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Disaster Relief Supply Management

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Abstract

Disaster relief supplies (DRS) play a vital role in natural disaster rescue and relief operations. Often DRS management is initiated and supported by the government, yet the related cost issues have not been fully emphasized. In the face of highly uncertain disaster locations and timing, these supplies are usually prepositioned without proper consumption, which causes enormous waste in practice both economically and environmentally. This chapter highlights the potential to bring the reverse logistics strategies in conventional business practice into DRS management. Incorporating the reverse flow of removed relief items with DRS supply chain management not only benefits in cost reduction and environmental protection, but also enhance the daily management and quality control of DRS. Relying on social trust and efficient marketing network provided by government coordination and international cooperation, the stable quality level and relatively integrated inventories of the removed DRS can achieve economies of scale in the reverse supply chain operations. This chapter aims to develop an understanding of DRS reverse logistics, which energizes the responsible management of DRS for economic, social, and environmental sustainability.

Keywords: disaster relief supply, relief material, reverse logistics, marketing strategy, resale, coordination

1. Introduction - What is disaster relief supply?

1.1 Disaster and relief

Natural disasters pose a great threat to human lives and property in all aspects. The frequency, intensity, and severity of disasters, are in a fast-growing trend year by year. According to the World Disasters Report (2018) of the International Federation of Red Cross and Red Crescent Societies (IFRC), a decade's number of 3751 disasters triggered by natural hazards had affected 2 billion people and estimated \$1658 billion cost of damages. Floods, earthquakes, storms, tsunamis, wildfires, volcanic eruptions, and landslides are on the list of most common natural disasters over the last ten years (2008–2017). Some of them occur frequently in a year, such as floods (average 152) and storms (average 101), while some are not that frequent but extremely deadly, such as earthquakes (average 30) that caused 351,968 deaths and some 49% of the total [1]. There has been a big increase in the number of responses to disasters this decade. Along with this situation, a large amount of disaster rescue and relief supplies has experienced tremendous growth, particularly in those major disasters such as forest fire, earthquake, typhoon, and floods.

Disaster relief supplies (DRS), including life necessities (e.g., food and drinks), living security items (e.g., clothes and shelters), medical supplies (e.g., medicines and healthcare products), and life-saving tools and equipment (digging tools, emergency lights, and large equipment), in response to disasters and crisis, play critical roles in saving lives and reconstructing communities in all recovering stages. Different supplies have different characteristics in terms of material lifetime and demand urgency and therefore need different management mechanisms. First, the demand for DRS is unpredictable due to the unexpected event at unexpected locations in most of the situations. Second, the amount, type, and emergency of demand are highly uncertain due to the different damage levels and geographic conditions. Third, the timely efficiency of the availability and delivery of DRS is extremely important in the relief process. Lastly, the demand and supply of these materials and equipment are mandatory and have strong social value. Furthermore, due to the low economic or market value of DRS, government agencies are responsible for the collection, purchasing, storing, delivery, and coordination of materials most of the time and situations.

1.2 Disaster relief supply management

DRS have different properties and thus are normally stored and managed in different ways. Under the central government regulations, there are typically two different management DRS management systems, centralized or decentralized, covering a country [2]. In a centralized system, such as that in China, DRS are properly arranged in different governmental levels and integrated by the central government level. A decentralized system, such as that in the US, DRS are physically handled at the state level.

In terms of material items, different supplies are held in different places. The immediate life necessities and living security items, including food, drink, basic digging tools, and simple clothes and shelters are normally stored in grassroots level facilities. These materials are of low value but have crucial importance in the initial rescuing period. Medical supplies, including medicines, dressing, first aids, surgical supports, are kept in the local hospitals and clinics. These supplies are vital in the first few days of life-saving and pain relief and need to be available in time. Other expensive medicines, surgical equipment, and special tools are available, and most of them are in actual daily uses, in large hospitals in large towns and cities. Large life-saving mechanical tools, equipment, and transportation modes are stored in the main facilities. These storages are all integrated into a largely complete network covering a whole region or a country.

Because of the uncertainty and emergency of disaster events, the demand for DRS usually cannot be satisfied by the prepositioned supplies in almost all cases. In these situations, private sectors, including non-government organizations (NGO), industrial organizations, and international organizations, collect and coordinate a large number of supplies. These supplies are planned and prepared by government agencies or obtained from all aspects of donations with various types, different amounts, and diversified conditions. They could be stored in anywhere of the country, nearby or far away. To properly manage these supplies is never an easy and simple task.

1.3 Management issues

Since the DRS are of much different market values, high uncertainty of demand time and amount, and involve multiple operations players, following management issues are frequently observed in rescue and relief practices.

1. The basic DRS of living necessities and first hand rescuing tools stored in the first line local warehouses are of low market value. They are prepared by government agencies and managed by grassroots staff. These people only obtain some basic training and spend a very limited time on material management. This implies that the daily management operations are not in a professional and even a bureaucratic manner. For instance, tons of bags of rice and flour were found expired and deteriorated in the warehouses of some affected towns several years after the 2008 Sichuan earthquake due to the lack of regular monitoring and management. It is hard to have these grassroots organizations efficiently coordinated with other organizations to provide support for the first time.
2. The time efficiency of disaster relief operations is extremely important, but the operations capability is usually very limited, particularly in those sudden-onset disasters such as earthquakes, forest fires, or tsunamis. The 2008 Sichuan earthquake in China lasted for less than a few minutes but took away around 70,000 lives, hundreds of thousands injured and a million houses crashed. Even it is possible to forecast some disasters such as typhoons and hurricanes, the precise information about the development and impact levels are hard to be obtained. Therefore, it is difficult to prepare the time availability of DRS.
3. The high uncertainties of disaster determine that the information about the timing, location, damage assessment, relief demand, and resource availability is limited, inaccurate, hysteretic, and even confusing. Besides, the demand is ever-changing due to the changing disaster environment, such as secondary disasters and volunteer coordination. Within 48 hours after the Sichuan earthquake in 2008 China, the number of rescue workers and volunteers surging into the earthquake centre town was four times more than the affected residents. Heavy rains and continuous aftershocks largely accelerated the running out of food and water. Also, broken infrastructure, limited professional manpower, poor communication, weak coordination, and unanticipated natural conditions together make the resource allocation extremely difficult.
4. Multiple relief sectors are always involved with complex coordination issues, particularly in the large natural disaster. Disaster relief operations involve thousands of converging supply chains to be coordinated in the rescuing and relief processes. However, it is often observed that these participants are too smart to be coordinated but want to be the coordinator. Many volunteers are keen to work in the sites exposed by major media, while the urgent needs in corners are often overlooked. Inefficiencies, duplications, and overlap in the management of DRS in the sites are frequently caused by poor information communication, unprofessional operations, or even language understanding. Furthermore, the scarcity of resources also poses inevitable allocation guideline issues about racial, class, ethical, and moral implications [3]. Furthermore, it is often confusing in rules, regulations, and other legal issues about social welfare in a life and death situation [4]. Poor coordination reduces the delivery time efficiency, pushes up the inventory and transportation cost, and results in huge economic and environmental waste. The phenomena are witnessed in almost all disasters like the 2008 Sichuan earthquake, the 2010 Haiti earthquake, and the 2011 Tohoku earthquake.
5. A disaster, such as an earthquake, flood, or tsunami, occurs once for years, without any regular pattern or warning signal. But once it happens, particularly in the early response periods, a large number of people and money are

needed. Relief groups, such as local community organizations, volunteer groups, or individuals are often short of budget to support their rescuing and relief operations. The regular budget provided by the government is minimal and only support the basic regular management. Disaster preparedness, including material, professional training, and community education, is often of the budget shortage. Large funds and donations are largely obtained after the disaster rather than in the earlier pre-disaster stages. The Brookings Institution investigates the hysteretic issues of donor funding, finding that the loss percentage could reach 7–28% per dollar [5]. The Federal Emergency Management Agency (FEMA) declares that every \$1 the Federal Government invests in mitigation saves taxpayers an average of \$6 in future spending [6], which shows that pre-disaster investment indeed works.

6. Both natural and social environments in the disaster area are always complicated and changing. Locally prepositioned disaster relief inventories are most likely damaged and the nearby procurements are extremely difficult. A large amount of donated relief supplies moves in the disaster relief area need to be carefully inspected, classified, and coordinated. Some of these supplies are often found not much helpful or even useless. In the US 1988 earthquake rescuing process, more than 1000 tons of medical supplies, donated from different organizations, were destroyed or discarded due to the conformity of related regulations. Therefore, complex and ever-changing DRS policies need to be designed based on a combined effect of the political, economic, demographic, and environmental realities of disaster-prone areas. It is reported that many developing countries have strong bureaucracy, weak economic capability, poor transportation network, and slow information systems. New issues appear without any signal, but require disaster rescuing and relieving organizations to undertake non-regular tasks. During the 2002 African flood crisis, most of the disaster-affected countries refused to accept the food provided by the World Food Programme (WFP) as they found that these food products were genetically modified (GM) and forced the WFP to replace them with the non-GM products [7].

2. DRS resale and refill

2.1 High availability and huge waste

Since the ultimate goal of managing disaster relief inventories is to guarantee the availability of emergency supplies, studies on inventory pre-positioning mostly focus on the problems of material type and quantity and the accessibility for rescue and relief operations. Yet, another critical issue of DRS management is to ensure the quality level of these supplies. These disaster supplies and the related inventory management issues are significantly different from those of commercial business products. First of all, the prepositioning of DRS is mostly initiated, organized, and managed by the government. In China, 25 national-level warehouses for disaster relief purposes have been established in different regions, more than 300 provincial/city-level and about 2500 county-level disaster relief warehouses cover the most population of major cities and towns. The state budget on the essential purchase of disaster relief supplies reaches 1.35 billion RMB in the year 2016. Enormous money has been spent to ensure an available supply source when a disaster occurs.

However, disasters are highly unpredictable so that estimating the potential future needs for rescue and relief activities is very difficult. We can never tell when

an earthquake comes, what the affected population is, how much the infrastructure is destroyed, and how long the influence can last. To assume social responsibility, government agencies must keep high inventory level as rescue insurance against destructive catastrophes. On the other hand, a region is unlikely to be frequently struck by catastrophic event within a year. Even on the earthquake belt area, earthquakes occur at different places. It is then often observed that DRS are stored in idle for a long time. In practice, many warehouses are suffering great waste because of the expiry dates of some essential items, such as food, water, and medicine. Due to a lack of regular monitory and proper management, a considerable amount is stored out of date and discarded afterward. After the Sichuan Earthquake in 2008, many warehouses for the anti-disaster purpose have been set up in neighboring areas. In the following years, there have been successively reported that emergency supplies like expired food, water, and sanitation articles, have run to enormous waste. Furthermore, most local warehouses are not well operated, even without professional regular monitory. It results in a surprising number of financial losses every year.

In addition, when emergency supplies are needed, what is worse is that the quality of some short-life items can be at risk if without any turnover of the inventories. When an earthquake strikes, people are usually stuck in extreme situations of necessity shortages. Food, water, medicine, tents, and communication equipment are in desperate need. Emergency supplies need to be replenished with fresh items regularly to guarantee their quality availability in case of providing stale goods to affected people. Nevertheless, unqualified delivery of unfresh or even expired relief goods has been witnessed in the response operations to almost, if not all, disasters and crises. Because these consumable materials have a relatively short lifetime but are stored in a large volume, once out of date, they must be destroyed or discarded and then cause huge waste.

2.2 Resale and refill strategy

It is then clear that the DRS management should be considered from a business perspective, to work with upstream producers, suppliers and logistics service providers on product manufacturing, procurement planning, inventory policy implementing and logistics service operations. We need to define and examine the responsiveness of product value to changes in time to find out the turning point of the quality change. From the operations management point of view, a value deterioration function of an emergency supply item can be constructed to determine the optimal timing to remove old inventories for resale and replenish with new items, provided the trade-off among the logistics cost, the holding cost and the value depreciation.

Removed packaged food and bottled drinks, especially those dried items stored for disaster relief, are in good condition and might be welcomed to a secondary market. Although the freshness degrades over time, the food still has acceptable quality, clothes and essential rescue tools are almost at the same quality levels as new. From a business perspective, reselling the old inventories with markdown prices to a legitimate secondary market not only guarantees accurate access to available emergency supplies but also benefits the economy and environment by reducing tremendous waste. Therefore, managing the DRS is far more than to maintain the right type, quantity, and time availability of them. To design a detailed plan for monitoring the supplies in the inventory, understanding the secondary market, selling them at the right time points, and refilling the inventory has great potential.

The key point of the resale and refill strategy is to properly estimate the time point of turnovers. Long-time storage causes the quality level and commercial value

of these items decreasing while too frequent replenishment can directly push up the logistics cost. Therefore, we need to identify the best timing to refresh old items. It depends on the deterioration of product quality and market value over time. Different than the fresh product, users mainly estimate the freshness of packaged food from expiry date information because the value deterioration is difficult to see in appearance. Thus, how product value perishes with age is another question to answer.

To start the resale and refill strategy, we first need to investigate the perishability in the quality of emergency supplies over time. Generally, the value of package food is depreciated very little at the initial period but suffers a drastic reduction when approaching the end of the lifetime. To recognize the turning point of the deterioration in product value, we consider the time responsiveness of value to show the responsive sensibility of the value deterioration to changes in time. Then, we can define the benefit function of DRS and conduct numerical analysis based on the historical data to manage the optimal replenishment timing to remove old items and replenish them with fresh ones. Our research reveals that there always exists a maximum benefit point throughout the product's lifetime for each item type.

Furthermore, to manage DRS in the business process, we need to work closely with product suppliers and logistics service providers. It is essentially a disaster relief supply chain management problem that aims at reducing the operational cost and enhancing the social and humanity effectiveness and efficiency. A sufficient cooperation and coordination scheme promises an overall successful implementation for the resale and refill strategy even it is not profit-oriented. It gives room for product manufacturers in material purchasing, production planning, and quality control, for disaster relief material merchandiser in product searching, purchasing and storage planning, for transportation service providers in earlier programming, routing design and labour arrangement in each refresh cycle.

Lastly, perhaps the most critically, the business perspective based operations can significantly improve the DRS management level. The government initiated and led DRS inventory, particularly in those local and first-line warehouses, does not have much incentive of economic revenue, and even neglects the management cost. A large number of local warehouses are assigned to local government agencies as a small part of their daily duty and are thus managed not at a professional standard. It inevitably causes undermined quality control problem and accelerates the product deterioration. With a proper revenue-sharing scheme, the local government is encouraged to assign officers specifically to be in charge of the DRS management. The job duties are clearly defined so that economic key performance indexes would be designed. They are responsible for secondary market research, various marketing operations, communication with product suppliers, and logistics service providers. This resale and refill initiative has been tested and implemented in a town in China for more than three years on a small scale. The practices are currently under research from both regulation and sociological aspects, to study the related issues and evaluate the effects. But the initial implementation experience shows that the quality of the operations is largely enhanced, the management cost is significantly reduced, and grassroots government agencies generally perform positive to tasks.

3. DRS reverse logistics

This section first introduces the scope and purpose of DRS reverse logistics. Then, we briefly describe the concept of conventional reverse logistics and identify the operational difficulties. Afterwards, we discuss the operational aspects of DRS reverse logistics for practical implementation.

3.1 Scope of DRS reverse logistics

The outbreak of coronavirus disease (COVID-19) from the beginning of the year 2020 has once again emphasized the significant importance of relief supply chain management as the critical items used for personal protection, diagnosis, and clinical care are facing a severe global shortage. On March 3, 2020, the World Health Organization (WHO) has issued a call for industry and governments to increase manufacturing by 40% to meet rising global demand in response to the shortage of personal protective equipment endangering health workers worldwide. Such predicament that produces additional human sufferings forces the relief supply chains to expand their capabilities in preparedness and response. While satisfying the increasing beneficiary needs and wants that generated by highly influential but low frequent disasters and crises, humanitarian decision-makers should think the reverse flow of diverse relief materials in “green” terms to quality-efficiently and cost-effectively manage the relief inventories at least cost to the environment.

There are four classes of DRS items and wastes including the following. (1) Most of the fundamental living necessities, including food, drink, simple tool, and basic medicine stored for disaster rescue and relief purposes are consumable. Take the massively reserved food commodities as an example. The “food waste hierarchy” has been widely discussed in relevant food-management research [8, 9], which indicates that the reuse option for surplus food. (2) The post-disaster relief materials, including medical support, disinfection purpose equipment, and medicine, tent, and clothes, have a longer lifetime but the quality and market quality also deteriorate. (3) Capital items and equipment, including large pieces of machinery used for life-savings, high-value medical equipment, advanced communication equipment, and large electrical generators, are usually expensive in investment but risky in technological obsolescence with relatively low-frequent demand. (4) All types of waste generated in the rescue and relief operations bring harm to the environment as well as increases the overall operational costs, which should be controlled at a minimum level. **Table 1** summarizes the types of DRS reverse logistics.

3.2 Purpose of DRS reverse logistics

DRS reverse logistics is about the recovery management of all sorts of relief supplies that are sent to the reverse flows, together with the green marketing strategies to ensure the efficient and cost-effective reuse and recycling of materials. Successful recovery management of relief materials can largely reduce the waste in need of proper disposal.

Hiding behind the humanitarian goals with highest priorities, the reverse logistics of relief supplies that fall short somewhere along the relief supply chain, or require removals from the points of consumption is not fully highlighted by the academic research or practical applications. However, the public has seen successive

Type	Example
Living necessities	Food, drink
Post-disaster relief materials	Shelters, clothes
Capital items and equipment	Life-saving machinery, medical equipment
All types of waste	Debris, packaging

Table 1.
Types of DRS reverse logistics.

reports about expired living necessities and rusty tools stored in emergency warehouses, spoiled food and out of date sanitation articles sent to the affected population, useless donations rushing into the disaster areas, etc. In the face of quality concerns, cost implications, and social responsibilities, managing reverse logistics of relief supplies should not be far from the decision-making core of humanitarian operations. While many operational issues, such as the pre-positioning, the procurement and the location-allocation of relief supplies, have attracted extensive attention in both academia and practice, the changing scope and significance of reverse logistics have not received much academic attention.

This is especially important in the humanitarian context. As “social” inventories, relief supplies should be handled in a responsible manner for economic, social, and environmental sustainability, not only due to limited budget and intensive public attention but rather on the macro-level protection of the degraded environment which is often one of the causes for humanitarian assistance [10].

3.3 Conventional reverse logistics

Reverse logistics or reverse supply chain has gained more and more attention in society through the whole product life due to the seriously declining natural environment. The essential role of the conventional reverse logistics is to recover the value of the products dropped out at different stages of the forward supply chain, including the production wastes in the manufacturing process, logistics damage in the transportation and inventory process, sample wear or unsold in the retailing stages, and most likely the end-of-life products after the consuming, so that physically discarded materials are reduced to the minimum level.

The operations in reverse logistics cover reuse, remarketing, repair, refurbishing, remanufacturing, cannibalization, recycling, and disposal. There are several difficulties in reverse logistics operations. The first one is the high operational cost in the inspection and classification of the returned products with different conditions, collection, and transportation of items with scattered locations, small amounts and uncertain timing, and remanufacturing and resale operations. In particular, the research reveals that moving a product back in reverse transportation may cost 5 to 9 times more than placing it in the original direction. To identify reusable product needs to inspect, classify, collect, repack, and allocate to the reuse locations where the related operational cost is much higher than to make a new product. Furthermore, special packaging material and process may need products collected but without preliminary package for reuse, remarketing, or even discarding, which causes more than double the cost of the forward product supply chain.

The second point is the economies of scale that are the most critical in all stages of any product supply chain, particularly logistics operations. A product or its component may get out of the forward supply chain due to different reasons in a random pattern. Therefore, all operations activities may be more or less unique. When a product can be at its end of use stage at any time, any place and with any quality conditions, which raises the issues of small collection and further inspection. To achieve the scale of operations, Walmart retailing network designed centralized returning centers and saved a considerable cost on product returns. In fact, the shortage of economies of scale can be seen in all aspects of the product reverse logistics, from recollection to inventory, from transportation to remanufacturing, and from recycling to remarketing.

The third point lies in the insufficient attention given by business management due to many business strategic reasons. These remanufactured products are of reduced quality and thus have a lower market value, but maybe even competitive to the original products. The market demand for these remanufactured products

is hard to be identified and confirmed even with the low price. In general, these remanufactured products, from the remanufacturing process to marketing promotion, are always given the lowest priority in the company strategical plan, with limited financial resource allocation and other related supports. The management information system for a product supply chain designed for its regular business seldom serves the part of the reverse logistics. Even a professional third-party logistics service provider would allocate its capacity to its forward logistics operations since the service revenue for reverse logistics is lower than normal.

3.4 DRS reverse logistics

To save the natural environment, the concept and operations of the reverse logistics should be considered and implemented in the disaster relief materials management. The DRS reverse logistics operations deals with a diversity of materials and waste from food surplus to medical surplus, consumable goods to durable goods, end-of-use product to end-of-life product, and packaging waste to debris waste, that exposes itself to the management challenges in the process of reusing (including the maintaining services), repairing, refurbishing, recycling and disposal. Some of the activities must be carried out under difficult situations simultaneously with disaster relief operations (e.g., removing unsolicited donations or debris waste), some of the decisions should take serious consideration of the social and environmental impacts in advance (e.g., resale options for the products with market values). Most importantly, given budget constraints and cost burdens, it lacks incentives, or even impossible for the DRS management and suppliers to operate a wide range of reverse systems simply with moral requirements or enforced regulations. Innovative and cost-effective business models for recapturing value or benefits from closing material loops are much more attractive for both academic research and practical applications [11, 12].

To bring the Right relief supplies with the Right quality and Right quantity at the Right time to the Right sites to serve the Right beneficiaries, called 6R rule in disaster rescue and relief operations [13], is well discussed and implemented in practice. However, a rich body of knowledge documented in commercial inventory management research provides limited insights in disastrous conditions. Comparing with the conventional practice, the DRS reverse logistics has at least several advantages in product value, operational cost, economies of scale in operations management, and management strategical consideration.

The products or parts handled in the conventional reverse logistics are of low value and not directly useful. But, most of the goods stored for disaster rescue and relief purposes are consumable [10]. Take the massively reserved food commodities as an example. The “food waste hierarchy” has been widely discussed in relevant food-management research, which indicates that the reuse option for surplus food, which refers to the removal of food from its intended supply chain, is highly recommended if the removed food is still fit for human consumption. Since the prevention of product depreciation is of top priority, food inventories should be updated and replenished with fresh items periodically before going expired. When removed, DRS managers and their suppliers could have a set of marketing choices. Transferring to legitimate secondary markets with markdown prices or selling with promotions and discounts in the supplier’s primary market are both cost-effective options, dependent on the residual value of the food. In addition, donating them to other ongoing humanitarian programs or local food aid services for the poor population could be taken into consideration.

Capital items and rescue and relief equipment are normally kept in a higher level of organization centers, which also provide regular maintenance and normal

repairing after operations. Quality guaranteed recovery management of these relief items should be incorporated into the overall planning because it may have a profound impact on the next disaster response operations. There is a chance to develop “sharing economy” markets between the suppliers and the equipment management organizations to seek the pooling of costs and risks, which lies within effective communication of information, proper design of cooperation schemes, and corresponding regulations or insurance to avoid moral hazard, bilaterally. Currently, there is not sufficient attention in either academic or business aspects addressing the recovery management issues of capital items and equipment in the humanitarian context.

The DRS items are in relatively concentrated storage and have about the same conditions. This feature gives the economies of scale in all operations of reverse logistics. The inspection process conducted before the removal can be implemented in the regular standards based on the statistical sampling instead of individual checking done in the conventional reverse logistics. These items can be assigned for reuse or remarketing simply at a lower price. The transportation and logistics in moving these items can be properly pre-arranged since the moving timing, purpose, and destination are all planned previously. The logistics cost is low due to the economies of scale. The operations can achieve high time efficiency for loading, transportation, unloading, refurbishing, remanufacturing, disposal, and others in the batch. This is the largest distinction comparing to the operations in reverse logistics in business supply chain management.

DRS are prepared, organized, and managed mainly by the government or semi-government agencies. This gives much flexibility and large room for DRS reverse logistics operations management. The fundamental purpose of DRS reverse logistics is to recover material value such that the operational cost can be saved and to minimize the waste so that the natural environment can be protected. Unlike the reverse logistics activities led by commercial organizations, the operations strategy of DRS reverse logistics is not restricted by other strategical considerations, such as profit maximization or market cannibalization.

4. Government, NGO, and private sector cooperation

Any product supply chain has a core player who coordinates or lead the whole process such that the business benefit and operations efficiency is maximized. Management responsibility of the DRS reverse logistics is inevitably carried by the government agencies who are currently in charge of the DRS management, from strategy development to operations implementation, from information system establishment to coordination with other organizations. It would significantly extend the lifetime of these items and reveal the utilization level of all supplies to achieve a much better social value of DRS.

4.1 Coordination and leadership

A business profit-oriented supply chain may be leaded or coordinated by a core player with a certain strong power, exemplified by a product leading company who own the key technology such as Boeing, or a retailing company who operates the huge retailing network with a comprehensive product range such as Walmart, or a trading company who has a complete network connecting retailers and manufacturers such as Li & Fung. A non-profit-oriented DRS management can only be initiated and operated by a government agency that has the legal authority and social reputation as its core power.

The DRS reverse logistics starts from the beginning of these material design and manufacturing. The most distinctive feature of DRS is “available just in case”. In other words, most of the consumable goods and even equipment must be well prepared but may not be used and would eventually move to the reverse logistics procedures. Therefore, it is critical to coordinate with the item suppliers in the product design stages. A consumable product for disaster relief purposes must be designed easily for inventory holding management and possibly for the secondary market. For example, a tent manufacturer slightly downgrades its product for disaster relief purpose, and buy them back with a predetermined lower price at the planned time for the secondary market. These tents are stored in the warehouses with perfect conditions, thus have almost the same market value as new since most of these tents are not for frequent use or even in single-use on the tourist market. Given the specified usage and characteristics of DRS, it is necessary to coordinate the multiple business partners in the whole product supply chain, from product manufacturing to transportation, not only to ensure the quality and functions needed but also to leave the possibility for reverse logistics.

During the rescue and relief process after the disaster event occurs, a large amount of relief items rushes into the sites from everywhere. In addition to the leading role of the DRS management in life-saving and reconstruction, government agency also needs to pay attention to material collection, screening, inspection, allocation, proper use, waste control, and surplus items reverse. Different organizations, individual volunteers, international rescue teams and military groups are all converging for life rescuing, but the precise material delivery, proper use, and waste generation issues are often ignored, even by the rescue authority. In the 2008 Sichuan earthquake, a huge amount of different materials was discarded, about one million tents were found useless and eventually reclaimed by a central government level authority.

Rescue and relief information systems play a vital role in DRS reverse logistics operations coordination. DRS are delivered to the disaster site in different rescue and relief stages. Along with the time moving forward, the demand and material information should be more and more clear, but yet properly and timely shared by different organizations. Besides, a large amount of false information and rumors are spreading in different ways. A legal and authorized government information platform is needed to provide the real information of demand, supply, management, and reverse logistics.

4.2 Purchasing for donation

To encourage the reuse of DRS items, we propose a “Purchasing-as-Donation” marketing strategy for selling relief material surplus in a cause-related marketplace. These organizations or individual consumers, retailers, traders, original suppliers, and donors. For every relief surplus item sold out, the income is calculated as a cash donation to the DRS management. In addition to the attractive price, the market is also promoted by the environment-friendly concept and social responsibility. The original suppliers who buy back their products and send them to other markets can also be rewarded by further purchasing for further DRS inventory. Traders buying and reselling these DRS products are offered further business opportunities in the future.

This strategy takes advantage of other reusing choices in many ways. Putting aside the economic value that purchasing-as-donation offers, it enables the DRS management to get access to the people in need with alternative sources, not limited to the population supported by aid programs. By using monetary transfers, the proportion of inappropriate deliveries would be controlled at a minimum level.

The purchasing-as-donation model also has positive impacts on inventory operations management. As the poor inventory management is always to be blamed for the enormous waste of relief supplies, DRS managers are forced to take good care of their relief inventories before transferring them to the cause-related consumers. On the other hand, selling relief surplus products by using online platforms and information technology almost eliminates the searching cost for potential recipients, and more importantly, discloses the inventory and donation information to the public in case of corruption.

To support the purchasing-as-donation strategy, it is important to set up related policies and regulations. These policies and regulations involve the various rights of personal or organization donations, rules for international rescue teams, reallocation of donated items or cash, and other aspects. Another important support task is to coordinate other markets, including the international market and related recycling companies to fully recapture the value of the surplus materials.

4.3 E-commerce platform

The diffusion of ownership has complicated the disaster relief supply chains. There could involve a variety of relief material providers, including governments at all levels, local and international social organizations, and private sectors. The Internet revolution has provided new platforms and innovative technologies that facilitate their communication needs in acquiring, delivering, and recycling relief supplies. Equipped with well-established information and delivery systems, the fast-growing e-commerce platforms are enjoying evolving engagement in disaster relief supply chains in the following two aspects.

1. Using their information systems to acquire relief supplies (forward-flow) and sell relief surplus products (reverse-flow).

Developing sources for the acquisition of relief items to satisfy the surging demand of beneficiaries during disaster relief operations is a key task of disaster planning [14]. Meanwhile, once the relief supplies are removed and replenished with fresh items, it is important to find a cost-effective and environmentally friendly way to ensure the appropriate reuse of relief surplus products. The e-commerce platforms, such as Amazon.com, JD.com, and Alibaba.com, cannot only act as the suppliers of a wide range of relief materials but also provide marketplace services to assist the reverse flow of relief surplus products.

During the recent outbreak of coronavirus disease (COVID-19), one of the leading online retailing E-platform in China, JD.com, has launched an information platform for emergency resource sharing, which serves over 15,000 customers around the nation, including thousands of government agencies and health care institutions. Based on the information platform, the company has provided, on aggregate, over 660 million pieces of relief items within the first month of the pandemic. On the other hand, selling relief surplus products by using online platforms and information technology enables the humanitarian organizations to get access to the people in need with alternative sources, whereby the proportion of inappropriate deliveries would be controlled at a minimum level. Because poor inventory management is always to blame for the great waste of relief supplies, selling relief surplus products via transparent online platforms also forces the humanitarian organizations to take good care of their relief inventories before transferring them to the re-users.

2. Using their delivery system to distribute the products.

Disaster relief is about 80% of logistics it would follow [7]. As relief supplies are very likely to be distributed in challenging situations while in presence of compromised infrastructure, destroyed or blocked roads and limited manpower and resources, a widely-covered supply chain network (including the supplier partnerships, warehousing, and transportation systems and personnel resources) with well-established logistics mandates and information system will save a lot of time in delivery. Many e-commerce platforms have their own self-supporting logistics service system like Amazon.com and JD.com [15], laying the groundwork for a highly efficient distribution network. To combat the pandemic COVID-19, the Hubei Provincial Government cooperated with the JD logistics to manage the disaster relief supply chains. By utilizing their supplier resources and logistics system, JD logistics has distributed over 2000 tons of relief supplies to Wuhan and its neighboring areas in the first twenty days since Wuhan's lockdown. Without the support of JD logistics, it would be extremely difficult for the local hospitals and community to acquire the whole and complete medical supplies and living necessities that were needed, and deliver them to the demand point in such a timely and cost-effective manner.

Using the e-commerce platform's delivery system is beneficial for the integration of humanitarian logistics activities. While there may involve thousands of converging supply chains in disaster relief operations, lack of coordination is the chief cause of material, manpower, and information convergence. In contrast, given that the e-commerce platforms provide systematic logistics services through bridging the real-time demand with their partner suppliers' capacity, sharing their logistics services can reduce the overall logistics cost and improve the efficiency of rescue and relief operations.

4.4 Retailer network

Demand is highly uncertain in the humanitarian context. Information concerning the disaster timing and location, available resources, functional infrastructure, type and size of beneficiaries' needs, is always limited, rough, inaccurate, and hysteretic. Prepositioned inventories held or managed by the government or humanitarian organizations may sometimes not satisfy the beneficiaries' demand in type and quantity, or cannot be transported to the disaster sites in time. In case of such failures, the local government and humanitarian organizations with the official background (e.g., the Red Cross) should make the full use of social resources. Requisitioning local retailers' reserves of needed commodities or signing agreements with local convenience or pharmaceutical chain stores to stockpile relief inventories are both honored to ensure the efficiency of disaster relief supply chains. In 2015, the Chinese Ministry of Civil Affairs has published the *Guidance on Strengthening the Construction of Relief Material Reserve System for Natural Disasters* wherein the social reserves are recommended as necessary supplements to the governmental reserves. Most local governments in the high-risk areas of natural disasters have established partnerships of stockpiling relief supplies with private sectors. Supported by its vast retailing network in Sichuan Province, for instance, the distribution centers of Chengdu Hongqi Chain Store were on standby 24/7 to guarantee the supply and allocation of emergency materials during the yearly flood season.

Other than supporting the last-mile delivery of relief supplies, the retailer network is also distributed as the outlet for the public to acquire relief and living commodities, particularly under the quarantine and distancing policy in prevention for the pandemic.

4.5 Community education

Education is the basis of reducing the impact of disasters on human security and sustainable development [16]. In the face of intensifying threats of disasters and crisis, education is no longer a schooling thing, but the whole community should be engaged in continuous learning and practicing in response to disasters. “Community-Based Disaster Risk Management” needs to establish with the linkages of disaster education to the community and household [17].

The strategies towards disaster education and risk reduction differ with the vulnerability of the community [17]. Strengthening the community capacity in terms of the individuals, families and communities is essential in the process of disaster education based on the local context [18], which concentrates on understanding the traditional knowledge, resources and practices of the local communities, and the corresponding skills, support, and structures for disaster preparedness and mitigation [16]. For instance, the social networks of the urban and rural communities are quite different. People live in the pretty intense urban areas usually have poorer communication and interactions with the community, whereas the rural communities have scattered population to connect in the process of disaster education.

Japan is widely acknowledged that has world-class disaster education in school. However, the long commuting distances have changed today’s Japanese life style that few individuals and families can afford the time spent on establishing and maintaining relationships with the communities. The disaster education focused on the Japanese communities needs to emphasize the connection between self-help and collaboration with the community and public [17]. Community-based approaches to improve the resilience of the community and the people in response to disasters and crisis are also encouraged in the United States. The Los Angeles County Community Disaster Resilience (LACCCR) Project is structured on four levers: education, engagement, self-sufficiency, and partnership, in which disaster education lays the foundation of the other three levers by building the toolkit for the dissemination of information about preparedness, risks and resources [19].

In some other developing countries like China and India, disaster education at the community level must be addressed with other issues, such as the enhancement of school-based disaster education, the awareness of disaster risks and coping capability of less-educated population, the effective, sustainable and local-based cooperation of community issues and disaster education [17, 20].

Community-based disaster education through the understanding of the social networks in the local context is essential in building the resilience of disaster-prone areas. It should profoundly involve other stakeholders existing within the society, such as governmental agencies, educational institutions, social organizations, community leaders and groups, and policy-making bodies, to push the construction and development of disaster education systems at the community level in a large cooperative effort.

5. Conclusion

Disaster relief supplies, including consumable products and heavy equipment, play a vital role in natural disaster rescue and relief. To prepare sufficient relief supplies in terms of the availability in quality and quantity is an inevitable duty for all responsible government. DRS management should be initiated and supported by the government, yet the related cost issues are usually neglected. Due to the highly uncertain locations and timing of disaster events, DRS management is under-professional. Therefore, these supplies are usually well prepositioned but without

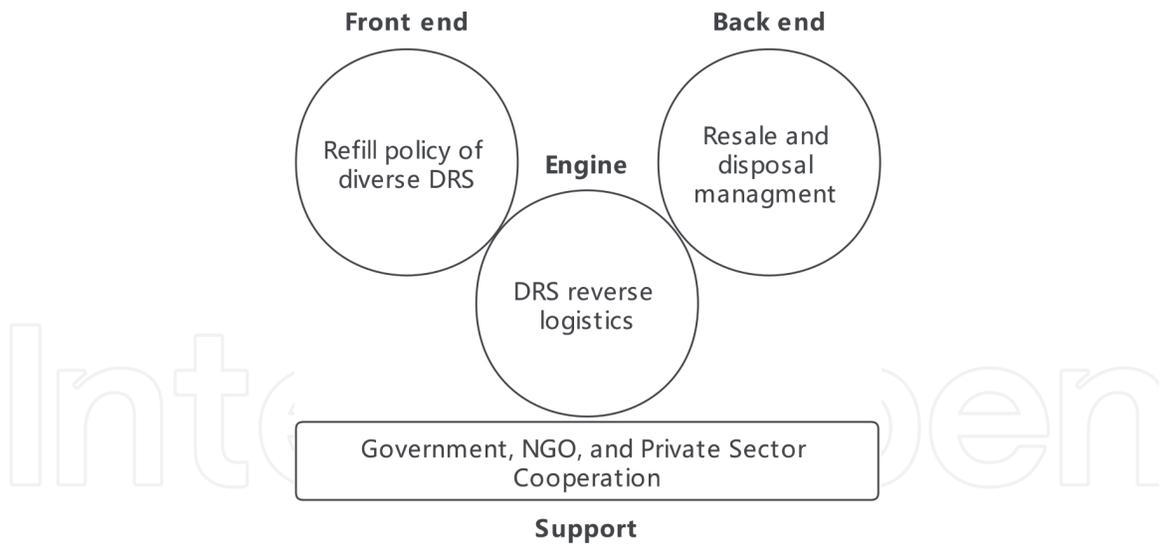


Figure 1.
A “green” view on DRS management.

proper consumption, which may cause a huge waste in practice both economically and environmentally. **Figure 1** presents our green view on the management of DRS.

To bring the reverse logistics strategies in conventional business practice into the disaster relief supply management not only benefits in cost reduction and environmental protection, but also improve the daily management of the DRS. The DRS reverse logistics, comparing with the conventional business reverse logistics, has many implementation advantages. The most critical point is the social trust and efficient marketing network provided by government coordination and international cooperation. Secondly, the stable quality level of these supplies and relatively integrated inventories bring the economies of scale in operations. After all, DRS reverse logistics would be expected to greatly energize the disaster rescue and relief activities.

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