UNIVERSIDAD DE OVIEDO

Development of a new tool for climate related natural disaster metrics

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Programa de doctorado: Investigaciones humanísticas

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Desarrollo de una nueva herramienta para la métrica de los desastres relacionados con el clima

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RESUMEN DEL CONTENIDO DE TESIS DOCTORAL

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RESUMEN (en español)

La herramienta para la métrica de desastres desarrollada y denominada "Índice YEW de gravedad de desastres" permite cuantificar, predecir y estudiar varios tipos de desastres naturales, incluidos los relacionados con el clima, de forma simultánea y continua, enfatizando los enfoques de vulnerabilidad y exposición incluidos en la definición de desastre, el impacto sobre las poblaciones humanas, la salvaguarda de vidas y los medios de vida, mediante la inversión en riesgos informados para la reducción del riesgo de desastres.

El riesgo informado que proporciona el índice y calculado en función de las métricas de desastres será beneficioso para entidades e instituciones a nivel mundial, desde países vulnerables a desastres relacionados con el clima hasta modelos de riesgo de catástrofes en seguros y reaseguros paramétricos y en la gestión de transferencia de riesgos.

Se incluyó el índice global de percepción de corrupción en la gobernanza de un país para estimar con mayor precisión la verdadera escala del desastre. La métrica de desastres se probó en 3 fases, principalmente retrospectivamente a lo largo del tiempo, en tiempo real y casi en tiempo real para la preparación, la reducción de riesgos y la respuesta. Se realizaron estudios de viabilidad y se encontró que eran significativos, antes de probarlo en las 3 fases mencionadas anteriormente. Como conclusión, las métricas de desastres analizadas sobre preparación, reducción de riesgos y respuesta pudieron calcular y proyectar la población humana impactando vidas y medios de vida en función de la magnitud o las intensidades documentado en un desastre.

RESUMEN (en Inglés)

The Disaster Metrics tool developed, titled 'The YEW Disaster Severity Index' was able to quantify, predict and test various natural disasters, including those climate related, simultaneously and continuously, underpinning the vulnerability and exposure of a disaster definition, impacting human population, thus saving lives and livelihood by investing in informed risk, on disaster risk reduction. The Risk Informed calculated based on the Disaster Metrics, will be beneficial to various stakeholders globally, from countries vulnerable to climate related disasters to catastrophe risk modelling in parametric insurance and reinsurance, risk transfer management. Global Corruption Perception Index in governance of a country was included to more accurately estimate the true scale of the Disaster. The Disaster Metrics was tested in 3 phases, mainly retrospectively across timeline, real-time and near-real-time for preparedness, risk reduction and response. Feasibility studies were done and found to be significant, prior to testing it in the above mentioned 3 phases. As a conclusion, the Disaster Metrics analysed on preparedness, risk reduction and response was able to calculate and project the human population impacting lives and livelihood based on magnitude or intensities recorded on a disaster.

SUMMARY OF THE DOCTORAL THESIS COMPENDIUM

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LIST OF ABBREVIATIONS

ACAPS	Assessment Capacities Project
API	Application Programming Interface
BKMG	Meteorology, Climatology, and Geophysical Agency of Indonesia
COW	Communication on Wing
CRED-EMDAT	Centre for Research in Epidemiology and Disasters, at Emergency Events Database
CRASAR	Centre for Robot-Assisted Search and Rescue
DSI	Disaster Severity Index
DSS	Disaster Severity Scale by Jan De Boer
EMT	Emergency Medical Teams
FAA	Federal Aviation Authority
GDP	Gross Domestic Product
GIS	Geographic Information System
IDNDR	International Decade of National Disaster Reduction
IoT	Internet of Things
JMA	Japan Meteorological Agency
UAVs	Unmanned Aerial Vehicles or drones
USD	United States of America Dollar

UNISDR	United Nations Office for Disaster Risk Reduction
LiDAR	Light Detection and Ranging
MSE	Mean Squared Error
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic Atmospheric Administration
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PGV	Peak Ground Velocity
PGA	Peak Ground Acceleration
SDGs	Sustainable Development Goals
SGD	Stochastic Gradient Descend
SEDAC	Socioeconomic Data and Applications Centre
WMO	World Meteorological Organization

1. INTRODUCTION

Background and Significant of Studies with Literature Review

The Ring of Fire[1], a horseshoe shape string of the worlds' most active volcanic and seismic activities is at the Atlantic and Pacific Oceans, also the basins location path of the hurricane and typhoon alley[2,3,4], are home to more than 50% of the world population in 2019[5]. 2016, 2019 and 2020 recorded as the top three hottest temperature in decades, due to El Niño extreme warm climate, despite the cooling La Nina effect at the end of 2020, confirmed by World Meteorological Organization (WMO),[6] as of January 14, 2021.

Increase in Ocean heat surface linked to hurricane such as Hurricane Harvey was also proven by Trenberth, K. E. et al., 2018[7]. 2019 was also the record setting ocean warming[8,9] and also global land warming[9]in human history since 1880 and has recorded a series of significant climate abnormalities and events, such as in hurricane, cyclone, and typhoon.

The Hurricane Season 2019 in the Atlantic Ocean[9], above average activities were recorded; mainly 18 storms and 6 hurricanes, with record setting Hurricane Dorian at the Bahamas. As for the Indian Ocean Cyclone Season 2019[9], 8 storms and a total of 6 cyclones, 3 of them sustained maximum winds of more than 185km/hour were recorded for the first time at the North Indian Ocean. Above average activities of 16 storms and 13 cyclones were also recorded at the South Indian Ocean. Tropical Cyclone Idai, was one of the deadliest and costliest cyclones ever recorded in the Southwest Indian Ocean, with a maximum sustained wind of 205km/hr. The 2019 Western North Pacific Ocean Typhoon Season[9] also recorded above average activities with 25 storms and 14 typhoons.

Climate related global warming due to the increase in surface sea temperature, causing significantly increased in intensities of Tropical Cyclones globally over the past four decades was recently published in May 2020 at the Journal of Proceedings of the National Academy of Sciences by Kossin J.P., et al[10], from the National Oceanic Atmospheric Administration and the University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies. This was evidenced with Typhoon Hagibis in 2019[9], the most rapidly intensified typhoon ever recorded in the Pacific Ocean with a maximum sustained wind of 260 km/hr. The current season of May 2020 Tropical Cyclone Amphan[11] intensified into 185km/hr within 24 hours prior to reaching the shore of West of Bengal, India, and border to Bangladesh.

This is major concern in climate related disasters, especially measuring or quantifying the estimation population impact at the affected area. Most of the tsunami, volcanic, seismic, hurricane and typhoon are measured in real-time magnitude or intensities of it; such as Volcanic Explosive Index[12], Richter Scale[13], Japan Meteorological Agency (JMA) Seismic Intensities Scale or Shindo Scale[14], Modified Mercalli Intensities Scale[15], Peak Ground Velocity[16], Peak Ground Acceleration[16], Beaufort Scale[17] and Saffir-Simpson Hurricane Wind Scale.[18,19] The Richter Scale[13] measures the magnitude of the seismic activity in terms of energy exert on ground using log algorithm. Peak Ground Velocity[16] and Peak Ground Acceleration[16] are both use in earthquake engineering, in measuring the ground motion intensities at a particular point, mainly for seismic risk assessment and building code. Peak Ground Velocity[16] measures the speed of ground shaking at a point of the ground, whereas Peak Ground Acceleration[16] measures the change in velocity at a particular point. Modified Mercalli Intensities Scale[15] measures the effect of an earthquake using individual perceived shake intensities in the aspect of people response, building structure and natural environment.

Beaufort Scale[17] measures the intensities of wind velocity especially in typhoon, cyclone, and maritime purposes. The Saffir-Simpson Hurricane Wind Scale[18,19] measures the maximum sustained 1 min wind speed intensities for hurricane classification, mainly use in the Western Hemisphere.

Recognizing the needs to measure the climate related disaster and its' population impact, a few disaster index or scale such as Medical Severity Index[20], Fatality Based Natural Disaster Scale[21], to Munich Reinsurance (MunichRE; Munich Germany)[22] damage or loss were formulated, underpinned the impact of a disaster definition. John Hopkins University (Baltimore, Maryland USA) and the International Federation of Red Cross and Red Crescent (Geneva, Switzerland)[23] have both claimed that there is no single measurement that is able to capture the full scope of a disaster.

At present, no existing frameworks or tools are able to integrate the aspect of humanitarian population impact needs[24,34], in measuring and quantifying various climate related disasters at the same time, simultaneously and continuously, retrospectively across timeline, real-time and near-real-time. The World Risk Index[25] analyzed the risk of climate related disaster such as earthquakes, cyclones, floods, droughts, and sea level rise globally, from the aspects of exposure, susceptibility, coping capacity and adaptive capacity, updated annually. Whereas the Assessment Capacities Project (ACAPS) INFORM Global Crisis Severity Index[26] measures the severity of humanitarian access to the sudden onset crisis globally such as Novel Coronavirus 2019 pandemic, complex emergencies armed conflict, and also climate related disaster, updated daily. Bayram JD, et al.[27] have proposed a quantitative assessment tool using the concept of SPHERE (Geneva, Switzerland) Minimum Standards[28]; which is the core standards for humanitarian assistance provided to the affected people in disasters. However, the climate related natural disasters data indicators were used to construct the tool for complex emergencies namely the Public Health Impact Severity Scale. Bayram JD, et al.[29] have also evaluated the De Boer's Disaster Severity Scale (DSS) of 13 points and 7 parameters scale applied to 144 earthquakes retrospectively, from 2003 to 2013 using database from the National Oceanic Atmospheric Administration (NOAA)[30] and US Geological Survey[31]. The study[29] was aimed to examine the reliability of De Boer's DSS scale application on earthquake events. However, the result concluded that it failed to hold statistically dataset of the earthquake events. Arcos Gonzalez P, et al. [32] have also applied the Jan De Boer's Disaster Severity Score in the case of Spain to quantify the consequences of man-made and climate related disasters. However, the results[32] were not generalizable to climate related disaster. The Severity Scoring Model of Complex Emergencies Tool by Eriksson et al.[33] was developed by using a holistic concept of human needs based on the Marlow Hierarchy of Needs.[34] Nevertheless, the tool[33] has not been tested on any sample size of complex emergencies, be it retrospective or real-time.

However, none of these measures, predict or estimate in real-time its' humanitarian population impact, based on the magnitude and intensities of a disaster and on the needs' to response[24,34-36], preparedness or risk reduction.[24,34-36] Key indicators of climate related disasters that are being taken into consideration includes vulnerability and exposure impacting lives and livelihood[50]such as search and rescue in accessibility to the impact site,[24] population density[37] and its' topography.[38] Other indicators includes population basic physiological needs[34] such as food security,[39] critical facilities such as public infrastructure,[35,36] healthcare capacity,[40] socio-determinants of health,[41] socio-economic impacting livelihood[42,43] and factoring the corruption perception index[44,45] to get a true scale estimation of the disaster impact. This posed a challenge in catastrophe risk reduction in preparedness and response, mainly from the aspect of disaster medicine, public health, various stakeholders from civil-military, governmental and international organization, reinsurance,[46] disaster risk informed[36,103] and risk transfer management[100,101] such as in parametric insurance;[47-49] mainly in decision and policy makers.

The new Disaster Metrics tool titled 'The YEW Disaster Severity Index (DSI)[50,52] was developed with the aim to estimate the humanitarian population impact using a quantitative method, by integrating magnitude and intensities of a climate related natural disaster. It underpinned the UNISDR disaster definition of the ability to cope within local capacity,[35,36] with median score of 3 for vulnerability and exposure indicators, median score percentage 100% and Medium YEW DSI total scoring, as baseline[50]. Therefore, scoring more than baseline coping capacity indicate external assistance or response needed.[35,36] Search and Rescue (SAR) effort can be based on indicators scoring such as Impact time[51,70] as the first 72 golden hours for victim survival, topography[38] as the islands are submerged underwater including airports, and Accessibility to the Impact Site,[24] whereby only seaplane or military helicopter are able to land at the island.

The new Disaster Metrics tool 'The Yew Disaster Severity Index' was presented at the 2017 World Congress of Disaster and Emergency Medicine[52] as conference proceeding paper, with the sample size of 30 various climate disasters tested retrospectively. The full paper of the new Disaster Metrics tool has been reviewed, verified, and published on 2nd, January 2019 at the Cambridge Core Journal of Prehospital and Disaster Medicine.[50]

Retrospective data on climate related disasters were easily available, especially on disaster databases such as Reliefweb[53] and CRED-EMDAT[54]. However, the reliability of the data needs triangulation with various sources of secondary data.[30-31,53-54]

Therefore, most of the climate related disaster analysis on various disaster scale, such as Disaster Severity Scale (DSS),[20] Hurricane Hazard Intensity[55] and Hurricane Intensity Index[55] were based on retrospective disaster data. The De Boer's Disaster Severity Scale (DSS)[20] of 13 points and 7 parameters scale was tested by Bayram JD, et al. [29] and Gonzalez P, et al.[32] retrospectively using climate related natural disaster data. Hurricane Hazard Intensity and Hurricane Intensity Index was developed by Kantha, L.(2006)[55] in the challenge to replace Saffir Simpson Hurricane Wind Scale.[18,19]Hurricane Hazard Intensity and Hurricane Intensity Index were both tested retrospectively[55] with hurricane data in 2005; mainly Hurricane Wilma, Rita, Katrina, and Andrew.

Retrospective data of various climate related natural hazards globally from 1900 to 2016[54] was used in the construction of the disaster metrics upper and lower limit score of the vulnerable and exposure indicators. It was considered reliable, the best available, easily accessible, and feasible data after triangulation with various sources. [30,31,53,54] The upper limit score of an indicator, on the Disaster Metrics[50] was constructed based on the highest vulnerability or exposure data retrospectively. The same with a lower limit on the Disaster Metrics[50] indicator, constructed based on the lowest vulnerability or exposure data retrospectively.

Number of deaths, an exposure indicator in the Disaster Metrics,[50] was defined by the CRED-EMDAT[54] which include person confirmed dead, missing, or presumed death. Indirect deaths from disease or epidemics occurred after the emergency phase of the disaster was excluded from the official deaths count. The lower limit scoring was based on CRED-EMDAT[54] criteria of a disaster, at least 10 or more killed. A search was done on CRED-EMDAT[54] database retrospectively from 1900 to 2016 for climate related natural disaster, excluding biological disaster. 2,000, 000 deaths were recorded for

Floods in China on 1959, hence the upper limit for the number of deaths indicator on the Disaster Metrics[50] was set at > 1,000 000.

Corruption Perception Index,[44,45] classified as one of the vulnerability indicators on the Disaster Metrics.[50] This Index[44] measures the level of perceived public sector corruption globally in each countries governance, with world-wide ranking updated annually using retrospective data collected prior to that. Transparency International[44] defined the score ranking into 0 (most corrupted) to 100 (very clean), which indicate the lower score as higher vulnerability to corruption and vice versa. Ranking score of a country with less than 50, indicates serious corruption problem. The Corruption Perception Index(Governance) [44] score ranking of 0 to 100, has been adjusted into 5 categories, to fit into the Disaster Metrics[50] based on vulnerability. The 5 categories were mainly: 0-20, >20-40,>40-60,>60-80, >80-100. The vulnerability indicator of the Corruption Perception Index[44] upper limit was set at 0-20, as 0 was defined by Transparency International[44] as most corrupt, and lower limit was set at >80-100, as 100 was considered clean.

Retrospective data[30,31,53,54] was used as an evidence-based framework, in the construction of the Disaster Metrics.[50] All the indicators in the development of the Disaster Metrics[50] were evidence-based, some were adapted from UN reports[40,41] SPHERE Minimum Standards[28] and Food Agriculture Organization for food security[39]in practice and guidelines. A number of indicators were updated annually, to stay relevant with the latest situation in the Disaster Metrics,[50] such as the Gridded Population Density of the World[37] from NASA Socioeconomic Data and Applications Centre (SEDAC), World Bank Data[55] on new country classification by income for the indicator on type of country economy, and Corruption Perception Index Ranking by Transparency International.[44] The use of retrospective data in the Disaster Metrics,[50] computing and comparing it simultaneously at any point of a specific disaster timeline, is also the first step towards testing it in real-time and near real time.

Across timeline, retrospective disaster data is a feasible and reliable source with evidence-based triangulation, in formulating the disaster metrics. [50] It acts as a manual machine learning database for big data and can be stored online, such as in dropbox[57] or google cloud.[58] However, the speed and reliability of real-time satellite data from disaster and meteorological centres globally,[11,30] data from Internet of Technology[68] such as Artificial Intelligence Algorithm Disaster Rescue Robots,[59,62,64,65]Unmanned Aerial Vehicles (UAVs) or drones,[60] google satellite map[61] and mobile applications are fast and real-time evidence based, compared to internet searched for situation reports, on Reliefweb[53] or CRED-EMDAT[54] database, as there is a delay timeline and gaps in data reporting.

The usage of this emerging technology in real-time data, such as Unmanned Aerial Vehicles (UAVs) or drone[60] and Artificial Intelligence Mobile Rescue Robots[59,62,64,65] in disaster response and relief operations have been deployed globally since September 11, 2001 Twin Tower Attack. [62,64,65] The drones[60] have multiple usage and potential, such as in natural disaster response and relief operations,[66,69,70] insurance claim response and risk assessment, [67,69,70]reconnaissance and high -resolution mapping of the entire impact site,[63,69,70] temporary communication relay infrastructure,[69,70] search and rescue and logistical

support.[66,69,70]

According to Greenwood F et al. (2020)[63], Unmanned Aerial Vehicles (UAVs) or drones flew into the hurricanes in real-time to assess and capture the damage impacted by 2017 Hurricane Harvey and Irma. Prior to that, Dr Robin Murphy[64,65]from the Center for Robot-Assisted Search and Rescue (CRASAR)[62] has recorded various government approved global drones deployments for disaster response and recovery from 2005-2018; [62,64] mainly 2005 Hurricane Katrina and Wilma in USA, 2009 L'aquila Earthquake in Italy and Typhoon Morakot in Taiwan, 2010 Earthquake in Haiti, 2011 Earthquake in Christchurch, New Zealand and Earthquake in Tohoku, Japan, 2011 Floods in Thailand, 2012 Earthquake in Finale Emilia, Italy, 2013 Typhoon Haiyan in Philippines, Earthquake Lushan, China, as well as Floods in Boulder Colorado, USA. Drones deployment in 2014 includes SR530 Mudslides Response and Recovery in USA, Floods in Serbia, Bosnia-Herzegovina, Landslides Collbran, USA and Earthquake in Yunnan, China. Rotorcraft UAVs was also deployed to Hurricane Harvey, Irma and Maria, on 2017 and the Kilauea Volcano Lower East Rift zone event on 2018.

Various type of drones[67,69,70]are also being use for insurance claim response in damage and risk assessment. By flying small airborne drones with fitted 3 Dimensions mapping sensors[69,70] such as Light Detection and Ranging (LiDAR)[71,72]over the disaster impacted area of post hurricane, or floods, the insurance claim assessor, emergency medical team or risk engineers are able to identify properties or critical infrastructure that has been damaged or flooded. Those drones[69,70] are able to reconnaissance extensively the entire area of viewing angle image that are not possible with manned aircraft and mapped it in critical real-time high resolution. Thus, enabling a full picture in inspection of structural damage assessment[69,70] for critical facilities and buildings, as well as identifying the real risk mitigation. This will reduce the risk[103] and unnecessary danger exposed by the Emergency Medical Teams (EMT), disaster response actors, claim adjustor and risk engineer.

Hurricane Michael 2018 landfall in Florida and Georgia, United States has left over 2.6 million people without electricity and communication connectivity at the affected area.[73] Recognizing the needs in connectivity, the AT&T deployed their creation of the extreme weather drone called 'The Flying (COW) Communication on Wing[74] to Mexico Beach, Florida and hovered at 200 feet above the ground area, served as a temporary communication relay structure. The Flying COW[74] carries a small battery cell and antenna to connect via tethering physically between the drones and the ground area in providing highly secured data connectivity. It uses satellite to transport text messages, calls and data were transported via satellite. The Flying COW[74] drone was also deployed to Puerto Rico[75] after the landfall of Hurricane Maria 2017, with Federal Aviation Authority approval.

Heavy lift drones, such as Lockheed Martin K-MAX Unmanned Aircraft System[76] can be used for logistical support[69,70,76] in the area of inaccessible topography via manned vehicle or aircraft during a disaster, in transporting essential lifesaving equipment and items; such as medicine, food and water. It can also be used as a Drone Ambulance[76,77] in transporting Emergency Medical Team personnel and rescue survivors from the disaster impact site to a safer area.

Smaller drones fitted with high resolution camera are excellent in locating missing people. Recently, The Royal Malaysian Police deployed drones fitted with high resolution thermal imaging[78] to the low visibility dense forest in Malaysia, in a search and rescue mission.[79]

Looking at the exponential usage and potential development in this sector, the US Congress Committee in Transportation and Infrastructure and the Federal Aviation Authority (FAA)[80,81] have also discussed and raised the concerns in integrating the drone real-time data technology safely into the national airspace in mitigating collisions prior to flying approval in the airspace. The challenge and concerns[80-82] include public privacy, autonomy, national and global safety, and integration it in disaster response and relief operations system, as well as national airspace.

Real-time satellite disaster data can also be obtained from google satellite map,[61] meteorological and disaster centre globally. It can be easily downloaded via mobile applications using Internet of Technology.[68] Google Satellite Map LLC[61] can be downloaded and easily accessible via mobile application, updating the current disaster area of the impact site live. Most of the Meteorological and Disaster Centres real-time satellite data are easily accessible and available to the public via mobile applications such as from The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA),[83] Meteorology, Climatology, and Geophysical Agency of Indonesia (BKMG), [84,85] National Oceanic and Atmospheric Authority (NOAA)[30] of The United States, India Meteorological Department Satellite,[86] China Meteorological Department,[87] Japan Meteorological Agency (JMA) Satellite[88] and Korea Meteorological Administration Satellite.[89]

However, there are some real-time disaster satellite application that are not accessible to the general public such as DisasterAWARE[90] by Pacific Disaster Centre.[91] According to the Pacific Disaster Center,[91] the DisasterAWARE[90] application accessibility are solely for emergency responder, to prevent traffic congestion to the satellite application during a disaster.

It is important to test the Disaster Metrics[50] humanitarian population impact in real-time and near real –time and in integrating it into practice and guidelines, based on real-time magnitude intensities. The new Internet of Technology[68] from Disaster Center Satellite and mobile applications were integrated and tested on the data collection of the real-time and near real-time feasibility study, mainly in Hurricane Lane Hawaii, USA[30,91] and Cyclone Bulbul, Bangladesh.[92-94] Real-time satellite data from the internet websites and mobile applications were collected from India Meteorological Department,[86] Storm Prediction Centre by National Oceanic Atmospheric Administration/National Weather Service,[30] Pacific Disaster Centre[91] and Bangladesh Department of Meteorological.[92-94] This is to estimate and predict the humanitarian population impact efficiently and timely response and relief operations. It can also be used as a guide key performance indicator in benchmarking the response, monitoring, evaluation, and future risk reduction. The Disaster Metrics[50] was developed as a continuity metrics rather than just a snapshot projection of the disaster humanitarian impact, with its' utility mainly on prediction estimation, impact analysis, monitoring or evaluation of response interventions.

Feasibility studies were done retrospectively from the year of 2006 to 2019 on sample size of 100 climate disasters mainly on earthquake, typhoon, tropical cyclone, or hurricane applied to the Disaster Metrics,[50] prior to testing it in real-time and also near real-time on preparedness and response. Testing in real-time preparedness and response were also done on a few predicted hurricane and cyclone and found to be the similar to the real-time local government and relevant international authorities' response.

Hurricane Lane Hawaii[30,91] predictions of its' impact were plotted on the Disaster Metrics[50], as 6.1 High YEW DSI[50] and submitted to the Pacific Disaster Centre[91], 72 hours prior to the landfall. The actual landfall scored a Moderate YEW DSI[50] of 5.9. Cyclone Bulbul Bangladesh[92-94] was also tested a few hours prior to the landfall and scored a High YEW DSI[50] of 6.8 on its' predicted impact. The predicted impact analysis result was sent to the Deputy Secretary of Bangladesh Ministry of Disaster Management and Relief[94] via email for referencing in preparedness, response and also evaluation benchmarking.

Future Risk Reduction in preparedness, recovery interventions or policies guidelines could be based on the evidence-based results of indicators scoring more than baseline coping capacity[50], High in Risk Informed[50] such as Healthcare Capacity[50] indicator by the Bangladesh Ministry of Health and Family Welfare[95], Main source of Economy[50] indicator by Ministry of Agriculture[96] and Ministry of Environment, Forests and Climate Change[97] especially in Sundarbans Delta, Public infrastructure (critical infrastructure)[50] indicator by the Bangladesh Ministry of Civil Aviation and Tourism[98], Port Authority, as well as schools by the Ministry of Education. [99]

The result of the feasibility study indicates the significance of the research in climate related natural disaster tested retrospectively, real-time response and near real-time preparedness application of disaster metrics[50] tool into practice, as an early warning prediction system[91-93,110], future risk reduction, risk transfer management[100,101] and risk financing[102] in response to a disaster or catastrophe.

With the feasibility results on the disaster metrics[50], further research on this tool could be used as an evidence-based indicator on humanitarian population impact, for transparency in guidelines and practice, based on magnitude and intensities recorded. Peak Ground Velocity and Peak Ground Acceleration indicators[16], use in earthquake engineering to measure the earthquake ground shake intensities. Both are used in disaster risk assessment[36] and risk informed[36,103], especially in building code for critical facilities such as hospital and population affected. These indicators[16] are also use in Disaster Risk Financing[102] and Disaster Risk Transfer[100,101] such as in Parametric Disaster Insurance.[47]

The Peak Ground Velocity (PGV)[16] and also Modified Mercalli Intensities Scale[15], both used as a benchmark guide in parametric earthquake insurance[49], whereby Jumpstart

Insurance using Lloyd's capacity linked parametric earthquake product payment to an agreed set of criteria, based on U.S. Geological Survey earthquake measurements.

Saffir-Simpson Hurricane Wind Scale[18,19] was also used as one of the hazard parameters for the Caribbean Catastrophe Risk Insurance Facility of Hurricane Parametric Insurance[47,48] coverage using System for Probabilistic Hazard Evaluation and Risk Assessment (SPHERA) Model[48] for pay-outs within 7-14 days of the Tropical Cyclone, as pre-agreed criteria in the premium policy purchased. The immediate pay-outs[47,48,49] lump sum amount to individual policyholders or government agencies, based on the ex-ante pre-agreed triggered criteria of the magnitude the event, will significantly speed up the immediate needs in disaster response, thus reducing the aftermath impact loss in disaster risk financing[47,102]. According to the National Association of Insurance Commissioners in 2019[47], this parametric disaster insurance payment effectiveness is equivalent to 3.5times of the delayed fund payment in donor aid.

Parametric Disaster Insurance[47] is in response to UN Sendai Framework for Action[104] 2015-2030 in Disaster Risk Reduction, target (c) to reduce direct economic loss in relation to global gross domestic product (GDP) by 2030. Globally, the gap within uninsured and insured[105] in countries vulnerable to natural disaster is more than 50%, especially in the developing countries.[103] This will impact the economic development, in terms of gross domestic product (GDP)[104] bringing the affected countries into long-term economic loss, impacting human security and development. The Economic Losses, Poverty and Disasters report[106] released on 2018 by United Nations Office for Disaster Risk Reduction (UNISDR) and Centre for Research on the Epidemiology of Disasters (CRED) showed that the economic loss has increased 2.5 times, although the mortality rate due to natural hazards has decreased for the past twenty years. Recognizing the importance of this matter, The United Nations Office for Disaster Risk Reduction

(UNISDR) has calls for Risk-Informed Investment Globally[103] , such as parametric insurance,[47] as a security blanket to mitigate the long-term economic impact of countries vulnerable to climate related natural disasters. [103,104]

The calls for risk informed investment[103] was almost identical with the 2019 Cyclone Bulbul, Bangladesh preparedness, that scored a High YEW DSI[50] of 6.8 in risk informed for preparedness on the Disaster Metrics[50] feasibility study. Moreover, prior to the landfall of the Cyclone Bulbul at Sundarban Delta,[92,94,104] more than 2 million people managed to be safely evacuated to the cyclone shelter, compared to 1991 Cyclone Bob[108] in Bangladesh, with more than a quarter million deaths. The 1990s was also designated by the UN General Assembly as the International Decade of National Disaster Reduction (IDNDR).[109] This showed a significant improvement on the Bangladesh Disaster Management System Cyclone Preparedness Programme[110] and the population at the affected areas, in terms of Disaster Risk Reduction prior to the cyclone landfall at the local community and district level.[104,110]

RESEARCH QUESTION:

How to analyze in real-time the human impact of climate related and natural disaster?

AIMS:

To be used as an indicator for various stakeholders such as Public Health, Emergency and Disaster Team, catastrophic bond investors, parametric insurance, international, governmental and civil-military, in disaster response, risk reduction, risk transfer management, as well as preparedness.

2. OBJECTIVES:

i) To develop a new quantitative Disaster Metrics tool underpinned the 'disaster' definition in measuring the climate related natural disasters, at any point of a disaster continuously, simultaneously, and retrospectively across timeline.

ii) To test the new Disaster Metrics tool on real-time or near real time climate related disaster impacting humanitarian response, based on magnitude or intensities recorded.

iii) To predict the humanitarian impact of climate related disaster on preparedness, risk reduction and response, using the new Disaster Metrics tool.

HYPOTHESIS:

There is a correlation between near real-time or real-time humanitarian impacts calculated in the Disaster Metrics and its' governmental response or preparedness, based on magnitude and intensities recorded.

NULL HYPOTHESIS:

There is no correlation between near-real time or real-time humanitarian impacts calculated in the Disaster Metrics and its' governmental response or preparedness, based on magnitude and intensities recorded.

METHOD:

Quantitative method will be used in the study of the new Disaster Metrics Tool titled 'The YEW Disaster Severity Index'.

METHODOLOGY:

The Disaster Metrics basically will be analyzed on 3 phases, mainly retrospectively, real-time response and near real-time impact on preparedness, risk reduction and response. Feasibility study was done prior to testing the Disaster Metrics in real-time or near real-time, as mentioned in background significant of studies.

3. DISCUSSION OF THE RESULTS

The new quantitative Disaster Metrics tool was constructed taking into consideration vulnerability and exposure indicators as well as multi-hazard, impacting human lives and livelihoods, underpinned the disaster definition of the ability to cope within local capacity, as baseline. To factor the true scale of a disaster estimation, Global Corruption Perception Index of governance by Transparency International,[44] updated annually was included in one of the vulnerability indicators. The approached provides a clearer picture in bringing gaps[124-127] from policy makers and practice of evidence-based lesson learned among decision making stakeholders, with the inclusion of the affected community. The Disaster Metrics transformed the disaster definition based on UNISDR Disaster terminology[35-36] into a mathematical measurement with baseline scoring of more than 3 or 100%, or Medium DSI, as the inability to cope within local capacity, thus needing outside assistance, tested in phases.

The Disaster Metrics was tested in 3 phases; mainly retrospectively, real-time, and near –real time to validate the reliability of the scale, which prior to that, also tested in the feasibility studies. The validity and reliability of the Disaster Metrics were tested with statistical analysis software[118] and critical analysis decisions by expert with evidence-based knowledge from the field. This is to reduce the bias in selection of indicators for the Disaster Metrics. Artificial Intelligence in Machine Learning Model[111-115] was also used as a trial to test, evaluate and predict the DSI algorithm accuracy.

In the first phase of testing in retrospectively , sample size of 30 various climate related natural disasters were calculated and plotted in the Disaster Metrics and tested against mean score percentage of 100%, the baseline ability to cope within local capacity. It was found that only 18 of the 20 that scored more than 100% requesting for national or international assistance, indicating inability to cope within local capacity.

When a disaster is a disaster? The remaining 2 of the 20 disasters that scored more than the mean score percentage of 100% were Earthquake China, with a score of 110% and Tropical Cyclone Hudhud India, with a score of 104%. Both countries were able to cope within national and local capacity although scored more than baseline, as UNISDR reports highlighted that China and India have developed a functional multi-agencies Emergency and Disaster Activation System under the National Disaster Management, which is similar to UN Office for Coordination in Humanitarian Actions Activation System. Earthquakes in Japan and Taiwan, which scored less than 100%, both were able to cope within local capacity on its' government responses, thus needing no outside assistance.

The results on the New Disaster Metrics revealed the ability to quantify and compare 30 various climate related and natural disasters continuously and simultaneously using retrospective data, across timeline. Its integration in the practice for decision making and policy makers at local community and district, is a hallmark in future guide for response design.

As for the second phase, the Disaster Metrics applied in real-time, in analyzing the impact and response to the Sulawesi Earthquake and Tsunami. Real-time data was obtained from the Indonesia Agency for Meteorological, Climatological and Geophysical, android mobile application with data triangulation on US Geological Survey (USGS; Reston, Virginia USA) site, Indonesia Meteorological official website, and Google LLC satellite maps.

The Disaster Metrics tool applied on the Sulawesi Earthquake and Tsunami, indicated the ability to project its estimated real-time humanitarian impact within 12 hours after the incident. With the Richter Scale of 7.7 and Modified Mercalli Intensities 7 in Donggala, the humanitarian impact calculated scored a High 7.4 in the YEW DSI, with 11 of the 17 indicators scoring more than baseline coping capacity. As for Palu, the Richer Scale recorded was 6.4 and Modified Mercalli Intensities was 6. The result of the tabulated humanitarian impact on Donggala was the same as Palu on the Disaster Metrics, however 13 of the 17 indicators scored more than the baseline coping capacity. The impact analysis report was sent to the Indonesian authorities within 12 hours of the incident, prior to the UN impact analysis report.

The real-time analysis results could be a concrete recommendation guide in practice by benchmarking the impact of the affected population. In the meantime, it could be an indicator guide in practice to the Indonesian Government agencies such as the Indonesian National Agency of Search and Rescue (BASARNAS;Jakarta Indonesia), Indonesian National Armed Forces (TNI;Jakarta, Indonesia) and Indonesian National Police (POLRI;Jakarta Indonesia), based on the indicator scoring more than baseline coping capacity, mainly accessibility to the impact site, topography, and impact time for search and rescue operations.

The Disaster Metrics results indicated almost an exact fit with the Indonesian National Response's four main priorities in real-time benchmarking. With these impact analysis report, statistical analysis was done on the Richter Scale magnitude, Modified Mercalli intensities at Palu and Donggala were also found to have a statistically significant correlation, 0.9280 with the humanitarian impact scored calculated on the Disaster Metrics as High 7.4 DSI. The new milestone on magnitude, intensities and humanitarian impact could be added into the prehospital and disaster medicine evidence-based knowledge for further research and practice.

However, lack of accessibility to the real-time data is a challenge and the main gap in the analysis of climate related natural disasters impact needs and responding to it. Concerns over the real-time data accessibility includes: autonomy, global security, and safety. This also includes factoring in the cost of corruption in increasing transparency for disaster risk reduction, response, recovery, and reconstruction.

The third phase of the Disaster Metrics was tested on hurricane risk reduction and preparedness, based on near-real-time impact analysis of Hurricane Dorian at the Bahamas. The analysis of the near-real-time for preparedness and its impact, both reports were benchmarked and submitted as evidence-based analysis to the relevant national and regional emergency and disaster authorities within 72 hours after the landfall, on September 6,2019.

Hurricane Dorian in Preparedness was calculated 48 hours prior to the landfall on the Disaster Metrics scored a High in Risk Informed of 6.8 in the YEW DSI, with the Saffir-Simpson Hurricane Wind Scale of Category 4 recorded by the National Oceanic Atmospheric Authority (NOAA; Miami, Florida USA) satellite at the National Hurricane Centre. 9 of the total 17 indicators in the Disaster Metrics scored inability to coping within local capacity, and an overall High in Risk Informed. Those indicators pointed out the target for Risk Informed Investment in Disaster Risk Reduction, strengthened, and call for actions by the UN Office for Disaster Risk Reduction (UNISDR;Geneva, Switzerland) and Centre for Research in Epidemiology and Disaster (CRED; Brussel, Belgium).[103] Furthermore, the call for Risk Informed Investment and Sendai Framework for Action 2015-2030 in Disaster Risk Reduction target c, [103] both made an explicit commitment in reducing the economy impact and Gross Domestic Product (GDP) by 2030.

The impact analysis on the Hurricane Dorian Bahamas scored a High 7.3 on the YEW DSI, with 12 of the total 17 indicators scoring more than baseline coping capacity, indicating external assistance or response needed. The Government of Bahamas had previously invested in the hurricane insurance policy with Caribbean Catastrophe Risk Insurance Facility (CCRIF; Cayman Islands), a parametric insurance focusing on Disaster Risk Financing and Risk Informed Insurance. The parametric insurance policy for Hurricane Dorian at the Bahamas was triggered immediately after the landfall, with a total payout of 11.5 million (USD)United States of America Dollar. The advance payment of the total 50% was received within the first 7 days and the remaining within the 14 days window of the event. The payout provides short term financial liquidity and preventing long term economic impact on the affected country.

This near-real time analysis on human population impact will provide various stakeholders, a guide in preparedness, thus reducing the future impact of a disaster. Noticeably, the new milestone on risk informed scored in preparedness on the Disaster Metrics, could be integrated into the evidence-based research and practice, in disaster risk analysis and also for disaster risk financing in parametric insurance.

The Saffir Simpson Hurricane Wind Scale and the Disaster Metrics, both recorded and applied on Preparedness and Impact analysis was benchmarked, using statistical analysis showed significant correlation of 0.9018. This result indicated the correlation between magnitude intensities of a disaster and its' impact on the affected population of the Disaster Metrics. Declaration of State of Exigency by the Government of the Bahamas demonstrated the inability to cope within local capacity, as evidenced in the Disaster Metrics. National Emergency Management Authority (NEMA), Regional

Caribbean Disaster Emergency Management Authority (CDEMA) and international assistance responded to it.

Near real-time data obtained via NOAA satellite was triangulated with its' Hurricane Hunter Aircrafts data recorded and Google LLC satellite map to ensure the reliability of the data. However, satellite data were not easily available and accessible due to defense and security purposes, which is also the main gap challenge in preparedness and response.

With the rapid growth and development in the Artificial Intelligence Machine Learning, in almost all the fields, the Disaster Risk Reduction and Management field such as the Disaster Metrics is no exceptional, as well. New cross cutting-edge devices and applications via the Internet of Thing(IoT)[68-69] are proliferating at a rapid rate globally, such as linking satellite data[72] to mobile phones, drones, and autonomous rescue robots.[62-69,76-78]

Therefore, to keep abreast with the latest development, the Disaster Metrics algorithm was tested in an infancy trial using Artificial Intelligence Machine Learning. The unplanned interesting trial findings regarding the accuracy of the Disaster Metrics algorithm, done by feeding the Disaster Metrics data that was hand written and manually calculated into the Neural Network of the Keras TensorFlow 2.0.[111-112] Keras is a high level Application Programming Interface(API) written in Python 3.9 code[111-112] and run in Artificial Intelligence Machine Learning latest platform of Keras Tensorflow 2.0[111-112]using Google Colaboratory.[113-115] This is to build and train the neural network in regression using supervised machine learning with Keras Sequential Model,[111-115] in learning and figuring out the relationship of the data in the Disaster Metrics algorithm. Hence, reducing the bias of the algorithm, which was handwritten and calculated, though proven its value in retrospective, real-time and near-real time, as well as in the feasibility study. As the algorithm was a handwritten code, the exact algorithm was known (DSI) y= (17x) 3 / 8, whereby the data and calculated in Microsoft Excel 365[118], whereby the data sets of ys =DSI 0,1,2,3,4,n and xs = total scoring of each DSI. However, the computer neural network has to train and learn by using the data of ys and xs fed into the neural network, without knowing the actual DSI model algorithm. The LOSS function using Mean Squared Error(MSE)[111-116], a function used in regression to measure the average of squared differences between the predicted value in the loss against the actual value of the dataset in the model of the DSI algorithm, in measuring how well or badly it did.

Then, it uses the OPTIMIZER function of Stochastic Gradient Descent(SGD) [111-114]to make another prediction, based on how the lost function result went, by trying to minimize the loss. The model was trained repeatedly in epochs and after 500 epochs, the predicted accuracy in loss function of MSE[111-116] as of 0.0065. The LOSS function[111-116] result after repeatedly in 500 epochs also did not show any overfitting or underfitting of the DSI Model algorithm. Thereby, the accuracy of the DSI Model algorithm prediction was 99.9935. The DSI Model algorithm is to be saved in Keras TensorFlow Machine Learning Model of H5 format,[111-114,116] as it is currently tested in it.

The future plan is to package and deploy the model to the free Artificial Intelligence Cloud Computing platforms such as Google Cloud,[58,114]Amazon Web Services Cloud,[119] iCloud[120] from Apple©, IBM Cloud,[121] Huawei Cloud[122] and Alibaba Cloud[123]. This is to generate predictions of the DSI model results especially in real-time and using web cloud computing application and convert it to TensorFlow Lite,[112] hence scaling and flexibility of deploying it into practice with Internet of Things (IoT)[68-69] such as mobile iOS, android, and edge devices,[62-65] to be easily available and accessible by many internet users such as relevant disaster stakeholders and the general public, as an early warning system. It can also be deployed in drones devices[60,76-78] together with the real-time Geographic Information System (GIS) mapping[61] for Disaster Response[69-72,76-77] in Search and Rescue,[59,62,64-65]or prior to the disaster,[66] as a Risk Informed analysis, especially for the parametric catastrophe risk informed reinsurance.[63,68]

However, the current challenge[58,114,119-123] in cloud computing also includes internet connectivity, data privacy and confidentiality, as well as level of cloud security. In the event where the internet data connectivity is lacking, the Disaster Metrics has its' flexibility to be reverted back to the offline Microsoft Excel 365[118] or even as simple as physical paper version.[50,52]

Globally, one third of the world population were still not covered by the Early Warning Systems in 2020,[124-125] which translate into the gaps in early interventions in saving lives and livelihoods. Therefore, surge capacity is needed for investment in Risk Informed at a global level coverage. The call for investment in early warning systems and Risk Informed[126-127] early actions or approaches was also amplified globally at the recent Climate Adaptation Summit,[128] held virtually at Geneva, Switzerland from 25 to 26 January 2021.

Looking at a bigger picture in response to Sendai Framework for Disaster Risk Reduction 2015-2030,[104,133] the Disaster Metrics was developed with the inclusion of 17 vulnerability and exposure indicators with hazards impacting lives and livelihoods of the affected population. However, long term equilibrium in Sustainable Development Goals (SDGs) and Actions[129-132] are needed in managing the Risk Informed Investment[124-127] in Preparedness, Response, Recovery and Reconstructions, which in this situation are projected in the Disaster Metrics and its indicators. Examples of indicators in the Disaster Metrics that are relevant to the Sustainable Development

Goals[131-132] include Clean Water and Sanitation Hygiene, Sustainable Cities and Communities in Critical Public Infrastructure, Zero Hunger in Food Security, Good Health and Well Being in Healthcare Capacity, Climate Action in Climate related Disaster Risk Reduction in local community to national and international stakeholders and Zero Poverty by implementing social protection system; such as basic physiological needs indicators of Water and Sanitation Hygiene, Food Security, Shelter and Healthcare Capacity.

The Disaster Metrics was tested, and its' results revealed the ability in assessing the risk, impact needs, monitoring and evaluation, simultaneously and continuously, across timeline in various phases of disaster.

It was able to calculate and predict the estimated impact of the affected population in risk informed assessment, based on the 17 indicators and the magnitude intensity of a disaster, thus saving lives and livelihoods, such as prior to the hurricane landfall or tsunami. The predicted estimation cost of damage in socioeconomic livelihood, based on preparedness and impact analysis will save the affected country economy in disaster risk financing and also in reinsurance risk transfer management such as parametric insurance for the Hurricane Dorian at the Bahamas and agriculture crops microinsurance for the Caribbean. The risk analysis on preparedness and risk reduction calculated, was also benchmarked with near-real-time impact, as a key performance indicator guide in evidence-based decision making in response, recovery, and reconstruction.

4. CONCLUSION

In conclusion, the Disaster Metrics human population impact tested on climate related and natural disasters in real-time, near-real-time and retrospectively were found to be correlated with the governmental responses and preparedness, as well as magnitude and intensities of the disasters recorded. The Disaster Metrics was put into practice by sending the real-time and near-real-time impact analysis reports to the relevant authorities, as well as disseminating the research results in National and World Congress of Disaster and Emergency Medicine for further research.

CONCLUSIONES (español)

En conclusión, se encontró que el impacto en la población humana de las métricas de desastres probados en desastres naturales y relacionados con el clima en tiempo real, casi en tiempo real y retrospectivamente se correlacionó con las respuestas gubernamentales y la preparación, así como con la magnitud e intensidad de los desastres registrados. Las Métricas de Desastres se pusieron en práctica enviando los informes de análisis de impacto en tiempo real y casi en tiempo real a las autoridades pertinentes, así como difundiendo los resultados de la investigación en el Congreso Nacional y Mundial de Medicina de Desastres y Emergencias para su posterior investigación.

5. REFERENCES:

1. US Geology Survey. Earthquake Hazards Program: Earthquake Glossary-Ring of Fire. https://earthquake.usgs.gov/learn/glossary/?termID=150 Published 2012. Accessed January 10, 2019 and May 1, 2020.

2. National Aeronautics and Space Administration (NASA) Earth Observatory: Hurricane Alley Heats Up (n.d.). Goddard Space Flight Center. Greenbelt, MD 20771, USA. https://earthobservatory.nasa.gov/images/5742/hurricane-alley-heats-up Accessed May 20, 2020.

3. Hurricane Alley Heats Up (n.d.). Goddard Space Flight Center. Greenbelt, MD 20771, USA. https://earthobservatory.nasa.gov/images/5742/hurricane-alley-heats-up Accessed May 20, 2020.

4. Balaguru K, GR Foltz, LR Leung, and KA Emanuel. (2017) US Department of Energy. Pacific Northwest National Laboratory (PNNL). Less Salty Ocean is Right Up Typhoons' Alley. *Atmospher Sci & Global Chg :Research Highlights.* pp.143-143. https://www.pnnl.gov/science/highlights/highlight.asp?id=4511 Published January 2017. Accessed May 20, 2020.

5. United Nations. Department of Economic and Social Affairs Population Dynamics. World Population Prospects: The 2019 Revision. https://population.un.org/wpp/ Accessed May 21, 2020.

6. World Meteorological Organization. WMO confirms 2020 was one of three warmest years on record. https://public.wmo.int/en/media/press-release/2020-

was-one-of-three-warmest-years-record Published January 14, 2021. Accessed January 18, 2021.

7. Trenberth, K. E., Cheng, L., Jacobs, P.,Zhang, Y., & Fasullo, J. (2018). Hurricane Harvey links to ocean heat content and climate change adaptation. Earth's Future, 6, 730–744. https://doi.org/10.1029/2018EF000825 Accessed May28, 2020.
8. Cheng, L., and Co-authors, 2020: Record-setting ocean warmth continued in 2019. *Adv. Atmos. Sci*., 37(2), 137−142, https://doi.org/10.1007/s00376-020-9283-7. Published February, 2020. Accessed May 28th, 2020.
9. US Department of Commerce. National Oceanic Atmospheric Administration (NOAA) National Center for Environmental Information : State of Climate Reports and the World Meteorological Organization (WMO) Global Climate Report –April 2020: Provisional Status of Climate in 2019. https://www.ncdc.noaa.gov/sotc/global/202004 Published April, 2020. Accessed May 30, 2020.
10. Kossin, J. P., Knapp, K.R., Olander, T.L., and Velden, C.S. (2020). Global increase in major tropical cyclone exceedance probability over the past four decades. *Journal of Proceedings of the National Academy of Science of the United States of America*. First Published May 18, 2020. DOI: 10.1073/pnas.1920849117 Accessed May 21, 2020.
11. India Meteorological Department, Ministry of Earth Sciences, Government of India. Tropical Cyclone Amphan. https://mausam.imd.gov.in/imd_latest/contents/cyclone.php. Published May 21, 2020. Accessed May 21, 2020.

12. US Geology Survey. Volcano Hazards Program: Glossary (VEI) - Volcanic Explosivity Index. https://volcanoes.usgs.gov/vsc/glossary/vei.html Accessed January 10th 2019 &May 22, 2020.

13. US Geology Survey. Earthquake Hazards Program: Earthquake Glossary-Richter Scale. http://earthquake.usgs.gov/learn/glossary/?term=Richter%20scale. Published 2016. Accessed January 10th, 2019 & May 22, 2020.

14. Japan Meteorological Agency. JMA Seismic Intensity Scale. https://www.jma.go.jp/jma/en/Activities/inttable.html Accessed January10th 2019 & May 22, 2020.

15. US Geological Survey (USGS). The Modified Mercalli Intensity Scale. https://earthquake.usgs.gov/learn/topics/mercalli.php. Accessed January 15, 2019 & May 22, 2020.

16. US Geological Survey (USGS). The ShakeMap Scientific Background. Rapid Instrumental Intensity Maps: Peak Ground Velocity (PGV) and Peak Ground Acceleration (PGA). https://web.archive.org/web/20110623092131/http://earthquake.usgs.gov/earthquakes/shakemap/background.php#intmaps Accessed May 22, 2020.

17. US Department of Commerce. Storm Prediction Centre. National Oceanic Atmospheric Administration (NOAA). Beaufort Wind Scale. Sir Francis Beaufort. https://w1.weather.gov/glossary/index.php?word=beaufort+scale+ Updated May 21, 2020. Accessed May 21, 2020.

18. Schott, T., Landsea, C., Hafele, G., et al. (2012, updated 2019). The Saffir –Simpson Hurricane Wind Scale (SSHWS). US Department of Commerce.

National Hurricane Center. National Oceanic and Atmospheric Administration (NOAA) factsheet. https://www.nhc.noaa.gov/pdf/sshws.pdf Published 2019. Accessed August 31, 2019.

19. Simpson, R.H., & Saffir, H. (1974). The hurricane potential scale. *Weatherwise*, 27(8), 169.

20. Boer JD. Order in Chaos: Modelling Medical Disaster Management. Free University Hospital (VUMC). Amsterdam, The Netherlands. Available from PreventionWeb. http://www.preventionweb.net/files/1936_VL206210.pdf. Published 1999. Accessed June 31, 2016 & May 31, 2020.

21. Wirasinghe SC, Caldera HJ, Durage SW, Ruwanpura JY. "Preliminary Analysis and Classification of Natural Disasters: Fatality Based Disaster Classification." Paper presented at 3rd World Conference of Disaster Risk Reduction; Sendai, Japan: 14-18th March 2015. http://www.wcdrr.org/conference/events/462 Accessed June 6, 2016 & May 31, 2020.

22. MunichRE. Munich, Germany (2020). https://www.munichre.com/en/homepage/index.html Accessed May 31, 2020.

23. The John Hopkins University (Baltimore, Maryland USA) and the International Federation of Red Cross and Red Crescent Societies (IFRC). *Public Health Guide for Emergencies*. 2nd edition. Geneva, Switzerland: IFRC; 2008: (1) 24-36.

24. Benini A. *A note for ACAPS Severity and priority. Their measurement in rapid needs assessments.* Assessment Capacities Project (ACAP); 2013: 1-59.

https://www.acaps.org/sites/acaps/files/resources/files/severity_and_priority-their_measurement_in_rapid_assessments_august_2013.pdf Accessed June 5, 2016 & May 31, 2020.

25. Welle, T, Birkmann, J. World Risk Index. Alliance Development Works and United Nations University – Institute for Environment and Human Security (UNU-EHS). University of Stuttgart. Institute of Spatial and Regional Planning (IREUS). https://www.ireus.uni-stuttgart.de/en/institute/world_risk_index/ (n.d.) Accessed May 31, 2020.
26. Assessment Capacities Project (ACAPS). INFORM Global Crisis Severity Index. https://www.acaps.org/sites/acaps/files/resources/files/gcsi_beta_brochure_spread.pdf (n.d.) Accessed May 31, 2020.
27. Bayram JD, Kysia R, Kirsch TD. Disaster Metrics: a proposed quantitative assessment tool in complex humanitarian emergencies-the Public Health Impact Severity Scale (PHISS). *PLOS Currents*.2012;1:4.
28. Sphere Association (Geneva, Switzerland). *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response.* 3rd edition. United Kingdom: Practical Action Publishing; 2011:1-393.
29. Bayram JD, Zuabi S, McCord CM, Sherak RA, Hsu EB, Kelen GD. Disaster Metrics: Evaluation of De Boer's Disaster Severity Scale (DSS) Applied to Earthquakes. *Prehospital and Disaster Medicine*. 2015;30(1):22‐27. doi:10.1017/S1049023X14001393 Published February, 2015. Accessed May 31st , 2020.

30. US Department of Commerce. National Oceanic and Atmospheric Administration. (NOAA). https://www.noaa.gov/climate (n.d.) Accessed May 31st, 2020.
31. US Geological Survey. Earthquake Hazards Program: Search Earthquake Catalog. https://earthquake.usgs.gov/earthquakes/search/ (n.d.) Accessed May 31st, 2020.
32. Arcos González P, Castro Delgado R, Mahabir R, Ferrero Fernández E. The feasibility of applying the Disaster Severity Score: The Case of Spain. *J Intensive & Critical Care*. 2016; 2(2):1-6.
33. Eriksson, A, Ohlsén, YK, Garfield, R, von Schreeb, J. Who is worst off? Developing a severity-scoring model of complex emergency affected countries in order to ensure needs-based funding. *PLoS Currents.* 2015;1:7.
34. Maslow, AH. A theory of human motivation. Psychological Review. 1943;50(4):370-396.
35. The United Nations Office for Disaster Risk Reduction-UNISDR, Geneva Switzerland. Terminology on disaster risk reduction. http://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf Published 2009. Accessed January, 2019 & May 31, 2020
36. The United Nations Office for Disaster Risk Reduction-UNISDR, Geneva Switzerland. Terminology on disaster risk reduction, updated February 2017. https://www.undrr.org/terminology Published 2017. Accessed October 6, 2018 & May 31, 2020.
37. Center for International Earth Science Information Network - CIESIN - Columbia University. (2016, updated 2019). Gridded Population of the World, Version 4 (GPWv4): Administrative Unit Center Points with Population Estimates. Palisades, NY: NASA Socioeconomic Data and Applications

Center (SEDAC). https://doi.org/10.7927/H4F47M2C Accessed September 4, 2019& May31, 2020.

38. Harper, D. Online Etymology Dictionary: Topography. http://www.etymonline.com/index.php?term=topography Accessed September 3, 2018 & May 31, 2020.
39. Food and Agriculture Organization of United Nations. Rome, Italy (2016). Food Security Indicators. http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.Ww7Cs0iFPIV Accessed June 3, 2016 & May 31, 2020.
40. World Health Organization (2010). Health Statistics and Information Systems. Monitoring the building blocks of health systems: a handbook of indicators and their measurement strategies. http://www.who.int/healthinfo/systems/WHO_MBHSS_2010_full_web.pdf?ua=1Geneva, Switzerland, 2010. Accessed June 3, 2016 & May 31, 2020.
41. World Health Organization. Social determinants of health https://www.who.int/social_determinants/sdh_definition/en/ Geneva, Switzerland: WHO; 2018. Accessed September 28, 2018 & May 31, 2020.
42. M.M.G.T. De Silva, A. Kawasaki. Socioeconomic Vulnerability to Disaster Risk: A Case Study of Flood and Drought Impact in a Rural Sri Lankan. *Ecological Economics* 152 (2018) :131–140. https://doi.org/10.1016/j.ecolecon.2018.05.010
Published online October, 2018. Accessed May 31, 2020.
43. M.M.G.T. De Silva, A. Kawasaki. A local-scale analysis to understand differences in socioeconomic factors affecting economic loss due to floods among different communities. *International Journal of Disaster Risk Reduction* 47(2020) 101526. https://doi.org/10.1016/j.ijdrr.2020.101526 Published online for August 2020 Journal Edition. Accessed May, 2020.

44. Transparency International. Berlin, Germany. Corruption Perception Index. https://www.transparency.org/cpi2020 Published Jan 28, 2021. Accessed January 31, 2020.

45. Alexander, D. (2017, October 26). Corruption and the Governance of Disaster Risk. *Oxford Research Encyclopedia of Natural Hazard Science.* Ed https://oxfordre.com/naturalhazardscience/view/10.1093/acrefore/9780199389407.001.0001/acrefore-9780199389407-e-253 Published October 26, 2017. Accessed on September 29, 2018 & June 8, 2020.

46. MunichRE. Munich Reinsurance Company of Canada. Why use reinsurance? https://www.munichre.com/ca-non-life/en/solutions/why-reinsurance.html (n.d.) Accessed May 31, 2020.

47. National Association of Insurance Commissioners. Parametric Disaster Insurance. https://content.naic.org/cipr_topics/topic_parametric_disaster_insurance.htm Updated September, 2019. Accessed May 30th, 2020.

48. The Caribbean Catastrophe Risk Insurance Facility (CCRIF). CCRIF Products: Hurricane Coverage Model Development. http://www.ccrif.org/content/aboutus/ccrif-products Published online February, 2019. Accessed May 28th, 2020.

49. Jergler, D. (2018). Insurtech Jumpstart Rolls out Parametric Earthquake Product for Californians. *The Insurance Journal*. https://www.insurancejournal.com/news/west/2018/10/02/503105.htm Published online October 2018. Accessed May 28th, 2020.

50. Yew, YY., Castro Delgado, R., Heslop, D., & Arcos González, P. (2019). The Yew Disaster Severity Index: A New Tool in Disaster Metrics. *Prehospital and Disaster Medicine*, 34(1), 8-19. doi:10.1017/S1049023X18001115

Published online 02 January 2019. Accessed January 2, 2019 & May 31, 2020.

51. Boer JD. Definition and classification of disasters: introduction of a disaster severity scale. *J Emerg Med.* 1990; 8(5):591-595.
52. Yew, YY., Arcos González, P., & Castro Delgado, R. (2017). YEW Disaster Severity Index: Proposal of a New Tool in Disaster Metrics. *Prehospital and Disaster Medicine*, 32(S1), S27-S27. doi:10.1017/S1049023X17000905 (Abstracts for Scientific Papers-WADEM Congress on Emergency and Disaster Medicine 2017) Published online April 2017. Accessed September, 2018 & May 31, 2020.
53. ReliefWeb by UN Office for the Coordination of Humanitarian Affairs (OCHA). Geneva, Switzerland/New York City, USA. http://reliefweb.int. Published 2020. Accessed May 15, 2020.
54. EM-DAT: The Emergency Events Database - Université Catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium. (n.d.) Accessed May 15, 2020.
55. Kantha, L. (2006), Time to replace the Saffir-Simpson hurricane scale? *Eos Trans*. AGU, 87(1), 3– 6, https://doi:10.1029/2006EO010003. Published online 3rd June, 2011. Accessed September 3rd, 2019 & May 31, 2020.
56. World Bank Data. Washington, DC USA. New country classifications by income level. https://blogs.worldbank.org/opendata/new-country-classifications-income-level-2019-2020 Published July, 2019. Accessed May 31, 2020
57. Dropbox, Inc., San Francisco, California. https://www.dropbox.com/ Accessed June 1, 2020.

58. Google Cloud. Google LLC Services. Mountain View, California USA. https://cloud.google.com/ Accessed June 1, 2020 & January, 2021
59. Community Research and Development Information Service (CORDIS). The Publications Office of the European Union, Luxembourg.
Final Report Summary -(RABOT) The real-time adaptive networked control of rescue robots- https://cordis.europa.eu/project/id/318902/reporting Published July 25, 2016. Accessed October 1, 2018 & June 1, 2020.
60. Ball, M. AI-Based Real-Time Drone (UAVs) Tracking & ID Software Released. Unmanned System Technology. EchoBlue Ltd. UK. https://www.unmannedsystemstechnology.com/2020/06/ai-based-real-time-drone-tracking-id-software-released/ Published online June 4, 2020. Accessed June 6, 2020.
61. Google Satellite Maps-Navigate &Explore (Wear OS) 10.41.2. Updated May 11, 2020 Google LLC Services. Mountain View, California USA.
62. Center for Robot-Assisted Search and Rescue (CRASAR). http://crasar.org/ Texas A&M Engineering Experiment Station, The Texas A&M University System. USA. Accessed May 30, 2020.
63. Greenwood F, Nelson EL, Greenough PG (2020) Flying into the hurricane: A case study of UAV use in damage assessment during the 2017 hurricanes in Texas and Florida. *PLOS ONE* 15(2): e0227808. https://doi.org/10.1371/journal.pone.0227808 Published online February, 2020. Accessed May 30th, 2020
64. Murphy, Robin R. *Disaster Robotics (Intelligence Robotic and Autonomous Agents Series).* The MIT Press, USA: 2015.
65. Murphy, Robin R. *Introduction to AI Robotics, Second Edition. (Intelligence Robotic and Autonomous Agents Series).* The MIT Press, USA: 2019.

66. UN Office for Coordination in Humanitarian Affairs (UN OCHA): Unmanned Aerial Vehicles (UAVs) or drones in Humanitarian Response. https://www.elrha.org/wp-content/uploads/2015/01/Unmanned-Aerial-Vehicles-in-Humanitarian-Response-OCHA-July-2014.pdf Accessed June 1, 2020.

67. Global Aerospace. Unmanned Aircraft System (UAS) Insurance (2020). https://www.global-aero.com/unmanned-aircraft-systems-uas-insurance/ Accessed June 1, 2020.

68. Guy Carpenter &Company, LLC. Wearables, Drones and the Internet of Things: The Next Wave of Workplace Safety and Claims Mitigation, Part 1& 2. https://www.gccapitalideas.com/2018/05/23/wearables-drones-and-the-internet-of-things-the-next-wave-of-workplace-safety-and-claims-mitigation-part-i/
https://www.gccapitalideas.com/2018/05/23/wearables-drones-and-the-internet-of-things-the-next-wave-of-workplace-safety-and-claims-mitigation-part-ii/
Published online May, 2018. Accessed June 1, 2020.

69. The American Red Cross & Measure, a 32 Advisors Company. *Drones for Disaster Response and Relief Operations Report.* USA. 2015: 1-52pp https://www.issuelab.org/resource/drones-for-disaster-response-and-relief-operations.html Published April 2015.

70. PrecisionHawk. Utilities: How Drones Aid in Disaster Response. https://www.precisionhawk.com/blog/how-drones-aid-in-disaster-response Published August 2019. Accessed June 1, 2020.

71. National Oceanic and Atmospheric Administration (NOAA). US Department of Commerce. What is LiDAR? https://oceanservice.noaa.gov/facts/lidar.html Updated April, 2020. Accessed June 1, 2020.

72. GIS Geography. Remote Sensing Software: A Complete Guide to LiDAR: Light Detection and Ranging. https://gisgeography.com/lidar-light-detection-and-ranging/ Updated April, 2020. Accessed June 1, 2020.

73. Edison Electric Institute. Hurricane Micheal. ESCC: Power Restored to 95 percents of customers as industry works to rebuild the most severely damage infrastructure. https://www.eei.org/resourcesandmedia/newsroom/Pages/Press%20Releases/Hurricane%20Michael%20Power%20Restored%20to%2095%20Percent%20of%20Customers.aspx Published October, 2018. Accessed June1, 2020.

74. AT&T Inc. AT&T Response to Hurricane Micheal: AT&T's Flying COW Deployed to Hard-Hit Mexico Beach. https://about.att.com/pages/hurricane_michael.html Published October 2018. Accessed June1, 2020.

75. Federal Aviation Administration (FAA). United State Department of Transportation. FAA Approves Drone to Restore Puerto Rico Cell Service. https://www.faa.gov/news/updates/?newsId=89185 Published November 2017. Accessed June 1, 2020.

76. Lockheed Martin Corp. K-MAX® Unmanned Aircraft System : A Power Lifter Transformed. https://www.lockheedmartin.com/content/dam/lockheed-martin/rms/documents/k-max/K-MAX-brochure.pdf (n.d.) Accessed June1, 2020.

77. Argodesign©2020. Drone Ambulance: A visionary solution to speed emergency care. https://www.argodesign.com/work/drone-ambulance-argodesign.html Accessed June1, 2020.

78. Adorama Camera, Inc. What Are Drone Thermal Imaging Cameras Used For? https://www.adorama.com/alc/what-are-drone-thermal-imaging-cameras-used-for Published February, 2020. Accessed June 1, 2020.

79. The Royal Malaysia Police (PDRM). PDRM using thermal imaging drone in searching for missing person. https://youtu.be/k89f6K3n3ks Available online August, 2020. Accessed June 1, 2020.

80. The House Committee on Transportation & Infrastructure. Congressional Hearings. Serial No. 115-30 (House Hearing) - Unmanned Aircraft Systems: Emerging Uses in a Changing National Airspace. November 29, 2017. https://www.govinfo.gov/app/details/CHRG-115hhrg28672/CHRG-115hhrg28672 Accessed June 1, 2020.

81. The House Committee on Transportation & Infrastructure. Congressional Hearings. Serial No. 115-36 (House Hearing) – The State of Aviation Safety. February 27, 2018. https://www.govinfo.gov/app/details/CHRG-115hhrg31404/CHRG-115hhrg31404 Accessed June 1, 2020.

82. Guoqing Li, Jing Zhao, Virginia Murray, Carol Song & Lianchong Zhang Gap analysis on open data interconnectivity for disaster risk research, *Geo-spatial Information Science*, 2019; 22 (1):45-58, DOI: 10.1080/10095020.2018.1560056 Accessed June 2, 2020.

83. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) Satellite: HIMAWARI-8 http://bagong.pagasa.dost.gov.ph/products-and-services/satellite Accessed June 3, 2020.

84. Indonesia Agency for Meteorological, Climatological and Geophysical (BMKG) android application. https://play.google.com/store/apps/details?id=com.Info_BMKG Accessed June 3, 2020.

85. Indonesia Agency for Meteorological, Climatological and Geophysical (BKMG) website. https://www.bmkg.go.id/ Accessed June 3, 2020.

86. India Meteorological Department, Ministry of Earth Sciences, Government of India Satellite:INSAT https://mausam.imd.gov.in/imd_latest/contents/satellite.php Accessed November 7-9, 2019 & June 3, 2020.

87. China Meterological Administration. National Satellite Meteorological Center. FENGYUN Satellite Data Center. http://satellite.nsmc.org.cn/portalsite/default.aspx?currentculture=en-US Accessed June 4, 2020.

88. Japan Meteorological Agency (JMA) Satellite: HimawariCast. https://www.jma.go.jp/jma/jma-eng/satellite/introduction/satobs.html Accessed June 4, 2020.

89. Korea Meteorological Administration (KMA) Satellite: GK2A. https://www.weather.go.kr/eng/weather/images/satellite.jsp Accessed June 5, 2020.

90. Pacific Disaster Center (PDC), University of Hawaii, USA. DisasterAWARE application. https://www.pdc.org/apps/disasteraware/ (n.d.) Accessed June 5, 2020.

91. Pacific Disaster Center (PDC).University of Hawaii, USA. https://www.pdc.org/ (n.d.) Accessed 20-23 August, 2018 & June 5, 2020.

92. Bangladesh Meteorological Department. Real-time weather data mobile application. http://live.bmd.gov.bd/p/MobApp/ Accessed November7-9, 2019 & June 6, 2020.

93. Bangladesh Meteorological Department. http://live3.bmd.gov.bd/ Accessed November 7-9, 2019 & June 6, 2020.

94. Ministry of Disaster Management and Relief. Government of the People's Republic of Bangladesh.https://modmr.gov.bd/site/page/465fe909-2a3a-48bb-b3c5-b78bfe105353/Contact-us Accessed November 7-9, 2019 & June 6, 2020.

95. Ministry of Health and Family Welfare. Government of the People's Republic of Bangladesh. http://www.mohfw.gov.bd/ Accessed November 7-9, 2019 & June 6, 2020.

96. Ministry of Agriculture. Government of the People's Republic of Bangladesh. https://moa.gov.bd/ Accessed November 7-9, 2019 & June 6, 2020.

97. Ministry of Environment, Forests and Climate Change. Government of the People's Republic of Bangladesh. https://moef.gov.bd/ Accessed November 7-9, 2019 & June 6, 2020.

98. Ministry of Civil Aviation and Tourism. Government of the People's Republic of Bangladesh. http://www.mocat.gov.bd/ Accessed November 7-9, 2019 & June 6, 2020.

99. Ministry of Education. Government of the People's Republic of Bangladesh. https://moedu.gov.bd/ Accessed November 7-9, 2019 & June 6, 2020

100. Guy Carpenter &Company, LLC. Managing Risk: Reinsurance Broking. http://www.guycarp.com/managing-risk/reinsurance-broking.html Updated 2019. Accessed June 7, 2020.

101. Boggs, CJ. Contractual Risk Transfer: The Basics. *The Insurance Journal*. https://www.insurancejournal.com/blogs/academy-journal/2015/03/16/ 360274.htm Published March, 2015. Accessed June 7, 2020.

102. Clarke, D., de Janvry, A., Sadoulet, E., Skoufias, E. (eds). 2015. *Disaster Risk Financing and Insurance: Issues and results.* FERDI, France, 1-105pp.

103. The United Nations Office for Disaster Risk Reduction-UNISDR, Geneva Switzerland. UNISDR Calls for Risk-Informed Investment. https://www.undrr.org/news/unisdr-calls-risk-informed-investment Accessed June 7, 2020

104. The United Nations Office for Disaster Risk Reduction-UNISDR, Geneva Switzerland. The Sendai Framework for Disaster Risk Reduction 2015-2030 in Action. https://www.undrr.org/implementing-sendai-framework/sendai-framework-action Updated 2020. Accessed June 7, 2020.

105. MunichRE. Munich, Germany. Natural disaster risks-Losses are trending upwards: High share of natural catastrophe losses remains uninsured https://www.munichre.com/en/risks/natural-disasters-losses-are-trending-upwards.html (n.d.) Accessed June 8, 2020.

106. Wallemacq, P.&House,R. *The Economic Losses, Poverty and Disaster Report 1998-2017.* Centre for Research on Epidemiology of Disasters (CRED) and The United Nations Office for Disaster Risk Reduction (UNISDR, Geneva Switzerland). (2018):1-33pp. https://www.undrr.org/publication/economic-losses-poverty-disasters-1998-2017 Accessed June 8, 2020.

107. The United Nations Office for Disaster Risk Reduction-UNISDR, Geneva Switzerland. Bangladesh goes beyond cyclones.

https://www.undrr.org/news/bangladesh-goes-beyond-cyclones Published December 2019. Accessed June 8, 2020.

108. Bern, C., Sniezek, J., Mathbor, G. M., Siddiqi, M. S., Ronsmans, C., Chowdhury, A. M., Choudhury, A. E., Islam, K., Bennish, M., & Noji, E. (1993). Risk factors for mortality in the Bangladesh cyclone of 1991. *Bulletin of the World Health Organization*, 71(1), 73–78.

109. The United Nations Office for Disaster Risk Reduction-UNISDR, Geneva Switzerland. International Decade for Natural Disaster Reduction (IDNDR) programme forum July 5-9, 1999 – proceedings. https://www.undrr.org/publication/international-decade-natural-disaster-reduction-idndr-programme-forum-1999-proceedings Accessed June 8, 2020.

110. Cyclone Preparedness Programme (CPP). Government of the People's Republic of Bangladesh. http://www.cpp.gov.bd/ Updated May, 2020. Accessed June8, 2020.

111. F. Chollet. (2018). *Deep Learning with Python.* Manning Publications Co., Shelter Island, NY 11964, The United States of America. pp1-386.

112. Abadi, M., Agarwal, A., Barham, P., et al. TensorFlow White Papers: Large-scale machine learning on heterogeneous systems, 2015. TensorFlow 2.0 Software available from tensorflow.org. Updated January, 2021. Acessed January, 2021.

113. Bisong E. (2019). *Google Colaboratory. In: Building Machine Learning and Deep Learning Models on Google Cloud Platform.* Apress, Berkeley, CA. 59-64pp. ISBN: 978-1-4842-4470-8. Available at https://doi.org/10.1007/978-1-

4842-4470-8_7 eBook Published online September 28, 2019. Acessed January, 2021.

114. Google LLC. Copyright (2019) Licensed under the Apache License, Version 2. https://www.apache.org/licenses/LICENSE-2.0 Accessed January, 2021.

115. Google LLC. What is Colaboratory? https://colab.research.google.com/notebooks/welcome.ipynb Accessed January, 2021.

116. Google LLC. Keras Tensorflow 2.0: The Sequential Model. https://www.tensorflow.org/guide/keras/sequential_model Accessed January, 2021.

117. Google LLC. Keras Tensorflow 2.0: Save and load Keras models. Keras H5 Format. https://www.tensorflow.org/guide/keras/save_and_serialize#keras_h5_format Accessed January, 2021.

118. Microsoft Corporation, Redmond, Washington, United States. Microsoft 365, Microsoft Excel. Statistical Analysis. https://www.microsoft.com/en-us/microsoft-365/excel Accessed January, 2021.

119. Amazon Web Services (AWS) Cloud. Amazon Web Services, Inc. P.O. Box 81226, Seattle, WA 98108-1226 http://aws.amazon.com Accessed January, 2021.

120. iCloud. Copyright 2021 Apple Inc. All rights reserved. Apple Inc., One Apple Park Way, Cupertino, CA 95014, USA.

https://www.apple.com/legal/internet-services/icloud/ Accessed January, 2021.

121. IBM Cloud. Copyright IBM Corporation 1994, 2021. IBM Cloud c/o SoftLayer Inc. 14001 North Dallas Parkway, Suite M100, Dallas, TX 75240 https://www.ibm.com/cloud Accessed January, 2021.

122. Huawei Cloud. 2021,Huawei Services (Hong Kong) Co., Limited. All rights reserved. https://activity.huaweicloud.com/intl/en-us/free_packages/ Accessed January, 2021.

123. Alibaba Cloud. 2009-2021, Copyright by Alibaba Cloud (Singapore) Private Limited. 8 Shenton Way, 45-01 AXA Tower, Singapore 068811. www.alibabacloud.com Accessed January, 2021.

124. World Meteorological Organization (WMO- No. 1252). 2020 State of Climate Services : Risk Information and Early Warning System. ISBN:978-92-63-11252-2 https://library.wmo.int/doc_num.php?explnum_id=10385 Published 2020. Accessed January, 2021

125. World Meteorological Organization (WMO). The gaps in the Global Basic Observing Network (GBON). Systematic Observations Financing Facility (SOFF). Weather and climate information for the global public good. SOFF Series- No. 02 https://library.wmo.int/doc_num.php?explnum_id=10377 Published 2020. Accessed January, 2021

126. World Meteorological Organization (WMO). Virtual Climate Adaptation Summit, 25-26 January 2021: The Systematic Observations Financing Facility: Filling the data gaps for effective adaptation investments. https://public.wmo.int/en/media/news/systematic-observations-financing-

facility-filling-data-gaps-effective-adaptation Published January 28, 2021. Accessed January 28, 2021

127. World Meteorological Organization (WMO). Establishing the Systematic Observations Financing Facility: A new way of financing basic observations. Systematic Observations Financing Facility (SOFF). Weather and climate information for the global public good. https://library.wmo.int/doc_num.php?explnum_id=10483

Version 2.0. Published December, 2020. Accessed January 28, 2021.

128. World Meteorological Organization (WMO). Virtual Climate Adaptation Summit, 25-26 January 2021: Invest in early warnings and early action. https://public.wmo.int/en/media/press-release/climate-adaptation-summit-invest-early-warnings-and-early-action Published January 26, 2021. Accessed January 28, 2021

129. Future Earth, The Earth League, World Climate Research Programme-WCRP (2021). 10 New Insights in Climate Science 2020. Stockholm. https://futureearth.org/10-insights-2020 Published online January 2021. Accessed January 31, 2021.

130. Pihl, E., Alfredsson, E., Bengtsson et al.,(2021). 10 New Insights in Climate Science 2020 - a Horizon Scan. *Cambridge Journal of Global Sustainability,* 1-65. doi:10.1017/sus.2021.2 Published online January 27, 2021. Accessed January 31, 2021.

131. The United Nations. Department of Economic and Social Affairs. Sustainable Development: The 17 Goals (n.d). https://sdgs.un.org/goals Accessed January, 2021

132. The United Nations General Assembly. Resolution adopted by the General Assembly on 6 July 2017. 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs). A/RES/71/313: Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development. https://undocs.org/A/RES/71/313 Accessed January,2021

133. The United Nations General Assembly.
Resolution adopted by the General Assembly on 3 June 2015.
A/RES/69/283: Sendai Framework for Disaster Risk Reduction 2015–2030.
https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_69_283.pdf Accessed January,2021

6. MANUSCRIPT PUBLICATIONS 1,2 AND 3

Manuscript Publication 1:

To analyze the Disaster Metrics retrospectively, 30 climate related natural disasters and its' governmental responses. The original research was published at the Cambridge Core Journal of Prehospital and Disaster Medicine on February 2019, after a double-blind peer review, titled **'The YEW Disaster Severity Index: A New Tool in Disaster Metrics'.** DOI: https://doi.org/10.1017/S1049023X18001115

Manuscript Publication 2:

To analyze the Disaster Metrics in real-time humanitarian impact and response in 2018 earthquake and tsunami at Donggala and Palu, Sulawesi in Indonesia. The impact analysis result was submitted to the relevant authorities for benchmarking it with responses. This special report analysis was presented at the 2nd National Pre-Hospital Care Conference and Championship on October 2018, Malaysia.[11]The full paper was published at the Cambridge Core Journal of Prehospital and Disaster Medicine on February 2020, after a double-blind peer review, titled '**Real-Time Impact Analysis and Response using A New Disaster Metrics: 2018 Sulawesi Earthquake and Tsunami**'. http://bit.ly/yew-dsi. DOI: https://doi.org/10.1017/S1049023X19005247

Manuscript Publication 3:

To analyze the Disaster Metric in near-real-time impact analysis of Hurricane Dorian Bahamas risk reduction, based on preparedness 36-48 hours prior to the landfall. The near-real-time impact analysis result was submitted to the national and regional disaster authorities for benchmarking its' preparedness, responses, and future risk reduction.

The special report analysis of the concept paper was published at the International Journal of Scientific and Engineering Research on April 2020, after being double blind reviewed, with the titled of ‘**A New Approached towards Hurricane Risk Reduction and Preparedness, Based on Near-Real-Time Impact Analysis: Hurricane Dorian Bahamas 2019.’**

DOI: 10.14299/ijser.2020.04.10

Este capítulo (p. 69-80) se corresponde con el artículo:

Yew, Y., Castro Delgado, R., Heslop, D., & Arcos González, P. (2019). The Yew Disaster Severity Index: A New Tool in Disaster Metrics. Prehospital and Disaster Medicine, 34(1), 8-19. doi:10.1017/S1049023X18001115

Debido a la política de autoarchivo de la publicación la versión de la editorial está disponible, únicamente para usuarios con suscripción de pago a la revista, en el siguiente enlace: https://doi.org/10.1017/S1049023X18001115

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Este capítulo (p. 81-87) se corresponde con el artículo:

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Debido a la política de autoarchivo de la publicación la versión de la editorial está disponible, únicamente para usuarios con suscripción de pago a la revista, en el siguiente enlace: https://doi.org/10.1017/S1049023X19005247

A New Approach towards Hurricane Risk Reduction and Preparedness, Based on Near-Real-Time Impact Analysis: Hurricane Dorian Bahamas 2019

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Abstract— Hurricanes are usually measured using wind speed intensities. The Saffir-Simpson Hurricane Wind Scale, which is currently being used in the United States and The Bahamas, mainly for a hurricane emergency response and preparedness for evacuation. However, it does not quantify the humanitarian needs at the point of impact or estimates the losses prior to the Hurricane landfall. This is a real challenge for various stakeholders in decision, and policymakers, especially in risk reduction and preparedness. The aim of this new concept approached towards an analysis of the Hurricane Dorian Bahamas Risk Reduction and Preparedness in measuring its' humanitarian impact. This was done by using the baseline ability to cope within local capacity, which includes the vulnerability and exposure population indicators, underpinned the definition of hazard or disaster in the new disaster metrics tool titled 'The YEW Disaster Metrics'. The near-real-time new concept analysis was submitted to the national and regional disaster authorities' on 6th September, 2019, within 72hours of the landfall.

Keywords— Dorian Bahamas, Dorian Impact, Disaster Severity Index, Hurricane Preparedness, Hurricane Wind Scale

INTRODUCTION

Hurricane, Typhoon or Tornado scales are commonly measured using wind speed intensities; such as Saffir-Simpson Hurricane Wind Scale (SSHWS)[1],[2], Beaufort Wind Scale[3], Enhanced Fujita Scale[4],[5],[6] and Tornado and Storm Research Organization (TORRO) Scale[7]. However, none of these measured the humanitarian impact in terms of risk reduction, based on preparedness; such as 36-48 hours prior to the landfall, or impact analysis. This posed a challenge for various stakeholders such as decision and policymakers, affected populations, reinsurance, civil-military, and other relevant governmental and non-governmental agencies in providing risk reduction planning and preparedness.

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To address this challenge, a new concept approach aiming towards an analysis of Hurricane Dorian Bahamas Preparedness and Near-Real-Time Humanitarian Impact, using a new disaster metrics tool titled 'The YEW Disaster Severity Index'. It uses 17 vulnerability and exposure population indicators, with median score 3, 100%, and Moderate DSI scoring, as the baseline, for the ability to cope within the local capacity. The 17 variable indicators[8] were mainly focusing on the aspect of search and rescue golden hours in terms of time occurrence and impact time, accessibility to the impact site and its' radius, topography, population density, exposed population, communication, social determinants of health, socio-politico and economics of the affected site, and basic survival resources including water and sanitation hygiene, food security and shelter.

In quantifying the projected preparedness and risk reduction, indicators scoring more than the baseline median score of 3, or 100% or a Moderate DSI category, indicate a nonpreparedness for the forecasted Hurricane. As for the near-real-time impact analysis, scoring more than the baseline indicates a response is needed. The scoring criteria of the new disaster metrics tool was available on the YEW DSI [8]. This fast and short communication analysis is part of the ongoing research on the disaster metrics.

As Hurricane Dorian approached The Bahamas, the nearest satellite data available was from NOAA[9], and was used to quantifying hurricane preparedness, as well as its humanitarian aftermath impact, based on the wind speed intensities such as reported in the SSHWS[1],[2] and the Hurricane Dorian Advisory Reports[9],[10].

Consider this new concept and its' analysis:

1. HURRICANE DORIAN BAHAMAS PREPAREDNESS ANALYSIS: Table 1

Table 1: Hurricane Dorian Bahamas Preparedness Analysis using Yew DSI[8]

	Dorian Bahamas Preparedness		
Saffir-Simpson Hurricane Wind Scale (SSHWS)	4		
YEW Disaster Severity Index (DSI)	6.8		
Requirement Title	**Score**	**Fit Xtd**	**Fit %**
Time occurrence	5*	15	167%
Impact time	3	9	100%
Topography	5*	15	167%
Radius from the impact site	5*	15	167%
Accessibility to the impact site	5*	15	167%
Population density	5*	15	167%
Main source of economy at impact site	3	9	100%
Public Infrastructure	5*	15	167%
Communication	3	9	100%
Type of country	3	9	100%
Governance-Corruption Perception Index	2	6	67%
Water and Sanitation Hygiene	5*	15	167%
Food security	3	9	100%
Shelter	4*	12	167%
Healthcare capacity	4*	12	133%
No of deaths	0	3	33%
No of affected	3	9	100%
GRAND TOTAL	63	189	124%

Note: Computed Bahamas Preparedness DSI Scores Analysis, 30/8/2019 at 08:30

YEW DSI formula =

Total 17 indicators (vulnerability +exposure) x 3

8 (best fit scale of DSI 1-8)

= 63 x 3 / 8 (best fit scale of DSI 1-8)

=189, best fit DSI 6 ≈ **High DSI 6.8**

DSI categories, based on scoring criteria of the YEW DSI (online supplementary):

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

Preparedness Analysis showed 9/17 Indicators scoring more than 3 or 100% median score percentage (Fit %) in, with a High DSI, more than the baseline coping capacity, indicating High in Risk Informed and Preparedness needed.*

The NOAA [9] satellite at the National Hurricane Center at Miami, Florida, first detected Dorian as Tropical Depression on 24th August, 2019. Dorian later intensified into a Major Hurricane on 30th August, 2019 with a recorded maximum sustained wind speed, over the one minute averaging period of approximately 220km per hour and a Category 4 on the Saffir-Simpson Hurricane Wind Scale (SSHWS)[1],[2] , with additional strengthening to be expected, as recorded by NOAA[9] Hurricane Hunter

Aircraft. An immediate Hurricane Warning on Northwestern Bahamas and Hurricane Watch on Andros Islands respectively were issued 36 hours and 48 hours prior to the forecasted path by the NOAA[9] and The Government of Bahamas[10], Department of Meteorology.

Based on the report of the forecasted path and the wind speed intensities of the Hurricane Dorian on the 30th August, 2019, its' preparedness was plotted into the YEW DSI[8]. The estimated humanitarian impact calculated prior to the hurricane eye landfall scored a High 6.8 in the YEW DSI[8], with 9 of the total 17 indicators scoring more than baseline coping capacity. The 9 variable indicators' in the new disaster metrics[8] were mainly time occurrence, topography, radius from the impact site, accessibility to the impact site, shelter, public infrastructure (critical facilities), population density, water and sanitation hygiene, and healthcare capacity.

As forecasted by NOAA[9], Dorian will move over to the Bahamas on 30th August, 2019 Friday late at night or 31st August, 2019 Saturday early morning, scoring 5 in the YEW DSI[8]. It is expected to be near to United States, Florida, east coast on 2nd September, 2019 Monday late at night. The Dorian predicted path[9], impact time at the Bahamas from 30th August, 2019 late night to 2nd September, 2019 morning, ranging from 36-48 hours in the YEW DSI[8] scoring criteria, scored a 3. The forecasted path of Dorian[9] is expected to be over the Northwest Bahamas and Andros Islands, isolated islands situated 3 feet above sea level topography, scoring 5 in the Disaster Metrics[8]. The latest predicted path of Dorian[9], from the Bahamas to the United States, Florida, which the radius of the impact site more than 100km[9], scoring 5 in the scoring criteria[8].

The accessibility to the impact site of Hurricane Warning and Hurricane Watch at The Bahamas, based on the NOAA hurricane forecast advisory[9], scored 5, which is inaccessible due to the category 4 on the SSHWS[1],[2] and predicted storm surged with the minimum rise in the water level of 10 to 15 feet[9]. Shelter scored 4 [8], as more than 50% of the buildings are 1 to 2 levels height[18], which is approximately 3 to 10 feet, with a high possibility of those buildings submerging underwater. The same with the Public Infrastructure (Critical Facilities) such as airports and ports, ceasing operations prior to the Dorian, scoring 5 [8],[10],[13]. Water and Sanitation Hygiene, scored 5[8], as sewage sanitation water will be overflowed and contaminated due to the predicted rise in water level[9], which is of public health concern, especially in communicable disease. Healthcare capacity overall scoring 4 [8], due to healthcare personnel shortage and strikes with referral to the Industrial Tribunal [14] prior to the Hurricane Dorian.

Population Density at the Dorian forecasted path[9],[19] is high, urban and slum, scoring 5[8]. Communication for early warning evacuation was done by the National Emergency Management Agency (NEMA) and the Bahamas Department of Meteorology via official websites[10],[12], as well as loudspeakers or hailers and door to door notifications[10],[12], scoring 3.

2. HURRICANE DORIAN BAHAMAS IMPACT ANALYSIS: Table 2

Table 2: Hurricane Dorian Bahamas Impact Analysis using Yew DSI[8]

	Dorian Bahamas Impact	
Saffir-Simpson Hurricane Wind Scale (SSHWS)	5	
YEW Disaster Severity Index (DSI)	7.3	

Requirement Title	Score	Fit Xtd	Fit %
Time occurrence	5*	15	167%
Impact time	5*	15	167%
Topography	5*	15	167%
Radius from the impact site	5*	15	167%
Accessibility to the impact site	5*	15	167%
Population density	5*	9	100%
Main source of economy at impact site	5*	15	167%
Public Infrastructure	5*	15	167%
Communication	3	15	167%
Type of country	3	15	167%
Governance-Corruption Perception Index	2	12	67%
Water and Sanitation Hygiene	5*	15	167%
Food security	4*	12	133%
Shelter	5*	15	167%
Healthcare capacity	4*	12	133%
No of deaths	0	0	0%
No of affected	3	9	100%
GRAND TOTAL	69	207	135%

Note: Computed Bahamas Impact DSI Scores Analysis, 5/9/2018 at 23:30

YEW DSI formula =

<u>Total 17 indicators (vulnerability +exposure) x 3</u>

8 (best fit scale of DSI 1-8)

= 69 x 3 / 8 (best fit scale of DSI 1-8)

= 207, best fit DSI 7 ≈ **High DSI 7.3**

DSI categories, based on scoring criteria of the YEW DSI (online supplementary):

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

*Impact Analysis showed * **12/17 Indicators** scoring 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.*

The Hurricane Dorian made the first landfall over to the Bahamas on 1st September, 2019 late night[9], scoring 5. The impact time at the Bahamas, was from 1st to 3rd September, 2019[9], scoring 5. Dorian was stronger than predicted, with a category 5 on the SSHWS[1],[2] and hurricane standstill for more than 24 hours[9]. Based on the near-real-time wind speed intensity of Category 5 on the SSHWS[1],[2], its' humanitarian impact calculated, scored a High 7.3 in the YEW DSI[8], with 12 of the total 17 variable indicators, scoring more than baseline coping capacity. The 12 variable indicators' in the new disaster metrics were mainly time occurrence, impact time, topography, radius from the impact site, accessibility to the impact site, shelter, public infrastructure (critical facilities), population density, main source of economy at the impact site, food security, water and sanitation hygiene, and healthcare capacity.

Northwest Bahamas with isolated archipelago islands topography[18], was hit by Dorian, scoring 5. Radius from the impact site, approximately more than 100km radius, at the Northwest Bahamas to the Florida[9],[18], scoring 5. It was inaccessible for evacuation or emergency search and rescue teams, during the hurricane eye landfall, as the wind gust was at 295km per hour[9],[13], scoring 5. The main public infrastructure (critical facilities), such as Ports were closed and Airports were submerged 6 feet underwater[10],[13],[18], scoring 5. With the wind speed gust of 295km per hour[9] and raised in water levels with a minimum of 18feet[9], more than 50 percent of the shelters, residential and commercial buildings were destroyed or submerged underwater[18], scoring 5. The tourism industry, the main source of economy of the country was greatly affected[10], scoring 5. The Dorian aftermath damage to the archipelago islands marine life, public, and critical infrastructure were submerged underwater, as well as spillage of oil refinery [10],[12],[13],[18] has immensely impacted the country's main economy.

The Grand Bahama and The Abacos Islands consisting of the urban and slum community with a high population density[13],[18],[19], scoring 5. More than 70 percent of the people living in informal settlements of The Muds and The Pigeon Peas, at Marsh Harbour were unaccounted for, most of them were vulnerable migrant population[13],[18],[19].

Sewage water overflowing, contaminated the drinking water source and lack of proper latrine submerging underwater[10], scoring 5. Emergency food stockpile at the emergency shelter was damaged by floodwaters[10],[12], and needs to be transported from the non-affected areas, scoring 4. More than 50 percent of the hospital capacity was either damaged partially or destroyed[13],[18], submerging underwater and contaminated with sewage water, scoring 4. The 2 most affected government hospitals were Rand Memorial Hospital, flooded with sewage water and Princess Margaret Hospital[13],[18], lack of hospital personnel[10],[14].

Detailed near real-time humanitarian impact analysis severity score calculated on 5th September, 2019 and raw data collected was sent to the relevant national and regional emergency, and disaster authorities[12],[13] on 6th September, 2019.

3. BENCHMARKING EVIDENCE-BASED IMPACT PREPAREDNESS: Table1,2

The Hurricane Dorian Bahamas Emergency and Disaster Preparedness and its' impact, benchmarking was based on the SSHWS[1],[2] reported and the YEW DSI[8] calculated, shown in Table 1.

Dorian Preparedness was done 36-48 hours prior to the hurricane eye landfall, with a Category 4 of the SSHWS[1],[2] recorded[9] and its' predicted humanitarian impact of 6.8, High in Risk-Informed, calculated in the YEW DSI[8]. In response to the commitment to the Sendai Framework 2015-2030, target c, in reducing economic losses from natural or climate change disasters, the UN Office for Disaster Risk Reduction (UNISDR)[15] emphasizes the importance of practice and investment by various stakeholders, to be based on risk-informed. This was supported by the UNISDR and Centre for Research on the Epidemiology of Disasters (CRED)[15],[16], showing the evidenced that for the past two decades, although there is a significant reduction in mortality rate due to natural disasters, the increased in economic losses by 2.5 is alarming for sustainable human development growth. Table 1 provides the YEW DSI[8] scoring in Preparedness. 9 of the 17 variable indicators' scored inability to cope within local capacity, scoring High in Risk Informed[8], hence pointing out the targeted key indicators for risk reduction.

The scoring for near-real-time impact or aftermath was the same as preparedness for the 9 indicators, unfortunately for some indicators, it scored worst, summarized in Table 2. The 9 variable indicators were mainly time occurrence, topography, radius from the impact site, accessibility to the impact site, population density, public infrastructure (critical facilities), Water and Sanitation Hygiene, Shelter and Healthcare Capacity. The 17 variable indicators' of the YEW DSI[8] Preparedness and Impact in Table1,2, showed a strong correlation coefficient of 0.9018, using Microsoft Excel 2013, Pearson Correlation Coefficient Statistical Analysis[17].

The actual Dorian landfall impact recorded a Category 5, on the SSHWS[1],[2] and its' humanitarian impact calculated, scored a High 7.3 in YEW DSI[8]. Then, Hurricane Dorian Preparedness and its' near real-time hurricane landfall impact of the SSHWS[1],[2] and the YEW DSI[8] were benchmarked, using Microsoft Excel

2013, Pearson Correlation Coefficient Statistical Analysis[17], showed a strong correlation coefficient of 1.

Declaration of Exigency was announced by the Government of The Bahamas on 2nd September, 2019[11], indicating an inability to cope within national and local capacity, regional and international assistance was needed, thus demonstrating the evidence on the tabulated YEW DSI[8].

DISCUSSION

The computed analysis of the Hurricane Dorian Preparedness in the disaster metrics scored a High DSI in Risk-Informed. These indicators in the YEW DSI[8] will provide various stakeholders, such as policy and decision-makers, reinsurance establishments, emergency response and relief teams in preparedness, thus reducing any future impact. This is a new milestone, to be added into the evidence-based research and practice in public health and policy, complex mathematical modelling for disaster risk analysis, also for parametric insurance and climate change in natural disaster.

However, there are other challenges as satellite data from NOAA[9], were not easily available or accessible due to defense or security purposes. The satellite data, which is considered a reliable source was also triangulated with its' NOAA Hurricane Hunter Aircrafts data recorded[9] and also Google LLC satellite maps[18]. Other natural or climate changed real-time disaster data, or predictions using complex computer modeling were not easily accessible by the public, although it is available to the reinsurance and risk transfer management agencies, as well as disaster centers globally.

A document searched, also on gray literature, found that World Risk Index[20] and Sea, Lake, and Overland Surge from Hurricanes (SLOSH)[21], Hurricane Hazard Intensity[22] and Hurricane Intensity Index[22] include hazard and vulnerability. However, it does not include socio-political and economic, as well as social determinants of health. Also the amplification of the economic impact by factoring political corruption in the disaster metrics. This was done by using an annually updated Corruption Perception Index[23] from Transparency International, in quantifying the true magnitude and scale of the disaster such as hurricanes.

CONCLUSION

As a conclusion, the analysis of the Preparedness and Near-Real-Time Impact using the new approach in disaster metrics showed a statistically significant correlation in the Disaster Metrics 17 indicators in quantifying the humanitarian aspect, and also the wind speed intensity of the SSHWS[1],[2] recorded. The State of Exigency was declared by the Government of The Bahamas on 2nd September, 2019[11] indicating an inability to cope within local and national capacity, demonstrating that regional and international assistance would be needed.

LIST OF ABBREVIATIONS

SSHWS Saffir-Simpson Hurricane Wind Scale

TORRO Tornado and Storm Research Organization

DSI Disaster Severity Index

NOAA National Oceanic and Atmospheric Administration

NHC National Hurricane Center, Florida

NEMA National Emergency Management Agency

SLOSH Sea, Lake, and Overland Surge from Hurricanes

UNISDR United Nations Office for Disaster Risk Reduction

CRED Centre for Research on the Epidemiology of Disasters

REFERENCES

[1] Schott, T., Landsea, C., Hafele, G., et al. (2012, updated 2019). The Saffir –Simpson Hurricane Wind Scale (SSHWS). US Department of Commerce. National Hurricane Center. National Oceanic and Atmospheric Administration (NOAA) factsheet. https://www.nhc.noaa.gov/pdf/sshws.pdf Published 2019. Accessed August 31, 2019.

[2] Simpson, R.H., & Saffir, H. (1974). The hurricane potential scale. *Weatherwise,* 27(8), 169.

[3] US Department of Commerce. Storm Prediction Centre. National Oceanic and Atmospheric Administration (NOAA) Beaufort Wind Scale. Sir Francis Beaufort. http://www.spc. noaa.gov/faq/tornado/beaufort.html. Accessed August 31, 2019

[4] US Department of Commerce. Storm Prediction Centre. National Oceanic and Atmospheric Administration (NOAA) Enhanced Fujita Scale. https://www.spc.noaa.gov/efscale/ Accessed August 31, 2019

[5] Wind Science and Engineering Center, October 10, 2006: A Recommendation for an Enhanced Fujita Scale (EF-Scale) to National Weather Service. Texas Tech University, Lubbock, Texas 79409, United States. http://www.depts.ttu.edu/nwi/Pubs/FScale/EFScale.pdf Accessed August 31, 2019

[6] Fujita, T.T., 1981: Tornadoes and Downbursts in the Context of Generalized Planetary Scales. *J. Atmos. Sci.*, 38, 1511–1534. https://doi.org/10.1175/1520-0469(1981)038<1511:TADITC>2.0.CO;2 Accessed August 31, 2019

[7] Meaden, G.T., 1975: Tornado and Storm Research Organization. (TORRO) T-Scale. http://www.torro.org.uk/tscale.php Updated 2019. Accessed September 1, 2019.

[8] Yew, YY., Castro Delgado, R., Heslop, D., & Arcos González, P. (2019). The Yew Disaster Severity Index: A New Tool in Disaster Metrics. *Prehospital and Disaster Medicine,* 34(1), 8-19. doi:10.1017/S1049023X18001115 Accessed August 31, 2019

[9] US Department of Commerce. National Hurricane Center. National Oceanic Atmospheric Administration (NOAA). Hurricane Dorian Advisory. https://www.nhc.noaa.gov/archive/2019/a105/. Accessed 24th August- 3rd September, 2019.

[10] The Government of The Bahamas Information Services. Public Announcement, News and Press Release. Monarch Building, Bay Street. P. O. Box N 8172 Nassau, N.P., The Bahamas. http://www.bahamas.gov.bs/wps/portal/public/gov/government/ Accessed 30th August- 5th September, 2019.

[11] The Government of the Bahamas Customs Department, Customs House, Thompson Blvd. P.O. Box N-155, Nassau, N.P., The Bahamas. https://www.bahamascustoms.gov.bs/hurricane-dorian-exigency-order-of-september-2-2019/ Accessed 2nd September, 2019

[12] 12.National Emergency Management Agency (NEMA). The Government of The Bahamas, Gladstone Road South of Aquinas College, P.O. Box N-7147 Nassau, N.P., The Bahamas. http://www.bahamas.gov.bs/nema Accessed 30th August- 5th September, 2019.

[13] Caribbean Disaster Emergency Management Agency (CDEMA). Resilience Way, Lower Estate. St. Michael, Barbados. CDEMA Situation Reports- Major Hurricane Dorian. http://www.cdema.org/news-centre/situation-reports?start=15 Accessed 30th August- 5th September, 2019.

[14] Industrial Tribunal of The Commonwealth of the Bahamas. Suite 106 Saffrey Square, East St, Nassau, The Bahamas. Referral to the Industrial Tribunal Court-The Bahamas Doctors Union versus The Ministry of Health. http://industrialtribunal.org/referrals/referrals/272/
The Bahamas Doctors Union versus Public Hospital Authority. http://industrialtribunal.org/referrals/referrals/273/ Published August, 2019. Accessed September 1st, 2019.

[15] The United Nations Office for Disaster Risk Reduction (UNISDR). Geneva, Switzerland. UNISDR calls for risk-informed investment. https://www.unisdr.org/archive/61164. Published 2018. Accessed September 31, 2019.

[16] Centre for Research on the Epidemiology of Disasters – CRED. School of Public Health. Université Catholique de Louvain. Clos Chapelle-aux-Champs, Bte B1.30.15, 1200 Brussels, Belgium.

[17] Microsoft Corporation, Redmond, Washington, United States. Microsoft Excel 2013.Statistical Analysis. https://download.cnet.com/Microsoft-Excel-2013/30002077_4-75855629.html Downloaded/Accessed September 31, 2019.

[18] Google Maps- Navigate & Explore (Wear OS) 10.1.0. Updated October 10, 2018. Google LLC Services. Mountain View, California USA.
[Google Maps on Grand Bahama, The Bahamas].
https://www.google.com/maps/search/google+map+grand+bahama+september+4,+2019/@26.6394254,-78.9557258,9z/data=!3m1!4b1
[Google Maps on Great Abaco, The Bahamas].
https://www.google.com/maps/search/google+map+great+abaco+september+4,+2019/@26.3832984,-77.2911335,9z/data=!3m1!4b1
Accessed September 4, 2019.

[19] Center for International Earth Science Information Network - CIESIN - Columbia University. (2016, updated 2019). Gridded Population of the World, Version 4 (GPWv4): Administrative Unit Center Points with Population Estimates. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H4F47M2C
Accessed September 4, 2019.

[20] Bündnis Entwicklung HilftI- Ruhr University Bochum – Institute for International Law of Peace and Armed Conflict (IFHV). Berlin, Germany. World Risk Report 2019. https://reliefweb.int/sites/reliefweb.int/files/resources/WorldRiskReport-2019_Online_english.pdf Published 2019. Accessed Sept 1, 2019

[21] Jelesnianski, C.P.; Chen, J.; Shaffer, W.A. SLOSH: Sea, Lake, and Overland Surges From Hurricanes; US Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Weather Service, Silver Spring, MD, USA, 1992

[22] Kantha, L. (2006), Time to replace the Saffir-Simpson hurricane scale? Eos Trans. AGU, 87(1), 3– 6, https://doi:10.1029/2006EO010003. Published online 3rd June, 2011. Accessed September 3rd, 2019.

[23] Transparency International. Berlin, Germany. Corruption Perception Index. https:// www.transparency.org/cpi2018. Published January 2019. Accessed September 3rd, 2019.

6. REPORT ON THE JOURNAL PUBLICATIONS IMPACT FACTOR

Manuscript Publication 1 Titled : 'The YEW Disaster Severity Index: A New Tool in Disaster Metrics'. It was published on Volume 34, Issue 1, February 2019 as an original research. The ISSN of **Prehospital and Disaster Medicine** is **1049023X**, and published by the Cambridge University Press, United Kingdom. The Journal Impact Factor for 2019-2020 on the Cambridge Core Journal of **Prehospital and Disaster Medicine** was **1.080,** available at https://academic-accelerator.com/Impact-Factor-IF/Prehospital-and-Disaster-Medicine The latest Hirsch index (H-Index) for this journal is 43, available at https://academic-accelerator.com/H-Index/Prehospital-and-Disaster-Medicine

Manuscript Publication 2 Titled: '**Real-Time Impact Analysis and Response using A New Disaster Metrics: 2018 Sulawesi Earthquake and Tsunami**'. It was published on Volume 35, Issue 1, February 2020 as a special report. The ISSN of **Prehospital and Disaster Medicine** is **1049023X**, and published by the Cambridge University Press, United Kingdom. The Journal Impact Factor for 2019-2020 on the Cambridge Core Journal of **Prehospital and Disaster Medicine** was **1.080,** available at https://academic-accelerator.com/Impact-Factor-IF/Prehospital-and-Disaster-Medicine The latest Hirsch index (H-Index) for the Journal of Prehospital and Disaster Medicine is 43, available at https://academic-accelerator.com/H-Index/Prehospital-and-Disaster-Medicine

Manuscript Publication 3 Titled: 'A New Approached towards Hurricane Risk Reduction and Preparedness, Based on Near-Real-Time Impact Analysis: Hurricane Dorian Bahamas 2019.' It was published on Volume 11, Issue 4, April

2020, as a special report, fast communication concept paper, which is part of the doctoral thesis research result. The ISSN of **International Journal of Scientific & Engineering Research** is **2229-5518**, and published by IJSER Press, United States. The latest Journal Impact Factor on this journal is **4.4**, available at https://www.ijser.org/ The journal impact factor history was also available on https://www.ijser.org/Impact_factor.aspx The latest Hirsch index (H-Index) for the **International Journal of Scientific & Engineering Research** is 40, available at https://www.ijser.org/