Evaluating the Applicability of Sea Basing to Support the Preparation for, and Response to, Rapid Onset Disasters

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Using the response of the International Federation of Red Cross/Red Crescent Societies (IFRC) to the 2005 Pakistan earthquake as a case study, this paper analyses the advantages and challenges inherent in the provision of logistics support in the response to a rapid onset natural disaster through the use of a floating warehouse, otherwise known as 'sea-basing'. Through a comparison of the costs and benefits of the use of alternative sea-basing models with the actual cost of air transport incurred by the IFRC, the paper demonstrates that the use of sea-basing would offer responding agencies significant cost and flexibility benefits, and that the concept has the potential to be extended significantly through the use of a bespoke vessel rather than a standard commercial container ship.

Managerial Relevance Statement

It is estimated that some 60% of the income of Non-Government Organizations (NGOs) is spent on the procurement, transport, warehousing and delivery of supplies that are needed in development/emergency response operations. This paper demonstrates how, even in the aftermath of a rapid onset disasters such as an earthquake, the use of sea – as distinct from air – transport into the affected region has the potential to deliver a significantly more efficient response with the potential for further effectiveness enhancements. Depending on the actual model of shipping used, the saving in transport costs is, potentially, as high as 40%. It is argued, therefore, that further detailed research into the potential use of sea-basing (or

‘floating warehouses’) should be undertaken as this approach represents a highly practical and sustainable way of providing support to those affected by such events.

Keywords: humanitarian logistics, sea-basing, disaster relief, inventory location, Pakistan Earthquake

Article Classification: Research Paper

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1. Introduction

Balancing the trade-off between efficiency and effectiveness is central to the management of any supply network. Achieving cost reduction based on predictable demand without compromising the surge capacity that is needed to meet the unforeseen is one of the key ways in which supply chain management can contribute to commercial success [1]. But outside the world of business, logisticians in many other fields also face the challenge of successfully managing the transition between steady state and surge situations. This is particularly true for humanitarian logisticians preparing and executing their organisations' response to a rapid onset disaster where the price of failure can be counted in lives lost rather than reduced profits. Thus, there is a general recognition that improving the logistic aspects of disaster response has much to gain from supply chain management thinking [2], [3], [4] and this, in turn, has led to a growth in academic research. For example, recent literature reviews by Overstreet, Hall, Hanna, and Rainer [5], Caunhye, Nie and Pokharel [6], Kunz and Reiner [7], and Leiras, de Brito, Peres, Bertazzo and Yoshaziki [8] give a clear indication of the breadth and depth of the investigations to date in this relatively new field.

Within the literature, different inventory management strategies have been proposed for use by the humanitarian logistician in preparation for, and in the immediate aftermath of, a rapid onset disaster – see, for example, the work of Beamon and Kotleba [9], Balcik and Beamon [10], Arora, Raghu and Vinze [11], and Afshar and Haghani [12]. To date, however, there appears to have been no discussion of the use of sea-basing as a potential pre-positioning strategy within the humanitarian logistic literature. This aim of this paper is, therefore, to explore the benefits and challenges of this concept as a means of supporting the response to a rapid onset disaster using the 2005 Pakistan earthquake as an example.

Sea-basing can best be described as the use of a floating warehouse that is located in the vicinity of a disaster-prone area, and which can move at relatively short notice to support the immediate response phase. Although, as indicated above, se-basing has not featured in the emerging discussion of ways in which the humanitarian logistician can respond to a disaster more efficiently and effectively, it is an established concept in military logistics (see, for example, Parker [13]). However, such military vessels are optimised for their primary role in supporting a non-permissive operation such as an amphibious landing and, thus, space is given over to facilities such as accommodation for the embarked personnel and self-defence weapons. Furthermore, whilst they have the capability to use their facilities in the permissive situation described in this paper, the associated cost of such a ship - for example the recently procured HMAS Canberra - is of the order of $3Bn, a figure that should be compared with the capital cost of some $10-20M for a merchant ship that is capable of carrying 500 @ 20ft containers (See discussion in Section 5 of this paper).

The paper is structured as follows: first, a brief overview of pre-positioning in humanitarian logistics is offered, after which the concept of sea-basing is described. The next section outlines the initial stages of the October 2005 Pakistan earthquake, before discussing the response of one particular humanitarian organisation, the

International Federation of Red Cross and Red Crescent Societies (IFRC). This is followed by a comparison of the cost of providing initial relief aid using air freight with that of the sea-basing approach using a standard commercial container ship. The final section broadens the discussion to cover the potential additional benefits of using a bespoke vessel, and the extent to which this approach would have been of theoretical value in response to disasters in the period 2005-2013.

2. Pre-positioning in Humanitarian Logistics

The aftermath of a disaster or complex emergency of any significance requires the development of a unique supply network that will either replace or enhance the pre-existing means of providing the affected population with food, water, accommodation, medicines, etc. This is often achieved by the local authorities within the country or region but, in the case of major events their efforts are supplemented by external assistance from a range of United Nations (UN) agencies and national or international non-government organisations (NGOs) - hereinafter referred to as 'aid agencies'.

The resultant practice of humanitarian logistics (HL) has been defined by Thomas and Mizushima [14, p. 60] as "the process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials as well as related information, from the point of origin to the point of consumption for the purpose of meeting the end beneficiary's requirements." Unsurprisingly, given that in 2013 alone, 315 natural disasters were reported which affected over 95M people with an estimated economic cost in excess of US$115BN [15], there is a significant drive to develop ways in which the efficiency and effectiveness of the HL preparation and response activities can be improved. Indeed, it is estimated that HL operations (as defined above, i.e. procurement, transport into and within the affected country, warehousing and 'last mile' distribution, together with the associated information management) consumes some 60-80% of the income of aid agencies – i.e. some $US10-15Bn/year [16].

At one level, the HL challenge is somewhat easier than that facing a typical supermarket chain – not least as the number of stock keeping units (SKUs) involved is significantly less. For example whilst the IFRC catalogue contains some 10,000 items in three volumes, two of these are devoted to medical equipment. Thus, the non-food item (NFI) range is of the order of 3,000 SKUs – which can be compared to a typical supermarket which will manage some 40-45,000 SKUs [17].

On the other hand, the core challenge of matching supply with demand is significantly more complex in the humanitarian context. Firstly this is because it involves the assessment of demand in respect of an uncertain future event in which the timing, location, impact and consequential needs of the affected population are extremely challenging to forecast. Furthermore, in the immediate aftermath of a disaster the number of people affected, their location, and their gender/age/culturally-specific needs frequently have to be assessed by the responding agencies on behalf of the beneficiaries as these individuals are primarily focussed on staying alive and keeping safe.

Secondly, there are multiple challenges to the supply side of the equation, including the likelihood of significant damage to the physical (e.g. road and bridges) and telecommunications infrastructure, multiple casualties, and potential disruptions to the normal rule of law. As a result, aid agencies are faced with the challenge of assessing what items of food and non-food items to locate where and in what quantities in order to achieve the most efficient and effective response.

For each agency, the result will reflect their perception of the optimum mix between locating stock in the region, sourcing the required material locally, or transporting it into the affected country from an external source. Clearly the use of regional warehouses has significant potential benefit in that they can service a number of countries from a single depot, in much the same way that a commercial regional distribution centre will service a number of supermarkets. However, such warehouses are in a fixed location and so may well require the use of expensive air transport to achieve timely delivery of the required stock to the affected country. Such reliance on air transport is not only expensive, but can also represent a source of considerable risk if the disaster event impacts the planned point of disembarkation as was the case in 2010 Haiti earthquake and when Cyclone Haiyan struck the Philippines in 2013.

Much of humanitarian logistics literature has, therefore, focused on the question of how, where, and how much to pre-position. However, as Whybark [18] emphasises, this is not only a question of the trade-off between sourcing and holding stock, but also that of the security of stock locations and the problem of insecurities with respect of the timing of the need of items vs. the stock shelf-life. Bemley, Davis and Brock [19] further consider the exposure of pre-positioned stock itself to damage from a disaster under this general heading of security. In a similar vein, Gatignon, Van

Wassenhove and Charles [20] evaluate the impact of the decentralisation of stock to various locations on the performance of a humanitarian organisation in terms of serving beneficiaries quickly, more cost-effectively, and generally “better”. An important factor in their evaluation of the number of facilities required is the number and magnitude of disasters in a region.

In the case of the actual location and capacity of a warehouse for pre-positioning other factors must also be considered such as the availability of different transportation modes and their ease of access to ports and airports [20]. Multiple mathematical models have been proposed for determining the number and location of such facilities for pre-positioning and the optimal quantities to be held on stock (for an overview see [19]), yet alternatives to fixed stock locations have not been considered. One such an alternative would be offered by the concept of sea-basing, which is the focus of this paper.

3. The 2005 Pakistan earthquake, 2008 Myanmar Typhoon, 2013 Philippines typhoon, and 2015 Nepal earthquake

An earthquake of magnitude 7.6 on the Richter scale occurred on 8th October 2005 at 0850 local time in an area centred 95km (60 mi) Northeast of Pakistan’s capital, Islamabad. The quake caused damage over an area of some 30,000 sq km (11,500 sq mi), and the main event was followed by 978 aftershocks of magnitude 4.0 or above over the following three weeks.

The affected area was similar in size to that of Belgium or the US State of South Carolina, but is characterised by a harsh mountainous terrain with many villages located at considerable altitude (> 1000 m or 3,000 ft). These are supported by a network of tracks that are frequently only passable on foot or with pack animals, albeit there is a better road network in the base of the main valleys.

The remoteness of the area, the destruction of such roads and bridges that existed, the difficulty of the terrain and the harsh winter conditions shortly after the earthquake all conspired to make the evaluation of the immediate needs of the population an extremely difficult undertaking. As a consequence, although some emergency goods arrived quite quickly from both within Pakistan and from other countries, significant volumes of international aid did not begin to reach Islamabad until some 6 days after the earthquake [21]. Thereafter much of this international aid was delivered (at least for the first month) by air freight and, indeed, the use of air transport continued well into the following year (ie some 3 months after the earthquake).

In practice, for the first month airfreight was the primary mode of transport for internationally sourced relief goods entering the country. Thus, whilst the figures are not entirely reliable as there is potential for some double counting, an analysis of a variety of sources including data published by USAID, NATO, DFID, IFRC and UNJLC indicates that just under 200 cargo planes landed at Islamabad airport in the first thirty days after the earthquake, carrying a total of around 3,900MT of supplies; a figure which increased to a total of around 10,000MT flown in by the end of 2005 [22].

Tropical cyclone Nargis made landfall in Myanmar on the 2nd of May 2008 leaving in its wake 138,366 dead, 2,420,000people affected and 4 billion in damages (1). It hit the Irrawaddy Delta which includes Yangon and is densely populated during the rainy season. The meteorological conditions as well as the poorly developed transport infrastructure now badly affected by the disaster presented some issues to organizations (2, 3). Another major issue especially when considering sea-basing was that the main port of Yangon was affected by the disaster and was estimated to be out of service for at least 2 weeks (3). Furthermore, politics also played a role in creating issues in the immediate aftermath as the government kept normal customs and visa practices (4) and NGO charters had serious problems to be released from customs (5). Other issues in the on-set of the Typhoon included fuel access and availability of trucks (4).

Nevertheless, air was at first the main way to reach Yangon and move goods and the WFP and logistics cluster organized an air bridge from Bangkok to Yangon in addition to chartered planes used by individual NGOs. By the end of the deployment of the cluster on the 10th of August the air bridge had operated 230 rotations and transported 4,005 mt of cargo (2). To effectively deliver goods throughout the delta waterways played a crucial role with the logistics cluster chartering four barges and three boats with a capacity of 3,900 mt (2) as well as smaller boats of 1 and 2 mt capacity (6). The number of material moved on rivers by the logistic cluster totalled 8,664 MT, while roads transport moved 1,849 MT and helicopters 912 MT. Even though, the air bridge operated until the from the 24th of May to the 29th of July (7), the Yangon port was operational by the 16th of May more than a week before the air bridge was established and two weeks after the cyclone made landfall (8). Sea shipment were arranged as well with the first 2 consignments by sea for the IFRC arriving around the 20th of June (9) while the first sea shipment arranged via the logistic cluster arrived at Yangon on August 5th.

(1) D. Guha-Sapir, R. Below, Ph. Hoyois - EM-DAT: International Disaster Database – www.emdat.be – Université Catholique de Louvain – Brussels – Belgium, http://www.emdat.be/disaster_list/index.html, accessed, 06/07/2015

(2) Logcluster end of mission report

(3) IFRC operations update 2

(4) logcluster meeting Bangkok 2008-05-08

(5) logcluster meeting Bangkok 2008-05-13

(6) logcluster meeting Yangon 2008-05-27

(7) logcluster meeting Yangon 2008-07-29

(8) logcluster meeting Yangon 2008-05-16

(9) IFRC Operations update n° 17

Typhoon Haiyan (or Yolanda), one of the strongest tropical storm ever recorded made landfall multiple times in the Philippines on November 8 2013. The storm affected the provinces of Smar, Leyte, Cebu, Iloilo, Cpiz, Aklan and Palawan with an estimated 7 354 deaths, 16 106 870 people affected and damages of 10 billion USD (1). The storm damage was spread through multiple islands across the Philippines and affected some of the transportation infrastructure, in the hardest area the airport of Tlacoban was initially closed to non-military assets with no capacity for staff, storage, management or equipment and flights were directed towards Cebu (2).

The geographical area affected by the Typhoon made sea transport between islands relevant and the logistics cluster arranged to contract vessels to deliver goods. Vessels of different sizes were chartered at different point in time up until the 12th of January (8) The first vessel to deliver goods from the logistics cluster was at

Tacloban on the 19th of November 2013 (3) 11 days after the typhoon landfall. Road transportation was then constrained by fuel scarcity and access to trucks (5). However, by the 25th of November 17 days after the Typhoon, the logistics cluster identified readily available commercial transporters in the area and did not establish a common road transport (6). As for air transportation, helicopters and planes were mobilised not only from the Philippines government and through UNHAS but also from the US, Canadian, Australian, Italian military to name only a few. Although there is no current consolidated total measure of material sent to the disaster affected area as of May 2014 the humanitarian logistics cluster helped forward 11,800 m^3 of cargo by sea, 45,141 m^3 by road and 3,000 m^3 through military assets (7).

(1) D. Guha-Sapir, R. Below, Ph. Hoyois - EM-DAT: International Disaster Database – www.emdat.be – Université Catholique de Louvain – Brussels – Belgium, http://www.emdat.be/disaster_list/index.html, accessed, 06/07/2015

(2) www.logcluster.org/sites/default/files/documents/meeting-minutes-manila-131112

(3) logcluster: meeting-minutes-tacloban-131118

(4) logcluster meeting-minutes-manila-131115

(5) logcluster MeetingMinutes-Cebu-131121.pdf

(6) meeting-minutes-tacloban-131125

(7) Philipinnes snapshot May 2014

(8) loglcuster roxas 10th of January meeting minutes

Typhoon Pam hit Vanuatu on the 13th of March 2015 affecting around 166 000 people (1)

(1) D. Guha-Sapir, R. Below, Ph. Hoyois - EM-DAT: International Disaster Database – www.emdat.be – Université Catholique de Louvain – Brussels – Belgium, http://www.emdat.be/disaster_list/index.html, accessed, 14/07/2015

The 2015 Nepal Earthquake struck at 11:56:26 on April 25th with magnitude of 7.8 Northwest of Kathmandu as of the 10th of May the Nepalese Ministry of Home Affairs estimates approximately 8,020 deaths, 16,033 injured, 375 missing, 202,157 buildings fully destroyed and 214,202 buildings partially damaged (1). This first earthquake was accompanied by multiple aftershocks with a particularly strong one on the 12th of May 2015 with a magnitude of 7.3. The geography and remoteness of affected areas as well as the risk of landslides made the delivery of aid difficult with the use of helicopters, off road trucks and tractors as well as created a need for the rehabilitation of trekking trails and the use of alternative delivery methods such as porters and pack animals (8).

The first point of arrival for international aid was the Kathmandu airport which as first was restricted to 30MT (2) had limited slots for airplanes which improved about 9 days after the earthquake as the shortage of material handling equipment and personnel subsided although damage to the runway still limited the weight of the planes (3). The congestion at the airport had subsided by May 24th (4) and by the 16th of June there was an expected 2 charter flight a week arriving at the Kathmandu airport (5). Relief items were also transported by trucks and routes from India were opening as soon as the 11th of May (6) and the overland route from Kolkata took 7 to 10 days (7). By the 10th of July, the logistics cluster had handled 34,425 m^3 (11,297 MT) of cargo handled 60% for shelter, 20% for food, 6% for health, 5% for logistics, 3% for WASH, 2% for education and construction and 1% for protection and operational support (8).

(1) Ministry of Home Affairs, Nepal, Nepal Earthquake 2072 : Situation Update as of 11th May (available at : drrportal.gov.np/uploads/document/14.pdf) accessed 14/07/2015

(2) log cluster 27th of April minutes?

(3) log cluster 4th of May minutes?

(4) log cluster 24th of May minutes?

(5) log cluster 16th of June minutes?

(6) IFRC 11 may operations update?

(7) log cluster 17th of May minutes?

(8) Nepal - Infographic Earthquake Response as of 10 July 2015 (available at : http://www.logcluster.org/blog/nepal-infographic-earthquake-response-10-july-2015) accessed 14/07/2015

4. Sea-basing for disaster relief

Whilst there are obvious limitations to the involvement of (foreign) military actors in disaster relief, military logisticians share the same basic challenge as their humanitarian counterparts as both must have the plans, systems and materiel ready to transform their operations from a steady to a surge state in a very short timeframe [23]. One way in which this can be accomplished in a military context is through the use of the sea-basing concept outlined above. This use of such support ships is widely operated by the Armed Forces of a number of countries to support the initial insertion of soldiers into a potentially hostile environment. However, as indicated earlier, the cost of such purpose-built vessels is significantly higher that a normal container ship, and therefore this latter option will be the focus of the following discussion.

This section of the paper discusses the potential use of sea-basing for the purposes of disaster relief and evaluates its effectiveness with data from the Pakistan earthquake. In doing so, it has been assumed that the sea-based vessel will be located in Singapore in its dormant state. This country is at a strategic cross-road in South East Asia, with an anchorage that is relatively safe in terms of shelter and has a minimal danger from piracy. Singapore is also very widely used to anchor numerous vessels for crew changes, repairs and whilst awaiting orders. Singapore has, therefore, a comprehensive set of support services for anchored vessels such as workboats to provide personnel, supplies, materials, fuel and repairs as necessary.

The exemplar vessel would be stocked with an appropriate selection of food, non-food items and medical items and, on the assumption that it is partially crewed with key personnel at all times, should be able to sail within 24 hours to a selected destination. Estimated transit times (at 14kt) to a number of potential ports in the area are shown in Figure 1. In the context of the Pakistan earthquake, such a vessel could arrive in Karachi (the country's main port) some 9 days after leaving Singapore. To this must be added the unloading time (24 hours) and the in country transit time between Karachi and Islamabad (1,600km – 1,000mi) which would add some 2-3 days to the journey.

Thus, in this scenario, the total elapsed time from the onset of the earthquake to the arrival of the goods from the vessel at Islamabad would have been some 14 days. The choice of Islamabad as the interim destination is designed to provide a comparator to the alternative of air transport which also used Islamabad as the main disembarkation point. In both cases (sea and air) it was clearly necessary to achieve the onward transportation to the affected area, but this would be carried out in the same way for both incoming transport modes.

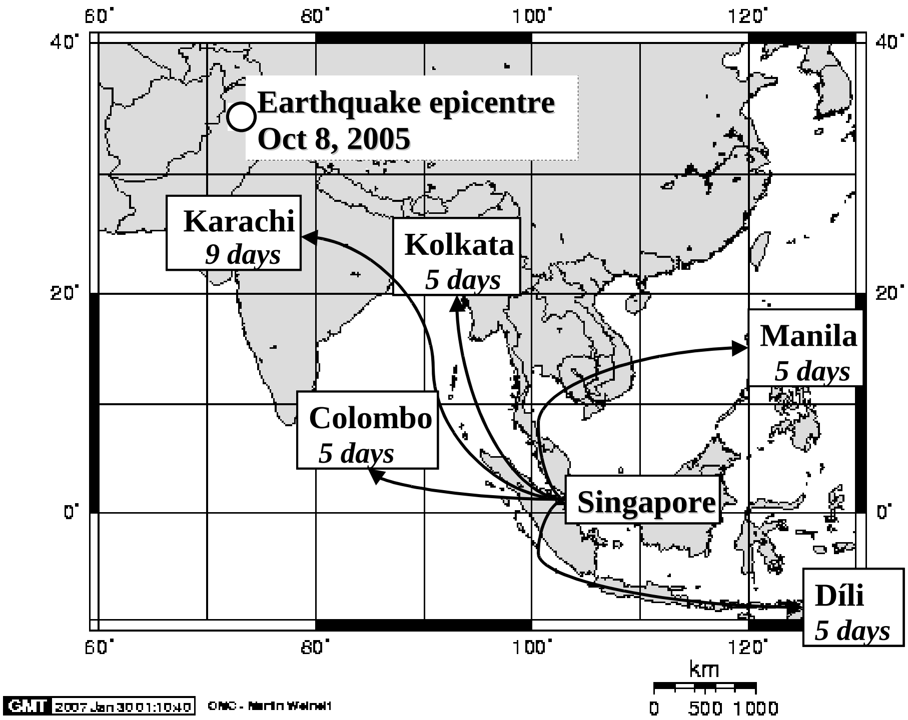

Figure 1: Transit times (at 14kt) from Singapore to selected destinations based on the Dataloy Distance Table [24] with times rounded up to the nearest whole day.

A time-line comparison to the actual international relief using air freight shows that although initial flights began to arrive at E+6, the bulk arrived the following week – i.e. broadly in the same timeframe as that from the use of a sea-basing approach.

Furthermore, the volume potentially delivered by sea at E+14 was not matched until E+30 using air freight. With this overview in mind, the next section presents further more detailed cost and volume comparisons between the use of air freight and the sea-basing response to the Pakistan earthquake. The broader feasibility of sea-basing in the SE Asian region is then discussed in the sensitivity analysis section of the paper.

5. Comparing sea-basing to air freight

To evaluate the potential use of sea-basing in rapid onset disaster relief, data on volumes moved into Pakistan in response to the earthquake were assembled from the operational reports of the IFRC. In addition, the authors were granted access to IFRC databases that contain the detailed quantities, weights and volumes of relief aid that was transported to the area of the earthquake. This data shows that, during the first 30 days after the earthquake, the IFRC flew in some 70 flights containing around 1,750MT of equipment and stores. Using the mass and volume data for the relevant commodities drawn from the IFRC catalogue [25], it was possible to assess the number of 20ft ISO Containers (TEUs) that this would have required.

The resultant best estimate is that the total volume of IFRC airfreight moved during this period equates to 344 TEUs. Unfortunately, the data set did not contain all of the relevant weights and volumes – for example those of the Norwegian Field Hospital (that was moved to Pakistan in the first weeks of the relief operation) were not included. Furthermore, and almost inevitably given the degree of confusion that surrounds the initial stages of such a rapid onset disaster relief operation, there is potential for mis-recording of data. Therefore, in order to present a conservative estimate of the above metrics, they have been rounded up and the base case will assume that the total volume of airfreight transported by the IFRC in the first 30 days after the earthquake equate to 400 TEUs.

As a result, the cost data for sea-basing was related to a 500TEU (nominal) standard geared container vessel with a base in Singapore, and this was compared with data from the IFRC's response to the first 30 days of the Pakistan earthquake. The reason for using a 500TEU (nominal) vessel reflects the limitations of useable vessel capacities in comparison to their nominal capacities – in practice, weight and stability restrictions mean that a 500TEU (nominal) vessel has a useable capacity of around 400 TEUs. The dimensions of such a vessel would be approximately:

Length: 130m Breadth: 20m Draught: 7.5m (when fully laden)

Displacement: 8,000 DWT Crew: 10-12 Speed: 14kt

At the same time, limiting the vessel size in this way helps to ensure that most commercial ports would have the required materials handling capabilities to load/unload such a ship, as well as sufficient water in their harbour to accommodate it. However, the selection of a 'geared' vessel means that it incorporates its own winch/crane system and is, therefore, able to unload the containers even if the dockside cranes were disabled as was the case of the port of Haiti in 2010. This obviously provides a measure of additional redundancy in the event that, for whatever reason, the port facilities are not available.

The next stage of the analysis was to understand the transport cost for the airfreight used by the IFRC in support of the Pakistan earthquake. Whilst broadly similar, different sources offer different estimates for such costs:

Table 1. Broad order costs of IFRC air cargo over the first 30 days

Source	Base Cost	Cost to IFRC Days 1-30
Heigh [26]	$100,000/Flight	$7,000,000
NATO [27]	$117,647/Flight	$8,235,000
Goodhand [28]	$4/kg (for 1750MT)	$7,000,000

These figures have been reviewed to ensure that they reflect current (2014) cost levels and, in discussion with senior HL practitioners, there is agreement that they reflect a broad order of magnitude - although, if anything, they are on the low side. Therefore, in line with the adoption of conservative approach to this analysis, the lowest of these estimates ($7M) will be used for comparison with sea-basing options. As an aside, whilst this figure alone may appear at first sight to be significant, it should be placed alongside the IFRC's total logistics costs (including stock procurement) for the first 60 days of operations in Pakistan which are estimated to have exceeded $50M [26].

As indicated earlier, the base case container ship to be used for comparison is a 500TEU (nominal) vessel. The movement of the resultant 400 TEUs can be achieved by:

(A) Purchase of a suitable vessel (new or second hand).

(B) Hire of capacity on an existing vessel

(C) Charter of a vessel on a long-term basis.

The actual charges incurred by the owner/charter differ across the three options as shown in Table 2.

Table 2: Comparative charges for sea-basing options

	Purchase (Option A)	**Hire of Capacity (Option B)**	**Long Term Charter (Option C)**
Vessel Purchase	√		
Capacity Hire		√	
Vessel Charter			√
Crew	√		
Vessel Maintenance	√		
Vessel Insurance	√		
Fuel	√		√
Port Charges	√		√
Container On/Off Load	√		√
Container Purchase/Hire	√	√	√
Container Repatriation	√		√

Option A envisages the purchase of a 500TEU (nominal) vessel. The cost of such a ship has varied over the period 2005-2010 from $10M (2010) to $21M (2008), with a 10 year old vessel costing between $13M (2008) to $4M (2010) [29]. However, as indicated in Table 1, purchasing a vessel would result in additional costs (such as crewing, maintenance and ship insurance). Therefore, whilst this option might prove feasible once the sea-basing concept has been proven, it is a very risky approach at this stage of the maturity of the research and will, therefore, not be considered further.

Under Option B, the 400TEUs of equipment would be kept ashore, and a vessel chartered only as and when needed. That said, standing arrangements could be set up with an appropriate shipping company (it is estimated that there are 15-20 services/week operating out of Singapore to various ports in the SE Asia area [30]) that would aim to guarantee a response time – i.e. a suitable ship to be available and ready to load in Singapore within, say, 24-48 hours. Although this option would be relatively cheap (even with a guaranteed response time), it would increase the lead time between the disaster and the arrival of the relief stores by 3-5 days (vessel arrival in port + loading time), thereby compromising the flexibility of sea-basing. Given the conservative approach to the analysis within this paper, this option has been rejected for primary analysis in the light of the additional delay that would be incurred. However, it will be considered further in the sensitivity analysis (below) where alternatives to the base case are discussed.

Meanwhile, for the base case purposes, Option C is seen as the preferred alternative, and the estimated annual costs of this approach are summarised in Table 3. It should be noted that whilst the figures relating to the shipping costs have been developed from the sources as noted, that for the in-country transit costs is less robust. These are difficult to forecast as they will reflect both the distance between the port and the disaster area, and the country specific trucking rates which, typically, rise in the aftermath of an event. Furthermore, depending on the relative location of the airport, the container port and the disaster location, the differential between the air and sea freight options may be positive or negative. A final point is that trucking may be provided at reduce rates or even free of charge, as was the case for Atlas Logistique – a French NGO operating in Pakistan [22]. Nevertheless, in line with the conservative approach adopted in this analysis, a further $0.432 has been added bringing the total cost to $4.5M.

Table 3: Annual costs for Option C

Item	Base of calculation	Source of estimate	Annual Cost ($M)
Charter of 500TEU geared vessel	Average Daily rate of $7,500 over the period 2005-2014 (High: Jan 2005: $10K/day; Low: Dec 2011: $5K/day)	Alphaliner [31]	2.738
Fuel/Oil etc	20 Days/Year at sea @ 20MT/Day based on an average fuel price of IFO380* between Jan 2005 and Dec 2013 = $480/MT + 345 Days/Year at anchor @ 2 MT/Day based on an average price of MDO** between Jan 2005 and Dec 2013 = $745/MT	NZ Ministry of Transport [32]	0.706
Port Charges	Based on "layup" rate of $3,000/week	Dunford and Tang [33]	0.156
Container Hire	$2.00/Container/Day	CSSC [34]	0.292
Container On and Off Load	$110/Container On + $110/Container Off	DP World [35]	0.088
Container Back Load On/Off	$110/Container On + $110/Container Off	DP World [35]	0.088
In country trucking cost	Broad order estimate		0.432
TOTAL			**4.500**

*IFO380 is the standard marine grade fuel for motive power at sea.
**MDO is the standard fuel for the operation of auxiliary systems such as electric generation when at anchor or in harbour

6. Summarising the discussion of the Base Case

In summary, the annual cost of a long term charter for a 500TEU geared container ship, with 20 days at sea in any given year is some $4M. Therefore, using the Pakistan earthquake as a case study and including an estimate of $0.43M for in country transport, this would deliver 400TEUs from Singapore to Islamabad at around E+14 at a cost of some $4.5M. This should be compared with the equivalent using airfreight in which the 400TEUs were delivered at E+30 at a cost of around $7M. Thus, even if the data in Table 3 is less than totally accurate, there is a very considerable cost-benefit to the proposed use of sea-basing.

Apart from cost considerations, the broader positive and negative aspects of sea-basing need to be discussed and, in the humanitarian context, the former are perceived to be:

- Its inherent flexibility. The choice of disembarkation location can be selected as the disaster unfolds, and in some cases (eg cyclones) the vessel could be pre-deployed towards the danger area as soon as an early warning is published, thereby reducing the elapsed time between the disaster occurring and the arrival of the relief goods.

- Avoidance of single point of failure in the supply network. Reliance on a single airport (eg Banda Aceh in the 2004 Asian tsunami) created major difficulties for the supply network when this airport became overwhelmed by the volume of aircraft (and supplies) using it. By contrast, a 'geared' container vessel can operate its own derricks to offload the cargo in cases where the harbour facilities have been substantially reduced as well as, potentially, having a larger number of port options that it can use.

- More broadly, the environmental impact of using one vessel is several orders of magnitude less that the equivalent resulting from the use air cargo planes.

Clearly the concept has a number of disadvantages which include:

- The large unit load that must be deployed. Whilst this is appropriate for responding to major disasters, it is less so for ones that require only limited assistance.

- A large volume of stock is tied up in the vessel which, apart from capital cost considerations, may create stock turnover issues.

7. Feasibility and sensitivity analyses

Whilst at first pass, a financial comparison between the provision of emergency relief through sea-basing and air freight in support of the Pakistan earthquake would appear to be overwhelmingly favour the sea-based option, it is important to evaluate the feasibility of this solution. Three analyses have been carried out for this purpose: (1) a feasibility analysis looking at the probability of disasters in the South East Asia region, (2) sensitivity analyses related to key cost drivers, and (3) a further consideration of the potential for using existing commercial cargo capacity (ie revisiting option B).

7.1 Assessing the probability of disasters in Asia

Self-evidently, there is no ‘guarantee’ that a natural disaster will take place in any particular geographic location in any given year. However, some of the most respected data in this area has been produced by the Center for Hazards and Risk Research, and in a recent global risk analysis Dilley, Chen, Deichmann, Lerner-Lam and Arnold [36, p. 3] note that although their work is unable to offer a view on the “*absolute* level of risk posed by any specific hazard of combination of hazards, [the data is] adequate for identifying areas that are at relatively higher single or multiple hazard risk." (emphasis in original).

Nevertheless, these authors use sophisticated modelling to understand the risks of mortality, total economic loss and economic loss as a proportion of Gross Domestic Product (GDP) density. From the humanitarian perspective, the first of these three metrics is the most important and from Dilley and his colleagues' work it can be seen that, in relation to the hazards of cyclone, flood, earthquake and landslide, the area of Southern Asia falls into the "relatively high risk" category. This is reinforced by Dilley [37, p. 6] who state that: "[d]isaster-related mortality risks associated with hydro-meteorological hazards are highest across the sub-tropical zones, with drought related mortality risks being highest in semi-arid regions of Africa. *Mortality risks associated with geo-physical hazards are highest along plate boundaries, around the Pacific rim and across southern Asia. Some countries such as the Philippines and Indonesia are at a high risk from all three types of hazards."* (emphasis added).

This perspective is reinforced by a consideration of the World Disasters Report [38] for the period 2003-2012 which shows a total of 2,717 disasters in the Asian region. Clearly not all of this average of some 270 disasters/year would have been supportable by the sea-basing approach, but the evidence would suggest that the likelihood of a natural disaster occurring in the area under consideration is considerable. Thus it is concluded that, if the sea-basing concept is indeed to be operationalised, then the geographic area described in this paper presents a highly credible basis for continued research effort.

7.2 Cost drivers of sea-basing

Another issue to consider in a sensitivity analysis is to review the key cost drivers of sea-basing. Two major cost drivers have been identified, the charter hire itself and the cost of fuel. Long-term charter costs for a 500TEU (nominal) geared container ship have fluctuated from $5,000/day in 2000 to over $10,000/day in 2005, before dropping back to $5,000/day in 2011 [31]. While the average figure of $7,500/day was used for the base case calculation (Table 3), for the purposes of a sensitivity analysis, the high-end of $10,000/day will be used. The cost of the necessary fuel (380 Centistoke – IFO 380) has varied between $275/MT and $730/MT over the period 2005-2013 and so, as before, the higher figure has been used in the analysis. Similarly, a decade high figure of $1,165/MT has been used for the MDO fueld that is used to operate generators etc whilst the ship is at anchor. Finally, as acknowledged earlier in the case study, due to the paucity of robust data, the transposition from the estimated weight of airfreight to a number of TEUs (driven by volume) may be inaccurate. To overcome this, the costs of a larger (750TEU (nominal); 650 TEUs actual) vessel are also compared.

Based on this sensitivity analysis, it can be noted that even a high-end cost estimate for a 500TEU (nominal) vessel (at some $6.2M) continues to cost less than the equivalent airfreight ($7M). Furthermore, sea-basing only proves to be slightly more expensive if using a 750TEU (nominal) ship. However, given that such vessels have a higher passage speed (15-16kt), this would reduce the lead time for responding to a disaster by 12-24 hours depending on destination

Table 4: Cost sensitivity of sea-basing

Cost item	Annual Cost (US$M) Base Case 500 TEU (Nominal) 400 TEU (Actual) Average Estimate*	 500 TEU (Nominal) 400 TEU (Actual) High End Estimate**	 750 TEU (Nominal) 650 TEU (Actual) Average Estimate***
Ship Charter *	2.738	3.650	4.560
Fuel/Oil etc**	0.706	1.098	1.059
Port Charges	0.156	0.234	0.286
Container Hire	0.292	0.292	0.475
Container On and Off Load	0.088	0.088	0.143
Container Backload On & Offload	0.088	0.088	0.143
In country transport	0.432	0.750	1.000
TOTAL	**4.500**	**6.200**	**7.666**

* based on average ship charter and fuel rates used in Table 3
**based on ship charter of $10,000 daily, IFO380 @$735/MT and MDO @ $1165/MT; port charges of $4,500/week
*** based in estimated ship charter of $12,500/day; 30MT/Day of IFO380 @ $480/MT at sea and 3MT/Day of MDO @ $745/MT at anchor; port charges $5,500/week.

7.3 Hiring capacity for sea-basing

The base case, whilst clearly of significant benefit in the major emergency scenario, does not offer the flexibility to allow support for lesser scale operations. The aim of this section is, therefore, to explore the use of Option B, the comparable cost of which are:

Table 5: Estimate of the Cost of Option B (Hire of Capacity) based on Singapore to Karachi* (and return)

Cost item	**500 TEU (Nominal)** **400 TEU (Actual)** **Average Estimate ($M)**	**750 TEU (Nominal)** **650 TEU (Actual)** **Average Estimate ($M)**
Hire of Capacity (Outward Leg)**	0.440	0.715
Hire of Capacity (Return Leg)	0.200	0.325
Container Hire	0.292	0.475
In country transport	0.432	1.000
TOTAL	**1.364**	**2.515**

* As indicated in the description of Option B, Karachi was selected as the destination in view of its role as Pakistan's major commercial sea port.
** Because of the patterns of trade in the Asian area, the transport cost for Singapore to Karachi at $1,100/TEU (est) is double the return leg at $500/TEU [39].

In summary, this option is dramatically cheaper than the base case (Table 3) of moving 400 TEUs ($1.364M v $4.500M), but suffers from two disadvantages.

- Firstly, the initial load time is increased by 24-48 hours (reflecting the time needed to pack the containers with the specific stock needed for the particular emergency). In the case of the Pakistan earthquake, this would have seen the arrival of the emergency goods at E+15/16 (compared with E+14) in the base case. Nevertheless, this is delivers 400TEUs significantly faster than the air freight equivalent (E+30)

- Secondly, it relies on the availability of the necessary cargo capacity at the point of embarkation within the prescribed timescale (approx 48 hours). Whilst, theoretically, this should not present a significant risk, clearly this is a fundamental element underpinning the success of this option.

8. Extending the capabilities of sea-basing

Whilst this paper has evaluated only the simplest form of sea-basing for the purposes of disaster relief, i.e. the use of a floating warehouse, the original concept has been used with a variety of extensions in the military context. Mimicking the broad range of capabilities that are available in such a purpose built military vessel would require not only the ship itself (which almost certainly could not be chartered and would, therefore, incur a considerable capital outlay), but also a larger (and more expensive) crew skilled in the operation of relevant equipment. That said, purpose-built vessels could include enhanced capabilities and, although further research would be needed to understand how such facilities might be employed in practice, some possibilities might include:

- Provision of an ‘operations room’ with associated communications equipment for the local command and control of the relief effort.

- Medical facilities. These could be relatively limited or, through the sacrificing of some of the cargo space, could allow the installation of a field hospital.

- Secure accommodation (and associated rest and relaxation facilities) for humanitarian teams.

- A flight deck (with or without hangar facilities) that allows for the transfer of personnel and/or equipment.

- Landing craft could also, theoretically, be carried. However, the operation of these is limited by the prevailing sea state which may be high in the aftermath of a wind event such as a cyclone.

- In addition to its own fuel requirement, the vessel could provide a bulk storage capability for fuel that can be used in support of the disaster (e.g. diesel for vehicles, generators etc). Similarly, it could carry the facilities for bulk water purification and subsequent transport in country.

- The basic container vessel could also carry vehicles (e.g. 4*4s, as well as larger equipment such as diggers and/or bulldozers) and heavy plant such as cement mixers and (small) rock crushers etc.

9. Concluding discussion

The aim of this paper was to carry out an initial evaluation of the potential for the use of sea-basing in the aftermath of a rapid onset disaster. The cost and practicality of the use of a standard 500TEU (nominal) commercial container ship were compared with similar data from the IFRC's support to the 2005 Pakistan earthquake. This analysis showed that, had it been operational at the time of the earthquake, then a sea-based response could have delivered 400 TEUs of relief goods within 15 days of the disaster at a cost of some $4.5M. This should be compared with the 30 days that it actually took the IFRC to fly in a similar volume of supplies at a cost of some $7M.

The sensitivity of the sea-based cost assumptions was tested and, in the worst case, the cost of this option rose to $7.6M – a figure that remains broadly comparable with airfreight.

To be cost–effective, it is however recognised that a major disaster must take place within the operational area approximately once every two years. Whilst in recent history this requirement has, unfortunately, been all too well fulfilled, there is no guarantee that a similar frequency of such disasters will pertain in the future – albeit, as noted in the introduction to the paper, the trend is towards a greater impact of natural disasters. Nevertheless, the proposed operational area is highly geologically active leading to volcanoes, earthquakes and tsunamis; it is also subject to other natural disasters such as fires, floods and famine. Thus an assumption that a major disaster will continue to occur at least once every two years does not seem unreasonable.

It is also recognised that the geographical closeness of the actual disaster site to the sea is another limiting factor, but this can be offset by the potential availability of a number of disembarkation locations and avoidance of the ‘single point of failure’ (e.g. the difficulties of supporting a relief operation from a single airport such as Banda Aceh in the 2004 Asia tsunami).

Finally, and perhaps most critically of all, the sea-basing concept invites the donor community to finance a capability which, like an insurance policy, may never be used. This challenges the historic behaviour of donors who have shown a marked reluctance to fund such preparation phase activities in humanitarian logistics. It would be possible to mitigate the high cost of the base case by use of capacity taken up from the commercial container transport market, and this has the potential to reduce the cost of transporting the 400 TEUs to some $2M. However such an approach introduces a major element of risk in that it removes the guaranteed availability inherent in the base case under which the vessel is held on a long term charter.

Thus, whilst this initial study has clearly demonstrated a *prima facie* case for the use of the sea-basing concept, further research is needed to investigate each of the constraints and limitations described above and to evaluate the efficacy of the model in a broader number of scenarios and geographic locations in order to provide comparative data.

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