospital), economy (farmland, fishery, and enterprise support), cultural affairs (religious facilities) and Institutional development (government office). Then, the difference between the actual process of reconstruction and prepared recovery plans are discussed. In conclusion, the followings are clarified: (1) the progress of recovery of education, medical, and economy was hastened; (2) in other side, housing and infrastructure were delayed compared with other indicators; and (3) temporary housing was the earliest among all. Actually, the commencement of construction was delayed 7.6 months behind the scheduled recovery plan. The authors also discuss the reason of such problem based on its social context.

Keywords: recovery curve, Aceh, the 2004 Indian Ocean Tsunami, resettlement, urban infrastructure

• Introduction

1.1 Background

As of December 2010, six years have been since the 2004 Indian Ocean Tsunami. According to Reliefweb (2005) and WHO (2005), the catastrophic damage caused 300,000 people to die and 620,000 buildings to destroy in Southeast Asia and East Africa (Table 1). Aceh (Nanggröe Aceh Darussalam) in Indonesia was the heaviest of affected area where 240,000 people were lost or killed and 510,000 buildings were destroyed (Figure 1). The amount of damage in Indonesia was nearly 5 times more than that of Sri Lanka and 80% among all the affected countries. Especially, Kota (city) Banda Aceh and Kab (province) Aceh Besar was the main affected area and was also stricken by the impact of tsunami and earthquake. The range of damage in Indonesia reached to the inland area from the costal area. Therefore, Aceh had to recover almost all urban functions from the state of nothing. For example, the affected area that falls into a serious situation will have to spend a longer time and much more cost to complete the recovery. In addition, it may easily delay the recovery process comparing to the prepared recovery plan. However, the factor of delay is obvious because various stakeholders exist and they build a complicated relationship in the recovery process.
So, it is important to analyze the recovery process after disasters and to investigate the gap between actual process of reconstruction and prepared recovery plan of Aceh, concerning future post-disaster recovery initiatives. As a research method to analyze recovery process, this study applied Murao and Nakzato’s (2008) proposed “recovery curves” method based on the reconstruction situation data of building.

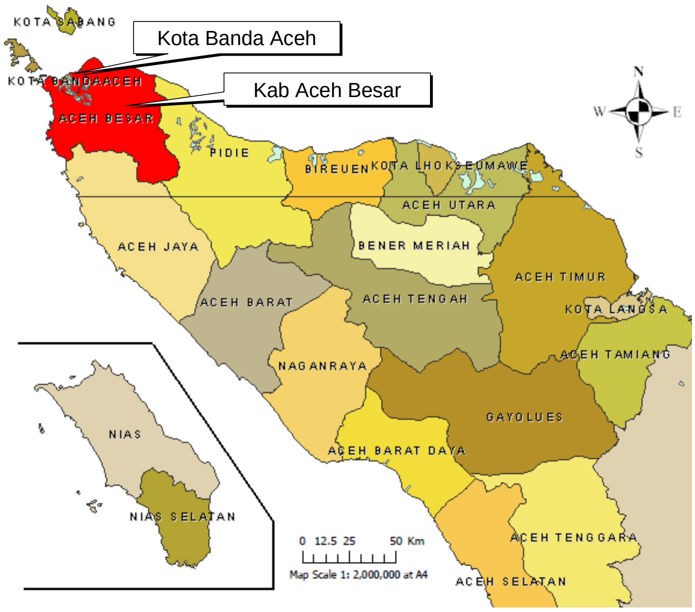


Figure 1: *Affected area in Indonesia (Nanggröe Aceh Darussalam)*

Table 1: *Damage of 2004 Indian Ocean Tsunami all over the world*

Affected countries	Indonesia	Sri Lanka	India	Thailand	Somalia	Maldives	Malaysia	Myanmar	Sesel	Total
Damage of buildings	514,150	103,753	-	4,806	-	3,997	-	592	-	627,298
Displaced People	417,438	500,668	112,588	-	2,320	11,568	8,000	2,592	160	942,746
Deaths	114,573	30,959	10,749	5,392	394	82	68	61	3	162,281
Missing	127,749	5,644	5,640	3,062	158	26	6	-	-	142,285
Deaths ＋Missing	242,322	36,603	16,389	8,454	552	108	74	61	3	304,566

1.2 Purpose

In this paper, the authors analyzed recovery process based on recovery curves by 14 kinds of urban infrastructure indicators such a department of housing (temporary housing and permanent housing), infrastructure (road, bridge, airport and seaport), education (school and training of teacher), medical (hospital), economy (farmland, fishery and enterprise support), cultural affairs (mosque or church) and Institutional development (government office). In addition, they investigated the differences between the actual process of reconstruction and prepared recovery plans.

- ## Methods

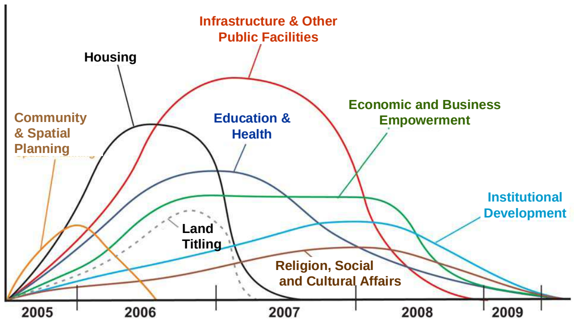
The procedure of this paper is shown as follows. The authors stepped on four stages in this study.

2.1 Data used

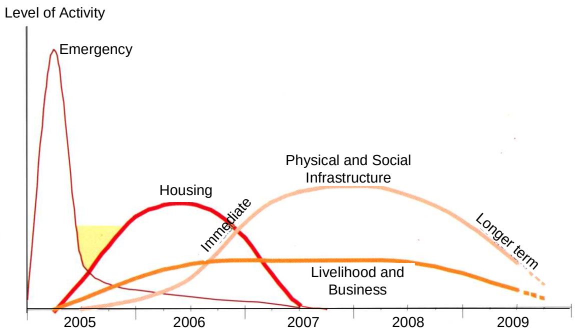
As of February 2008, the authors conducted field survey and interviews in the damaged area to investigate the recovery condition in Indonesia. During that time, they obtained a data set that had been compiled over 36 months since January 2005 by BRR (Badan Rehabilitasi dan Rekonstruksi NAD-Nias). Afterwards, the authors kept monitoring web contents of BRR and obtained new data set that had been compiled over 11 months since January 2008. Finally, the database was compiled over 47 months and gave the recovery condition of more than 19,000 traditional houses and 124,000 permanent houses reconstructed up to November 2008 in the damaged areas (BRR, 2007 and 2008). Moreover, they obtained six-monthly report (BRR, 2005b) and one year report (BRR, 2005a and 2006) that contained data on recovery condition and recovery plan.

2.2 Transition of recovery policy

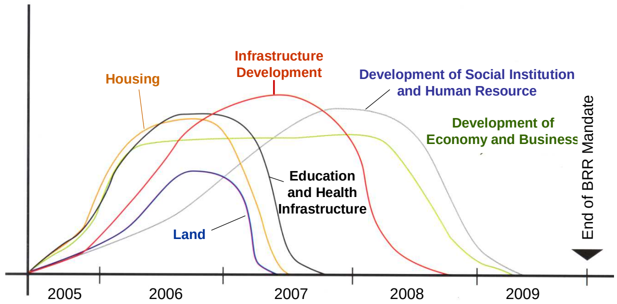
To understand the transition of the recovery policy, the authors arranged the conversion point of project period and the priority target according to recovery index.



(a) Recovery period (2005/10)



(b) Recovery period (2005/12)



(c) Recovery period (2006/4)

Figure 2: *Transition of recovery project period (2005/10-2006/4)*

Table 2: *The relationship between recovery section, index of infrastructure and planning period*

Recovery section	Recovery indicaters sample	Years	2005	2006	2007	2008	2009
Housing section	Permanent houses built Transitional houes built Damaged house repaired etc.	Planning period	Planned by 2005/10 (30 months) Planned by 2005/12 (30 months) Planned by 2006/4 (30 months)				
		Priority target	Recovery target ratio 30%	Recovery target ratio 90%	Recovery target ratio 100%		
Infrastructure & Other Public Facilities section	Roads, bridges, airport, seaport rebuilt/constructed Electric Power generated Water production facilities reconstructed/rehabilitated Houses supplied with sewage/sanitation etc.	Planning period	Planned by 2005/10 (48 months) Planned by 2005/12 (60 months or over) Planned by 2006/4 (45 months)				
		Priority target	High priority period to recovery transportation		Aceh: To recovery major road at west To reinforce major road at east and center		
				Planned time period for major local road, seaport and airport	Nias: To connect major road at north with south/To reinforce major road at east and west		
Education & health section	Schools, hospitals, built/repaired classrooms provided Teachers trained etc.	Planning period	Planned by 2005/10 (60 months or over) Planned by 2006/4 (33 months)				
		Priority target	High priority period to recovery education and health facilities		High priority period to reinforce education and health networks		
Economic & Business empowerment section	Agricultural land and fish ponds rehabilitated, fishing vessels provided/replaced, mangrove restored, Microfinance supported etc.	Planning period	Planned by 2005/10 (60 months or over) Planned by 2005/12 (60 months or over) Planned by 2006/4 (54 months)				
		Priority target	Job creation period	Growing of small and medium enterprise period	Deveropment of small and medium enterprise period	Recovery of tourism	
Religion, Social and Cultural section	Churchs, mosques and temple built/repaired etc.	Planning period	Planned by 2005/10 (60 months or over) Planned by 2005/12 (60 months or over)				
		Priority target	Under constructing at any time				
Institutional development section	Government buildings built/repaired, civil servants training, expert provided, radio station established etc.	Planning period	Planned by 2005/12 (60 months or over) Planned by 2006/4 (54 months)				
		Priority target	Providing of institutional capacity building				

2.3 Construction of recovery curve

To express the recovery condition of infrastructure, the authors classified the recovery process into 6 categories of 14 items by obtained data set based on the classification method of BRR. After this process, the authors constructed recovery curve according to the method of Murao and Nakzato (2008).

2.4 Analysis of recovery process

As a last step, the author compared the difference between the actual process of reconstruction and prepared recovery plans used by recovery curve and reported them in a Japanese paper (Murao and Nakazato, 2010). The method adds new information, the following sections explain how to develop the vulnerability functions and discuss the differences among the existed fragility curves.

- ## Transition of recovery plan

Up to now, the recovery project plan in Aceh has been published in three times. The first plan was published in October, 2005 (six-monthly report of BRR). Figure 2a shows the period of the first recovery project classified by recovery section. Table 2 shows the relationship between recovery section, index of infrastructure and planning period.

The longest recovery project period at the first plan was schemed to continue after 2010. Afterward, since the second plan was published in December, 2005 (one year report of BRR, Figure 2b), the third plan was published in April, 2006 (one year report of BRR, Figure 2c). The longest recovery project period at the third plan was schemed to finish in the first half of 2009. Finally, the recovery project period became half of a year. This reason is that BRR needed to be finished the main part of recovery project within their active period that had been decided until March, 2009.

- ## Construction of recovery curve

4.1 Recovery ratio calculation

In order to plot the recovery curves, it is necessary to normalize the recovery condition of damaged areas of varying size. This was done by comparing the recovery ratio of the number of buildings constructed per month with the total number of completed buildings as of November 2008.

4.2 Selection of recovery curve

For the time period of 50 months, the cumulative ratio of building completion is assumed to be fitted a sigmoid curve such as Cumulative Normal Distribution curve, Logistic curve, or Gompertz curve. Curves showing the highest correlation with observed data were considered to represent the most optimal recovery curve. However, according to previous research of Murao and Nakzato (2008), they concluded when the permanent housing was analyzed, Cumulative Normal Distribution curve is fitted. Also in this study, the permanent housing is the main analytical indicator. So the authors

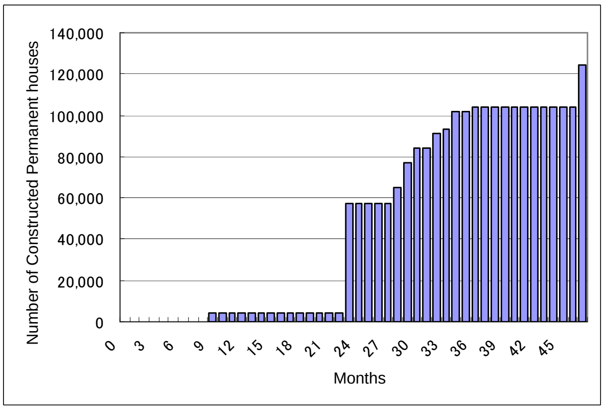


Figure 3: *Reconstruction of permanent houses*

Table 3: *Recovery process in Indonesia*

Recovery section				Housing		Infrastructure & Other Public Facilities				Education & Health			Economic and Business Empowerment			Religion, Social and Cultural Affairs	Institutional development section
Recovery indicaters				Transitional houes built (unit)	Permanent houses built (unit)	Roads built (km)	Bridges built(unit)	Airport built(unit)	Seaport built(unit)	Hospitals, built(unit)	Schools built(unit)	Teachers trained (person)	Fish ponds built (ha)	Agricultural land built, (ha)	Enterprises upport (unit)	Churchs and mosques built(unit)	Government buildings built(unit)
Amount of recovery target		Mar.2008		-	132,928	3,000	1,628	11	17	923	1,750	8,999	27,593ha	70,000ha	100,000	-	450
Recovery condition	Laying down the foundation for a better future	2005	Sep	5,634	4,083									6,689			
		≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀
	Tsunami Recovery Indicators Package	2006	Oct					4	2		556						
			Nov			1511	158			324		5,429	6,800		43,263		
	QUICK STAT		Dec	15,000	57,000	1500	158	5	14	328	747	5,385	6,800	50000	43,263		
		≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀
		2007	Apr	17,159	64,971	1553	181	7	17	384	782	17,115	12,385	75483			
			May	17,159	77,194	1553		7	17	405	782	17,115	12,385	75483		1364	
			Jun	17,159	84,387	1586	181	10	17	405	804	21,962	27,593	63923	77,316	1472	332
			≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀
			Aug	18,424	90,861	1586	216	10	17	515	822	22,436	12,935	64019	82,595	1477	367
			Sep	18,424	93,629	1586	216	10	17	515	822	22,436	12,935	64019	82,595	1477	367
			Oct	19,482	102,063	2006.8	216	10	17	534	837	22,548	12,935	64019	99,710	1477	367
			Nov	19,482	102,063	2191	226	10	17	613	868	23,095	12,935	64019	99,903	1481	795
			Dec	19,889	104,287	2191	226	10	17	613	888	23,270	13,570	78846	100,058	1512	808
		2008	Jan	19,889		2475	253	10	17	757	922	24,369	14,589	93554	100,196	1620	933
			≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀	≀
	e-aceh-nias.org		Nov	-	124,454	3,055	266	12	20	954	1,450	38,911		103,273	139,282	1620	979
Recovery ratio		at Nov.2008		-	93.6%	101.8%	16.3%	109.1%	117.6%	103.4%	82.6%	432.4%	52.9%	147.5%	139.3%	-	217.6%

accepted to analyze recovery process by Cumulative Normal Distribution curve.

4.3 Sample data of building construction

Table 3 shows the recovery process in Indonesia classified by 14 kinds of urban infrastructure indicators such as department of housing (temporary housing and permanent housing), Infrastructure (road, bridge, airport and seaport), education (school and training of teacher), medical (hospital), economy (farmland, fishery and enterprise support), cultural affairs (mosque or church) and Institutional development (government office) based on statistical data. Figure 3 shows the recovery process in Indonesia calculated by the cumulative number of completed permanent houses.

4.4 Plotting of recovery curves

The factors of time (months) and the ratio of building completion were used to draft the recovery functions. The time period begun in December 2004, with January 2005 is regarded as month "1", and extends over 50 months until February 2009. The ratio of building completion for a given time period is calculated based on the total amount of completed buildings. For a time period of t (months), the cumulative ratio of building completion $R(t)$ can be described by the Cumulative Normal Distribution curves, using the following equations:

a. Cumulative Normal Distribution curve

$$R(t) = \Phi((t - \lambda) / \zeta) \qquad [1]$$

Where Φ represents the standard Normal Distribution, and λ and ζ are the mean and standard deviation of t, respectively. The two parameters λ and ζ are determined using the least squares method on probability paper.

- **Analysis of recovery processes**

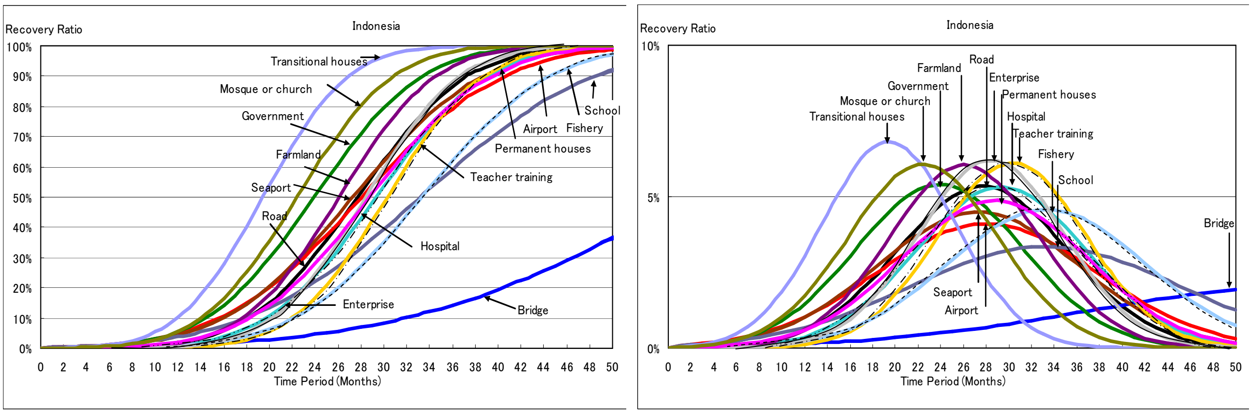
Figure 4 shows the recovery curves in Indonesia by 14 kinds of urban infrastructure indicators. Table 4 shows the parameters and recovery speed each of recovery curves. In this study, the authors assessed recovery curves by 2 point. First point was to analyze average completion months λ. It means the average period to complete recovery infrastructure. Second point was to analyze final completion months. It means the period of complete to recovery of all infrastructure.

5.1 Comparison of completion months

As a result of comparing the average completion months with the final completion months, the recovery process of transitional houses (Average: 19.4, Final: 37.6, Figure 5a) were the earliest all of indicators. And after followed by mosques and churches (Average: 22.4, Final: 42.8, Figure 5e), government buildings (Average: 23.9, Final: 45.2, Figure 5f), and Farm land (Average: 26.1, Final: 46.5, Figure 5d). These kept the same ranking in both average completion months and the final completion months. On the other hand, the recovery process of school (Average: 33.2, Final: 59.7, Figure 5c), fishpond (Average: 33.3, Final: 60.3, Figure 5d), bridges (Average: 56.7, Final: 83.2, Figure 5b) were slower than other indicators. And, bridge was the slowest all of indicators. In addition, permanent houses (Average: 28.8, Final: 54.2, Figure 5a), roads (Average: 27.7, Final: 50.8, Figure 5b), airports (Average: 28:1, Final: 53.1, Figure 5b), seaports (Average: 27.3, Final: 51.1, Figure 5b) drop the ranking from the average completion months to the final completion months.

5.2 Difference in plan and actual

In the last phase, the authors analyzed the difference between the plan and actual recovery process. Table 5 shows the data. As it is seen, the actual recovery process of transitional houses was delayed than that was planned by 7.6 months. Moreover, permanent houses delayed than the plan by 2 years (Figure 5a). It is thought that the confusion of recovery plan is a caused in this situation. On the other hand, mosques and churches, government buildings, Farm land kept early recovery speed (Figure 5d, e, f).



(a) Recovery curves (b) Probability density functions

Figure 4: *Recovery curves and probability density functions in Indonesia*

Table 4: *Recovery curve parameters and recovery speed in Indonesia*

Recovery section	Recovery indicaters	λ	ζ	R^2	Average completion period		Change Rank	Final completion period		Change Rank
					Months	Rank		Months	Rank	
Housing	Transitional houes built (unit)	19.4	5.855	0.888	19.4	1		37.6	1	–
	Permanent houses built (unit)	28.8	8.197	0.922	28.8	9		54.2	11	Down
Infrastructure & Other Public Facilities	Roads built (km)	27.7	7.468	0.938	27.7	6		50.8	8	Down
	Bridges built(unit)	56.7	19.417	0.845	56.7	14		83.2	14	–
	Airport built(unit)	28.1	9.699	0.940	28.1	7		53.1	10	Down
	Seaport built(unit)	27.3	8.889	0.861	27.3	5		51.1	9	Down
Education & Health	Hospitals, built(unit)	29.3	7.508	0.946	29.3	10		49.9	6	Up
	Schools built(unit)	33.2	11.919	0.890	33.2	12		59.7	12	–
	Teachers trained(person)	30.3	6.519	0.890	30.3	11		50.5	7	Up
Economic and Business Empowerment	Fish ponds built (ha)	33.3	8.718	0.945	33.3	13		60.3	13	–
	Farm land built (ha)	26.1	6.601	0.907	26.1	4		46.5	4	–
	Enterprise support(unit)	28.4	6.423	0.879	28.4	8		48.3	5	Up
Religion, Social and Cultural Affairs	Churchs and mosques built(unit)	22.4	6.579	0.928	22.4	2		42.8	2	–
Institutional development section	Government buildings built(unit)	23.9	7.380	0.933	23.9	3		45.2	3	–

Table 5: *Difference of plan and actual recovery process in Indonesia*

Recovery section	Recovery indicaters	Final completion period		Period of recovery plan								
		Months	Rank	First plan Oct.2005 (months)	Difference of plan (months)	Rank	Second plan Dec.2005 (months)	Difference of plan (months)	Rank	Third plan Apr.2006 (months)	Difference of plan (months)	Rank
Housing	Transitional houes built (unit)	37.6	1	30	Δ7.6 over	11	30	Δ7.6 over	9	30	Δ7.6 over	7
	Permanent houses built (unit)	54.2	11		Δ24.2 over	12		Δ24.2 over	11		Δ24.2 over	11
Infrastructure & Other Public Facilities	Roads built (km)	50.8	8	48	Δ2.8 over	8	60 or over	9.2 early	5	45	Δ5.8 over	4
	Bridges built(unit)	83.2	14		Δ35.2 over	13		Δ23.2 over	10		Δ38.2 over	13
	Airport built(unit)	53.1	10		Δ5.1 over	10		6.9 early	7		Δ8.1 over	8
	Seaport built(unit)	51.1	9		Δ3.1 over	9		8.9 early	6		Δ6.1 over	5
Education & Health	Hospitals, built(unit)	49.9	6	60 or over	10.1 early	4				33	Δ16.9 over	9
	Schools built(unit)	59.7	12		on schedule	6					Δ26.7 over	12
	Teachers trained(person)	50.5	7		9.5 early	5					△17.5 over	10
Economic and Business Empowerment	Fish ponds built (ha)	60.3	13	60 or over	on schedule	7	60 or over	on schedule	8	54	Δ6.3 over	6
	Farm land built (ha)	46.5	4		13.5 early	2		13.5 early	3		7.5 early	2
	Enterprise support(unit)	48.3	5		11.8 early	3		11.8 early	4		5.8 early	3
Religion, Social and Cultural Affairs	Churchs and mosques built (unit)	42.8	2	60 or over	17.2 early	1	60 or over	17.2 early	1			
Institutional development section	Government buildings built (unit)	45.2	3				60 or over	14.8 early	2	54 or over	8.8 early	1

6 Conclusion

In this study, recovery curves were developed to assess recovery from the 2004 Indian Ocean Tsunami using the construction ratio of urban infrastructure in Indonesia. In addition, the authors analyzed the difference between the actual process of reconstruction and prepared recovery plans.

It found the recovery process in average and final completion months of urban infrastructures in Indonesia. Recovery curves could be used to quantitatively assess the differences in recovery efforts of various urban infrastructures.

However, some problems remain in this study. The authors analyzed amount of infrastructure and period of recovery plan. But they did not refer to the cost problem of managing money and man power. These indicators are important to analyze the recovery process. So, it needs to consider combining. Moreover, this paper focused to capture the whole image of the recovery process in Indonesia. At the next stage, it is necessary to analyze the differences between regions.

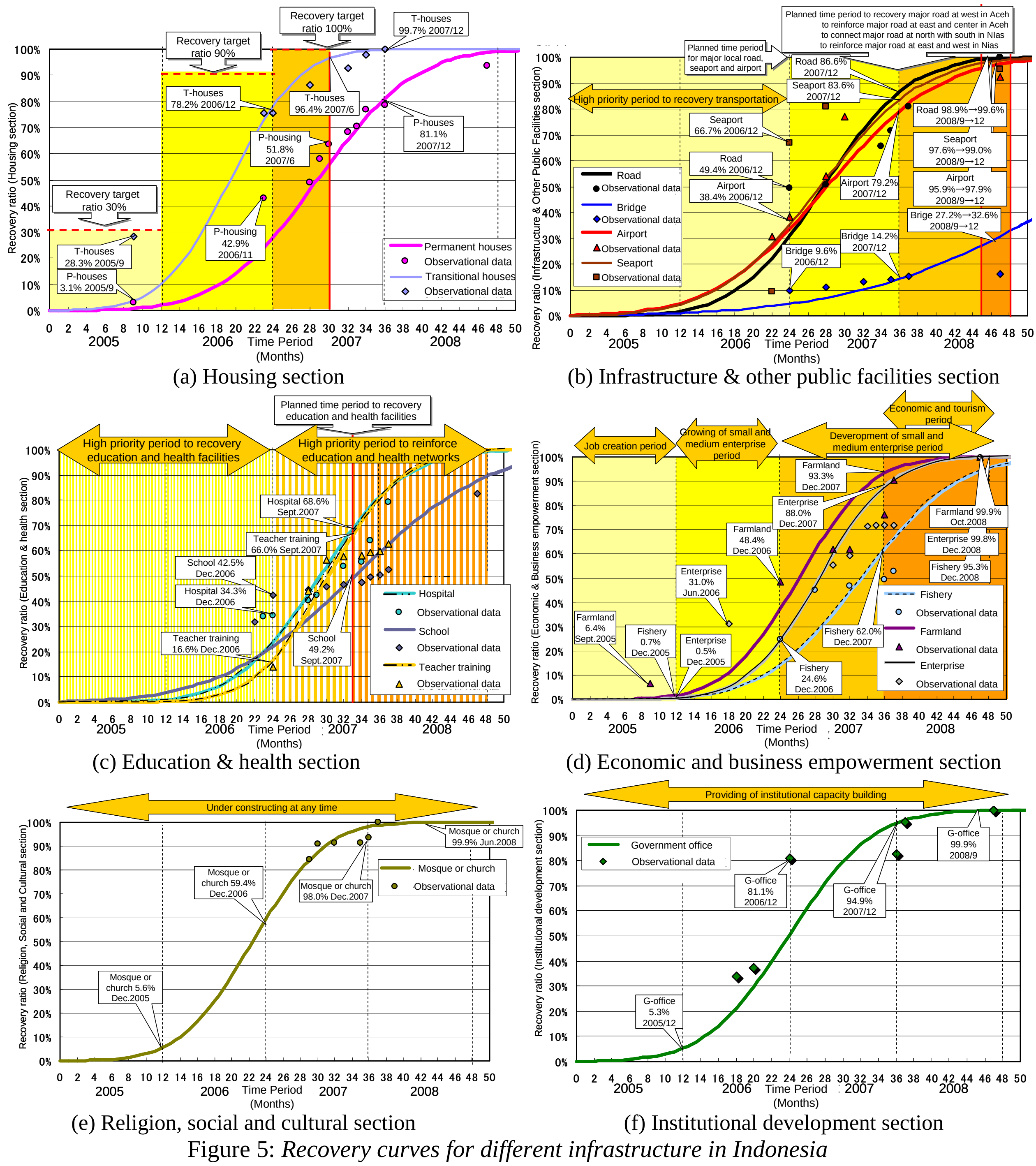


Figure 5: *Recovery curves for different infrastructure in Indonesia*

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Dr. Murao had researched on "Comparative Study of the Policy and Urban Planning for Disaster Management in the USA and Japan." in the US as a Fulbright Visiting Scholar 2009-2010 at Graduate School of Design, Harvard University, and Pacific Tsunami Museum managed by the University of Hawaii since July 2009. His recent research interest is the relationship between architectural/urban design and disaster mitigation.