Real-Time Impact Analysis and Response using a New Disaster Metrics: 2018 Sulawesi (Indonesia) Earthquake and Tsunami

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Abbreviations:
BASARNAS: Indonesia National Agency of Search and Rescue
BMKG: Meteorological, Climatological, and Geophysical Agency
DSI: Disaster Severity Index
POLRI: Indonesia National Police
TNI: Indonesia National Armed Forces
USGS: US Geological Survey

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Abstract

Introduction: The Richter Scale measures the magnitude of the seismic activity for an earthquake; however, it does not quantify the humanitarian need at the point of impact. This poses a challenge for humanitarian stakeholders in decision and policy making, especially in risk reduction, response, recovery, and reconstruction. The new disaster metrics tool titled "The YEW Disaster Severity Index" (DSI) was developed and presented at the 2017 World Congress of Disaster and Emergency Medicine, May 2017, Toronto, Canada. It uses a median score of three for vulnerability and exposure indicators, a median score percentage of 100%, and medium YEW DSI scoring of four to five as baseline, indicating the ability to cope within local capacity. Therefore, scoring more than baseline coping capacity indicates that external assistance is needed. This special real-time report was presented at the 2nd National Pre-Hospital Care Conference and Championship, October 2018, Malaysia.

Report: The aim of this analysis is to present the real-time humanitarian impact and response to the 2018 earthquake and tsunami at Donggala and Palu, Sulawesi in Indonesia using the new disaster metrics YEW DSI. Based on the earthquake (measuring 7.7 on the Richter Scale) and tsunami at Donggala, the humanitarian impact calculated on September 29, 2018 scored 7.4 High in the YEW DSI with 11 of the total 17 indicators scoring more than the baseline coping capacity. The same YEW DSI score of 7.4 was scored on the earthquake and tsunami at Palu, with 13 of the total 17 indicators scoring more than baseline ability to cope within local capacity. Impact analysis reports were sent to relevant authorities on September 30, 2018.

Discussion & Conclusion: A State of Emergency was declared for a national response, which indicated an inability to cope within the local capacity, shown by the YEW DSI. The strong correlation between the earthquake magnitude, intensities, and the humanitarian impact at Donggala and Palu reported could be added into the science of knowledge in prehospital care and disaster medicine research and practice. As a conclusion, the real-time disaster response was found to be almost an exact fit with the YEW DSI indicators, demonstrating the inability to cope within the local capacity.

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Introduction

Most of the earthquake scales either measures the real-time seismic magnitude or the intensities of it (such as Richter Scale;[1] Japan Meteorological Agency Seismic Intensities Scale, or Shindo Scale;[2] and Modified Mercalli Intensities Scale[3]). However, none of them measure the real-time humanitarian impact based on needs of response from the point of social determinants of health,[4] basic physiological needs,[5] critical infrastructure,[6] economy,[7] topography,[8] population density,[9] accessibility to the impact site,[5] and also corruption perception index.[10] This poses a challenge to public health responders and humanitarian stakeholders, mainly in decision and policy making for disaster risk reduction, response, recovery, and reconstruction. This special report was presented at the 2nd National Pre-Hospital Care Conference and Championship, October 2018, Malaysia.[11]

15 Vulnerability indicators	Criteria	Score
1.Time Ocurance	Morning (06:00-14:00)	1
	Afternoon or late evening (14:00-22:00)	3
	Night (22:00-06:00)	5
2.Impact Time/Duration	1-24 hours	1
	>24-72 hours	3
	>72hours	5
3.Topography	Planar	1
	Mountainous	3
	Isolated island	5
4.Radius from the impact site	1-10km (1district/town/village)	1
	>10km (>1 district/town)	3
	>100km (>10 districts/towns approximately)	5
5.Accessibility to the impact site	No distruption in main transport lifeline (road, air,sea)	0
	Accesible via land(motorbike/bicycle)	1
	Accesible via land(animals/by walking)	2
	Accesible via sea route (boat) & air (helicopter)	3
	Accesible via air (helicopter)	4
	Not accesible at all to the impact site	5
6.Population Density	Low (rural)	1
	Medium	3
	High (urban)	5
7.Main source of economy at impact site	not affected	1
	temporary affected	3
	long term affected	5
8.Public infrastructure	Public infrastructure not affected (no changes before/after disaster)	1
	Public infrastructure <25% affected but still functioning	2
	Public infrastructure <50% affected but still functioning	3
	Public infrastructure >50% affected, need assistance	4
	Public infrastructure totally affected , total assistance needed	5
9.Communication	Communication not affected (no changes before/after disaster)	1
	Communication partially affected, only able to communicate via radio satellite phone	3
	Total destruction of communication network	5
10.Type of country economic	high income country	1
Latest World Bank Classification-2018	middle income country	3
	low income country	5
11.Governance	Corruption Perception Index *Latest Ranking-2018, Transparency International*	
*in the case of countries ranking not available, global territories	0-20	5
average ranking will be selected.	>20-40	4
0 = highly corrupt	>40-60	3
100 = very clean	>60-80	2
<50 = serious corruption problem	>80-100	1

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Figure 1. Fifteen Vulnerability and Two Exposure Indicators and Their Criteria *(continued)*.

Report

The aim of this report is to analyze the real-time humanitarian impact needs and response to the 2018 earthquake and tsunami at Donggala and Palu, Sulawesi in Indonesia, using the new disaster metrics[12,13] titled the "YEW Disaster Severity Index" (DSI). As a benchmark in disaster response, the index is a comparison to be made with real-time relevant authorities' response and humanitarian impact needs, based on the disaster metrics scoring.

The new disaster metrics[12,13] tool, YEW DSI, was developed to estimate the humanitarian impact using a quantitative method in forming a full picture by integrating magnitude and intensities of a disaster. It uses a median score of three for 17 vulnerability and exposure indicators, median score percentage 100%, and medium YEW DSI scoring of four to five as baseline, indicating the ability to cope within local capacity.[6] Therefore, scoring more than baseline coping capacity indicates external assistance or response is needed, with scoring criteria shown in Figure 1.

A notification was received on the real-time major earthquake and tsunami that was activated by the Meteorological, Climatological, and Geophysical Agency (BMKG; Jakarta, Indonesia)[14] via android application on September 28, 2018 and continued until September 29, 2018 with more than 40 aftershocks. The real-time disaster notification was triangulated with the BKMG[15] official website for the earthquake with Richter Scale of ≥5.0, as well as the tsunami by the US Geological Survey (USGS; Reston, Virginia USA)[16] site.

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15 Vulnerability indicators	Criteria	Score
	Basic Survival Resources:Water and Sanitation Hygiene, Food Security, Shelter	
12.Water	No distruption in water infrastructure	0
	Distruption in water infrastructure	1
	Available of water source	2
and	Access to clean water via purification tablets/ceramic fliter	3
	Access to clean water via drillling bore hole well	4
	Non-potable water/Not available water source and inceased in diarrhoea, skin diseases & water related diseases	5
Sanitation Hygiene	No distruption in sanitation infrastructure	0
*Water&Sanitation scoring =	Distruption in sanitation infrastructure	1
(total water +sanitation scoring)/2	Available of mobile/ portable latrines ratio 1:<20	2
to get the average score	Available of mobile/ portable latrines ratio 1:≥20	3
	Available of some sort of damaged sanitation	4
	No access to improved sanitation facilities (Open defecation)&increased in diarrhoea and communicable diseases	5
13.Food Security	Food available & accessible (No changes before /after the disaster)	1
	Food available but needs transport from outside the impact site	2
	Food available but not accesible due to logistical & security issues	3
	Food stocks severely depleted (food scarcity)	4
	Food not available in or to the impact site.	5
14.Shelter	Shelter intact	1
	Shelter <25% destroyed	2
	<50% of the total shelter destroyed	3
	>50% of the total shelter destroyed	4
	All shelter totally destroyed	5
15.Healthcare Capacity	able to cope - all health facilites intact & functioning as normal situation	1
	- health facilities <25% destroyed	2
	- <50% of the total health facilities destroyed	3
	unable to cope - >50% of the total health facilities destroyed	4
	- All health facilities totally destroyed	5
	Total 15 vulnerability indicators score	
2 Exposure indicators	**Criteria**	**Score**
16.Number of Deaths	10-100	0
	>100-1000	1
*at least 10 or more= 0,	>1000-10 000	2
therefore less than 10= 0 score	>10 000-100 000	3
	>100 000-1 000 000	4
	>1 000 000	5
17.Number of Affected Persons	100-1000	0
CRED-EMDAT	>1000- 10 000	1
	>10 000- 100 000	2
	>100 000- 1 000 000	3
	>1 000 000- 100 000 000	4
	>100 000 000	5
	Total 2 exposure indicators score	

Figure 1 *(Continued)*. Fifteen Vulnerability and Two Exposure Indicators and Their Criteria.
Abbreviation: CRED-EMDAT, Center for Research on the Epidemiology of Disasters Emergency Events Database.

Donggala Impact Analysis (Table 1)

At Donggala, the earthquake measured 7.7 on the Richter Scale[14–16] and VII on the Modified Mercalli Intensities,[14–16] as well as the tsunami reported at the area. The humanitarian impact calculated within 12 hours of the incident scored a High Index of 7.4 on the YEW DSI,[12,13] based on its scoring criteria from Figure 1. The 11 out of the total 17 vulnerability and exposure indicators that scored more than three, or a median score percentage of 100%, the baseline coping capacity,[12,13] were: topography, radius from the impact site, accessibility to the impact site, main source of economy at the impact site, public infrastructure, communication, type of country, water and sanitation hygiene, governance (corruption perception index), shelter, and health care capacity.

Donggala[17] was located at an isolated island, scoring five with mountainous topography in Sulawesi, as its main roads were totally inaccessible. The nearest airport at Palu,[17,18] part of its runway was damaged, indicating totally inaccessible to the impact site and scoring five. The only accessible and functioning airport was via Balikpapan, Kalimantan,[17,18] the nearest island. The main road

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DSI with 17 Indicators	2018 Earthquake & Tsunami Donggala		
Requirement Title	**Score**	**Fit Xtd**	**Fit %**
Time Occurrence	3	9	100%
Impact Time	3	9	100%
Topography	**5**[a]	15	167%
Radius from the Impact Site	**5**[a]	15	167%
Accessibility to the Impact Site	**5**[a]	15	167%
Population Density	3	9	100%
Main Source of Economy at the Impact Site	**5**[a]	15	167%
Public Infrastructure	**5**[a]	15	167%
Communication	**5**[a]	15	167%
Type of Country	**5**[a]	15	167%
Governance (Corruption Perception Index)	**4**[a]	12	133%
Water and Sanitation Hygiene	**5**[a]	15	167%
Food Security	3	9	100%
Shelter	**5**[a]	15	167%
Health Care Capacity	**5**[a]	15	133%
No of Dead	1	3	33%
No of Affected	3	9	100%
GRAND TOTAL	70	210	137%
DSI		**7.4**	

Table 1. Donggala Impact Analysis using Yew Disaster Severity Index (DSI)[12,13]
Note: Computed Donggala DSI Scores Analysis on September 29, 2018 at 22:00.

$$\text{YEW DSI Formula} = \frac{\text{Total 17 indicators(vulnerability + exposure)} \times 3}{8(\text{best fit scale of DSI 1–8})}$$
$$= 70 \times 3/8(\text{best fit scale of DSI 1–8})$$
$$= 210,\ \text{best fit DSI } 7 \approx \text{High DSI } 7.4$$

DSI Categories, based on Figure 1 scoring criteria:

Low DSI	1	0–32
	2	>32–65
	3	>65–98
Moderate DSI	4	>98–131
(Baseline Coping Capacity)	5	>131–164
*High DSI	6	>164–197
	7	>197–230
	8	>230–263

[a] Overall, 11/17 indicators scored more than 3 or 100% median score percentage (Fit %), with a High DSI, more than the baseline coping capacity, indicating external assistance or response needed.

to Donggala[17,18] town via Jalan Poros Palu Mamuju was also totally inaccessible. The earthquake and tsunami impacts were felt in more than 10 districts, and also at neighboring countries as reported by USGS[16] and BMKG,[14,15] thus scoring five for radius of the impact site indicator. Communication and power supply[14,15] were totally cut off, scoring a maximum score of five. Most of the public or critical infrastructure and shelters were totally destroyed,[17,18] scoring five for both indicators, evidenced with the buildings and shelters less than two-stories high. The tsunami[14–16] had a reported wave height and velocity of approximately six meters with a wave speed of 800kph. Most of the affected population was trapped in a building due to its structure and height. As for health care capacity,[12,13] the nearest hospitals were located at Palu[17,18] town, thus scoring five. All 11 of the 17 indicators, as mentioned above, were plotted in the YEW DSI[12,13] scoring scale (Table 1) with 10 indicators that scored five, the maximum score of inability to cope within local capacity, and one indicator that scored four, above the baseline coping capacity. External assistance and disaster response were required based on the 11 indicator needs[6,12,13] and a High DSI of 7.4 in Table 1.

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DSI with 17 Indicators	2018 Earthquake &Tsunami Palu		
Requirement Title	**Score**	**Fit Xtd**	**Fit %**
Time Occurrence	**5**[a]	9	100%
Impact Time	1	9	100%
Topography	**5**[a]	15	167%
Radius from the Impact Site	**5**[a]	15	167%
Accessibility to the Impact Site	**4**[a]	15	167%
Population Density	**5**[a]	9	100%
Main Source of Economy at the Impact Site	**5**[a]	15	167%
Public Infrastructure	**5**[a]	15	167%
Communication	**5**[a]	15	167%
Type of Country	**5**[a]	15	167%
Governance (Corruption Perception Index)	**4**[a]	12	133%
Water and Sanitation Hygiene	**5**[a]	15	167%
Food Security	3	9	100%
Shelter	**5**[a]	15	167%
Health Care Capacity	**4**[a]	15	133%
No of Dead	1	3	33%
No of Affected	3	9	100%
GRAND TOTAL	70	210	137%
DSI		**7.4**	

Table 2. Palu Impact Analysis using Yew Disaster Severity Index (DSI)[12,13]
Note: Computed Palu DSI Scores Analysis on September 29, 2018 at 22:30.

$$\text{YEW DSI formula} = \frac{\text{Total 17 indicators(vulnerability + exposure)} \times 3}{8\text{(best fit scale of DSI 1–8)}}$$
$$= 70 \times 3/8\text{(best fit scale of DSI 1–8)}$$
$$= 210,\ \text{best fit DSI } 7 \approx \text{High DSI } 7.4$$

DSI categories, based on Figure 1 scoring criteria:

Low DSI	1	0–32
	2	>32–65
	3	>65–98
Moderate DSI	4	>98–131
(Baseline Coping Capacity)	5	>131–164
*High DSI	6	>164–197
	7	>197–230
	8	>230–263

[a] Overall, 13/17 indicators scored more than 3 or 100% median score percentage (Fit %), with a High DSI, more than the baseline coping capacity, indicating external assistance or response needed.

Palu Impact Analysis (Table 2)
The earthquake at Palu[17] measured 7.5 on the Richter Scale[14–16] and VI on the Modified Mercalli Intensities Scale, as well as the tsunami;[14–16] its humanitarian impact calculated also showed a High Index of 7.4 (Table 2) on the YEW DSI.[12,13] The 13 of the total 17 indicators scoring more than the baseline coping capacity,[12,13] based on the scoring criteria of the YEW DSI,[12,13] were: time occurrence and population density, with the remaining 11 indicators scoring the same as of Donggala. As Palu[17] was the main town, it had a higher population density[9,17] in the beach area, thus scoring five. Its topography[17] consists of isolated island, scoring five, and planar at Talise Beach. The main bridge[17,18] that connects the east and west of the Palu town was totally damaged and inaccessible. Palu airport's[17,18] runway was damaged, partially functioning, and accessible with smaller aircrafts, thus scoring four. The nearest accessible and fully functioning airport was via Balikpapan, Kalimantan.[17,18]

Most of the public or critical infrastructure and shelters were totally destroyed,[17,18] scoring five for both indicators, which was the same as of Donggala with the tsunami[14–16] wave height and velocity reported at approximately six meters with a wave speed of 800kph. Indonesia Tsunami Early Warning System[14,15] was

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	Donggala	Palu
DSI	7.4	7.4
Richter Scale	7.7	7.5
Modified Mercalli Intensities	7	6

Table 3. Pearson Correlation Coefficient Result
Note: Strong Correlation Coefficient, R-value = 0.92805.

called off after approximately 30 minutes of activation, and the community came out for beach cultural festival celebration after the earthquake at Talise Beach. Tsunami Early Warning Evacuation Siren was silent when the tsunami hit Palu. Most of the hospitals[17,18] located at east and west of Palu town were found either totally or partially damaged, with a score of four. Water and Sanitation and Hygiene facilities were totally damaged; only damaged latrines and non-potable water was available, thus indicating an inability to cope within local capacity[6,18] in Palu[17,18] and Donggala,[17,18] scoring 4.5≈5.

Detailed Humanitarian Impact Analysis scoring based on YEW DSI[12,13] (Table 1 and Table 2), as well as the real-time data, were sent to relevant authorities[19] on September 30, 2018 at 08:40. A State of Emergency[18] for Palu and Donggala, Sulawesi was declared by the Governor for national response.[19] The United Nations report and other nongovernmental organizations needs assessment reports only came out on October 2, 2018.[20]

Benchmarking the Response

The earthquake and tsunami at Palu and Donggala, with indicators and total scoring of an inability to cope within local capacity, were found to be almost an exact fit with the Indonesian Government's four main priorities[21] in Post-Disaster National Response, announced on October 2, 2018. The four main priorities follow.

The first priority[21] was on search and relief of the disaster-affected victims and evacuation during the golden hours. This was done by collaborating and mobilizing governmental agencies, such as Indonesian National Agency of Search and Rescue (BASARNAS; Jakarta, Indonesia),[22] Indonesian National Armed Forces (TNI; Jakarta, Indonesia),[23] and Indonesian National Police (POLRI; Jakarta, Indonesia).[24] The Ministry of Public Works and Public Housing of the Republic of Indonesia (PUPR; Jakarta, Indonesia)[25] also deployed more excavation heavy equipment, giving accessibility to the disaster impact site and aiding the BASARNAS Team.

The second priority[21] was setting up medical response services in terms of health care capacity for treating the affected victims. Mobile hospitals needed to be set up at the affected areas, and the Indonesian Military Sealift Command Hospital Ship[23] needed to deploy to the disaster impact sites. Mobile hospital tents were also being set up at the partially damaged Palu airport by the TNI.[23]

The third priority[21] was on fulfilment of basic needs and logistics for the affected victims, especially access to clean water and sanitation hygiene facilities. The TNI[23] and POLRI[24] were to be in charge of ensuring those basic needs were reachable to the affected communities.

The fourth priority[21] was focusing on reconstruction and restoration of critical facilities and public infrastructure, especially vital facilities such as airports, roads, electricity, and fuel supply. This would then revive the economy at the impact site, paving the road to recovery.

The 2018 Indonesian earthquake and tsunami real-time disaster response priorities[21] were almost an exact fit with the YEW DSI indicators, and the scoring of inability to cope within local capacity.[6] The State of Emergency declaration[18] indicated an inability to cope within local capacity, with external assistance and response needed. This was evidenced in a High DSI of 7.4 for both Donggala and Palu (Table 1 and Table 2) and national response[18] deployed from Jakarta and Kalimantan, as well as international response, based on needs.

The magnitude intensities of the Richter Scale[1] and the Modified Mercalli Scale[3] reported for Palu and Donggala and the humanitarian impact in the disaster metrics calculated were highly significant, with Pearson correlation coefficient of 0.9280 (Table 3) using Microsoft Excel 2013 (Microsoft Corp.; Redmond, Washington USA) statistical analysis.[26]

Discussion

The new disaster metrics[12,13] indicators and index scoring that has been applied to the 2018 Sulawesi earthquake and tsunami were able to calculate and project the impact within 12 hours after the incident. This can be used as a real-time guide in humanitarian impact by public health and humanitarian stakeholders, mainly in prehospital and disaster medicine response, reconstruction, and recovery, as well as preparedness in disaster risk reduction.

This special report showed statistically significant correlation between the Donggala and Palu earthquake magnitude reported in Richter Scale,[1] intensities reported in Modified Mercalli Intensities,[3] and its humanitarian impact calculated and reported in the YEW DSI.[12,13] The new discovery of the correlation between the earthquake magnitude, intensities, and the humanitarian impact in this special case study could be added to the prehospital and disaster medicine knowledge-base for further research.

However, evidence is shown from a search of literature that there is a lack of real-time data[27] for researchers and various stakeholders, which is the main gap in natural disaster impact needs and response. Concerns of the accessibility of real-time data from various sources[27–29] include: autonomy, global safety, and also factoring in the cost of corruption and increasing transparency of disaster risk reduction, response, and recovery.

Conclusion

The earthquake and tsunami at Donggala and Palu and their real-time humanitarian impact needs shown in the YEW DSI scored an inability to cope within local capacity, with outside assistance or response needed. Benchmarked response needs in the disaster metrics scored were found to be almost an exact fit benchmarking with the real-time Indonesian National Response's four main priorities. The real-time analysis also showed a statistically significant correlation, 0.9280, of the new disaster metrics with the Richter Scale and the Modified Mercalli Scale. With this statistical correlation, it will increase transparency of policy and decision making by using an evidence-based tool in humanitarian impact analysis.

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