

Humanitarian Aid for Wuhan with Crisis Logistics Management Approach

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Abstract

Humanitarian aid is one of the most popular and vital subjects nowadays. This is because, in some disasters like Corona epidemic in Wuhan, China, the regional assistance is not sufficient to compensate for the damages and to protect the people. Therefore, the management and distribution of these humanitarian aids are of paramount importance. In this manuscript, first, we model the need for the first aids in the city by considering the current situation, e.g., total population, number of sick people, dead people, number of needed hospital staff, and so forth. Then, this model solves two phases: (1) in the first phase, we ignore the cost criteria, and we use airplanes to provide the required materials to maximize the speed. (2) in the second phase, we consider the trade-off between cost and speed criteria, which introduces the train as the optimal solution.

Keywords

Humanitarian Aid, Supply Chain Management, Humanitarian Logistics, 2019-nCoV, Crisis Logistics

1. Introduction

Natural disasters are part of our lives forever. These problems do not belong to a particular country or region; therefore, all of us may suffer during our lives. In addition to regional aid, humanitarian aid is known as an efficient approach to help victims in emergencies. There are some important questions which should be answered. For example: when and where they have happened? And who is affected? In emergencies, the major goal of humanitarian aid would be considered the right amount of aid, which should be delivered to the right people at the right time in the right place with the right information and communication. In this case, Humanitarian Logistics (HL) manages whole operations to be slick, efficient, effective in logistics operations. It is clear that one of the major differences between a crisis logistic and a normal situation is the lack of stable conditions, and a level of anticipation must be taken into account so that it is immediately possible to change and modify the operation plan [1]. Based on these critical situations, some parameters should be considered in Humanitarian Logistics. 1) The operation plan should be fully flexible. It means that if more disasters happen in another location, HL should create a new plan for managing the new emergency. 2) Agility is a vital factor that should be considered to save more lives during a disaster [2]. 3) Efficiency in Logistics is an important factor that means to manage the physical movement of goods and vital information at the same time [2, 3]. 4) In emergency situation, “cost-opportunity” is more important than “cost-benefit”. This is because the life-saving of victims is defined as an opportunity that should not be compromised for the benefit [4]. 5) Humanitarian aid should consider in large-scale with full accountability and efficiency of forward and backward operations. 6) Irregular demands should be predicted and planned to provide them quickly (For instance, by simulation of similar disaster

models). So, demand forecasts will be determined and acted quickly. 7) Prediction of unusual constraints is a challenging issue that should be considered before. 8) There are some terms which should be defined in each disaster: Long-Term strategy perspective, Mid-Term tactical and planning perspective, and Short-Term technical and operational perspective. 9) Timely delivery and transportation of products should be based on purchase time, vendor lists, ordering processes and scheduling, and timely orders and operations [1]. 10) Managing the physical flow of goods and the flow of relevant information and services [4]. 11) Managing energy supply (water, gas, electricity, etc). 12) Packing and packaging 13) Considering distribution methods (by helicopters, drones, trucks, ships, trains) 14) Cooperation of Red Crescent and Red Cross forces [1].

Humanitarian logistic suffer from some limitations and challenges which should be predicted and tackled such as poor information reliability (what and how much materials are required), process fluctuations, products specification (lifecycle, chemical, inventory control), supply problems and long forecast horizons, inadequate transportation, housing, shelter and communication [3].

The primary process is divided into the following terms: preparedness, planning, procurement, transport, warehousing, tracking and tracing, and customs clearance. In preparedness, HL should plan to collect products from suppliers at the right time. Then the planning and procurement process will be done. Transportation is an important term, then the planning and procurement process will be done. Transportation is an essential term; in this case, this is because the time-consuming is not acceptable for emergencies. Therefore, an agile and efficient logistic system should be created with a highly professional transport network [1, 2]. Aid must sometimes travel through several countries using several modes of transportation, such as ships, aircraft, rail, and trucks [2]. The assistance should be distributed from the warehouse. So, one of the most critical questions is warehouse locations. Thus, the central warehouse should be considered at airports and terminals. As well as this, decentralized storage of materials and goods should be set in the nearest places to the affected areas. By tracking and tracing materials, HL managers can monitor real-time information. In the custom clearance process and inspection, complex documentation is required for customs and port clearance in the normal situation, while in emergencies, this process should be quick and smooth.

The relief items in emergencies are entirely different from the normal ones. For example, HL should provide basic needs such as food, water, and temporary shelter. Also, medicine as life-saving items should be accessible to victims with instruction of using drugs in the first hours, which is vital. As well as this, specialized input should be considered, such as medical personnel for medicines and medical care [1].

This paper focuses on the recent crisis in Wuhan city. The Coronavirus appears for the first time in this city, and the humanitarian aid will be required. The rest of this paper is organized as follows. Section 2 describes the related work in humanitarian assistance with logistics management approaches. Part 3 proposes the supply chain model for Wuhan, China. And finally, section 4 concludes this paper.

2. Related Work

Humanitarian Logistics and supply chain management have a significant role in response to both, disasters and complex emergencies and the suffering of vulnerable people [5]. Based to UNISDR (2013), “between 2002 and 2011, there were 4130 disasters recorded, resulting from natural hazards around the world where 1,117,527 people perished, and a minimum of US\$ 1,195 billion was recorded in losses. In the year 2011 alone, 302 disasters claimed 29,782 lives, affected 206 million people, and inflicted damages worth a minimum of estimated US\$ 366 billion.” UNISDR (2013) also mentioned that “the proportion of world population living in flood-prone river basins has increased by 114%, while those living on cyclone-exposed coastlines have grown by 192% over the past 30 years. Over half of the

world's large cities, with populations ranging from 2 to 15 million, are currently located in areas highly vulnerable to seismic activity [6]. However, the conducted Humanitarian Logistics and supply chain management has shown poor performance in efficiency and effectiveness at most natural or human-made caused disasters; thus, for the last decades, humanitarian organizations have been developing innovative and more agile strategies for humanitarian supply chain [5-7].

The Humanitarian Logistics and supply chain management is a complex problem due to it has multiple stakeholders such as Non-Government Organizations (NGOs), United Nation agencies, Red cross, governmental actors and so on, beside, it has a huge number of unknown parameters to be considered for the swift and efficient response as the failure of the actions can cause death or suffering of vulnerable people [5, 8]. What mentioned above makes the humanitarian supply chain for disasters being unstable and turbulent with a significant number of actors and parameters. Hence, several research studies (Nillson et al., 2010; Granot, 1999; Trim, 2004; Akhtar et al., 2012) have recommended that a proper definition of responsibilities of each stakeholder has the same importance as a well-coordinated effort to have a swift and agile response to the disasters [6, 9-12].

3. Proposed Model & Evaluation

Now, the infectious virus becomes a very damage enemy of a human being in that those infectious viruses threaten human being's health and life from time to time. In the 16th century, about 90,000,000 persons killed by smallpox within 100 years. In 1918, about 50,000,000 to 100,000,000 persons killed by Spanish flu. In 1991, 300,000 was infected by cholera and 4000 killed by it. In 1803, 29,000 persons were killed by yellow fever in North America [13]. Sars killed more than 700 persons in 2003 and infected more than 8000 persons.

Till today Feb.10 2020, it is about 42747 cases were found, 1017 people death on Feb. 11, 2020, according to the data of the National Health and Family Planning Commission of China (NHFPC). The mean incubation period was 5.2 days (95% confidence interval [CI], 4.1 to 7.0), with the 95th percentile of the distribution at 12.5 days. In its early stages, the epidemic doubled in size every 7.4 days. With a mean serial interval of 7.5 days (95% CI, 5.3 to 19), the primary reproductive number was estimated to be 2.2 (95% CI, 1.4 to 3.9) [14], which have significantly made affect all persons in Wuhan and this city is closed by government from on 23, Jan. to Feb.15 2020. Its logistics faces crisis all over the city, including a face mask, medical protection clothes, Oxygen, and other medicines, as well as those foods and living resources. How to and what to make a sustainable city logistics is so important for them. It could apply for airplanes, high-speed trains, ships, trucks, and cars to transport resources for them. Many countries like Japan, Korea, England, France, etc. sent aids to China during this 2019-nCoV crisis.

The first novel coronavirus (named 2019-nCoV) broke out in Wuhan, China, in December. From beginning to current, the 2019-nCoV infectious pneumonia (named NCIP) spread quicker than SARS in 2003. By the research of the Ministry of Science and Technology of China, it is confirmed that the 2019-nCoV could be the human-to-human transmission, which is very high risk if there is no control in that it can infect other persons by an infected person in 15 seconds contact. All places and vehicles, especially in closed vehicles like travel bus, high-speed train, ship, airplane, even home, are infectious sites if there is a person infected. Now the Wuhan city is closed by the government to defend, protect people, and control 2019-nCoV infection. When the city is closed, one big problem is how to make a good supply chain for those people in Wuhan, where live in 11,000,000 persons.

Figure 1 is the map of the supply chain for Wuhan city, which could be accessed by waterway, high train, airplane, and highway from outside of the city [5]. Wuhan city has appropriate approaches from around province access it and sites by high-speed trains, ships (Changjiang river also passes by the city) and trucks. The transportation condition shows that all resources outside the Wuhan can be transferred by all kinds of vehicles, if possible. In Figure 1, red arrows are the direction and sites for high-speed trains. Yellow arrows are the direction and sites for highways for

trucks or buses. Green circles show the port for large vessels, and along the river, for small vessels. Pentagons are for airplanes, including helicopters.

Figure 2 is the result of the research of China CDC for this 2019-nCoV, which may give some information about its development of 2019-nCoV and more in-depth analysis. According to the study and actual case of 2019-nCoV, it found that the 2019-nCoV has a shorter and stronger infection than SARS. Now the instances almost near 42,000 cases and suspicious cases are nearly 110,000 cases for about 1.5 months. The situation would become very emergency if there is no active control of 2019-nCoV infectious spread. Even currently the government takes the strongest measure for it, 2019-nCoV have already spread to all 31 provinces in China and spread many countries in the world, including U.S, Canada, France, German, ETC, even the Princess Cruises in Japan port has 135 persons [15] are infected on Feb.11 2020, and 2666 persons face the dangerous infection in the ship in that all rooms are relatively close and are easily spread 2019-nCoV by air circulation. Under the worst condition, infected people will arrive at 200,000. How to control Wuhan city and make crisis logistics is a big problem for people.

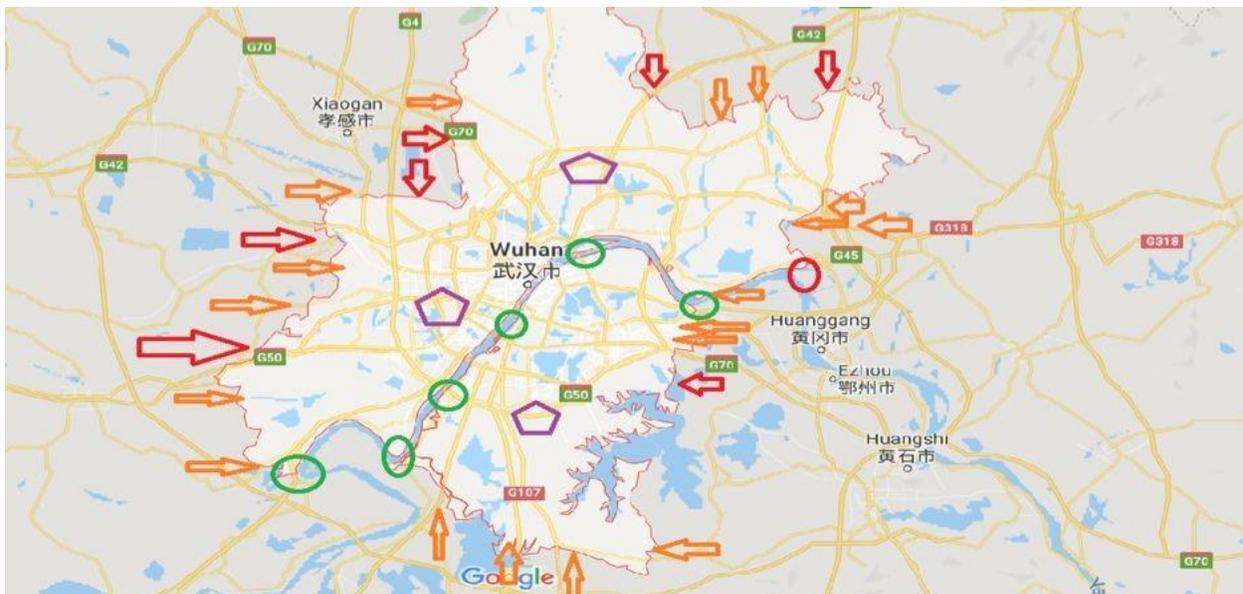


Figure 1: supply chain for Wuhan map

Wuhan City's supply chain is crucial because it has broken out 2019-nCoV, and 11,000,000 persons need a large quantity of water, foods, and other living resources. Currently, there are emergency aids for cotton, masks, medical protection clothes, and other medical requirements like oxygen, beds, separated space, and many Dr. and nurses [14]. As well as this, many animals in the city also need food. For example, a farmer has 100,000 chickens on his farm, which must supply meals for them. At the end of crisis logistics, how to deal with garbage is a significant problem in that all they are the infectious resource of 2019-nCoV, which is said that the feces of a human being may be infectious because of 2019-nCoV could live in it for a particular time. If it delivers to the scope of human being's activity, they will infect people and make them infectious.

Figure 3 is the calculation according to the infectious speed that the research indicates one person will infect about 2-3 persons [16] by spillover events on average, which is correct on the actual cases in currently, as shown in Figure 4 [17]. Till today, there are more than 42000 persons infected, about 7.5 days for one period. One month after, the

persons affected by the base of 42000 persons will increase to $42000 \times 2 \times 2 \times 2 = 672000$ persons, if no control of good measure for it, which will be a severe disaster.

Under the control of China government, now the infectious persons are about 2000-5000 persons in a day. Those increasing infectious persons make serious problems for hospitals and medical and health organizations that there are not enough beds and resources to treat those infected people who can overload one hospital in a day for the reason that one hospital normally could only receive about 1500 patients. Thus, there are two types of people that need to deal with; one is the infected people who urgently are treated in hospital and the other who is possibly infected but not immediately enter into a hospital. Those possible infected persons must be separated and diagnosed as negative (not infected) or positive characteristics (infected). This task is a big challenge in that every day there are more than 100,000 persons who need medical checks. And lots of people waiting for checking in hospitals with some symptom that has a significant probability of infecting other people while they expose in the public area. Specialists research most cases and show that about 83% [18] infectious cases happened in family contact. Therefore, there is very conflict; let people flow freely in the public area or separate at home or don't control them. If they make people free everywhere, it is hazardous for those who are infected. The second case shows that some of them are infected by their family member. Therefore, the most important problem is to diagnose all persons who are infected or potentially infected with 2019-nCoV, which has to focus on those resource of crisis logistics that could support to resolve the problem.

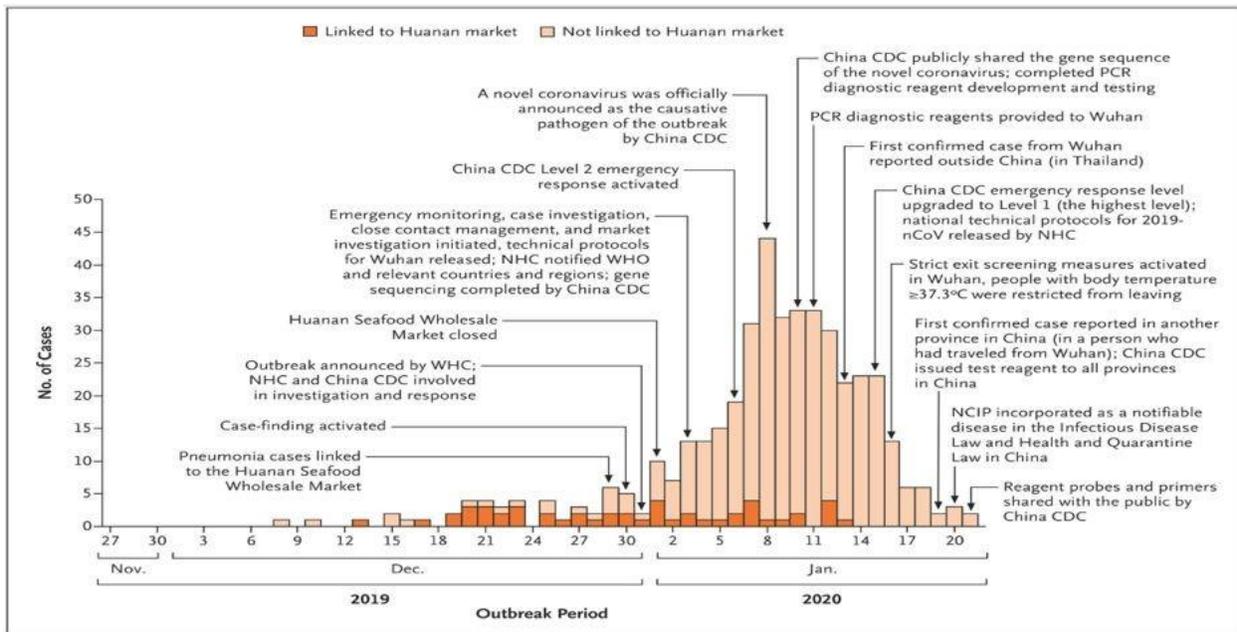


Figure 2: Onset of Illness among the First 425 Confirmed Cases of Novel Coronavirus (2019-nCoV)-Infected Pneumonia (NCIP) in Wuhan, China [6].

Figure 4 shows the increasing number of infected persons vs. time, according to CDC in China. The red line is the infected case, which is near 59,902 persons infected on Feb.12 2020. The blue line is possibly infected persons that is 13485. Moreover, the yellow line shows 6210 recovery people, and the black line is 1360 deaths at the same time. This figure demonstrates and has a clue for the prediction of the first aids and the daily assistance needed in Wuhan city. It also could figure out the crisis logistics for this city, accounting for its number of infected persons, which could speculate the resources that need to treat for patients and potential patients soon. For example, one nurse needs at least one set of medical protection clothes, two face masks one day. By this approach, humanitarian aids could be modeled,

which need lots of resources, including both medical and living support for Wuhan people and those who close to Wuhan city, those resources are:

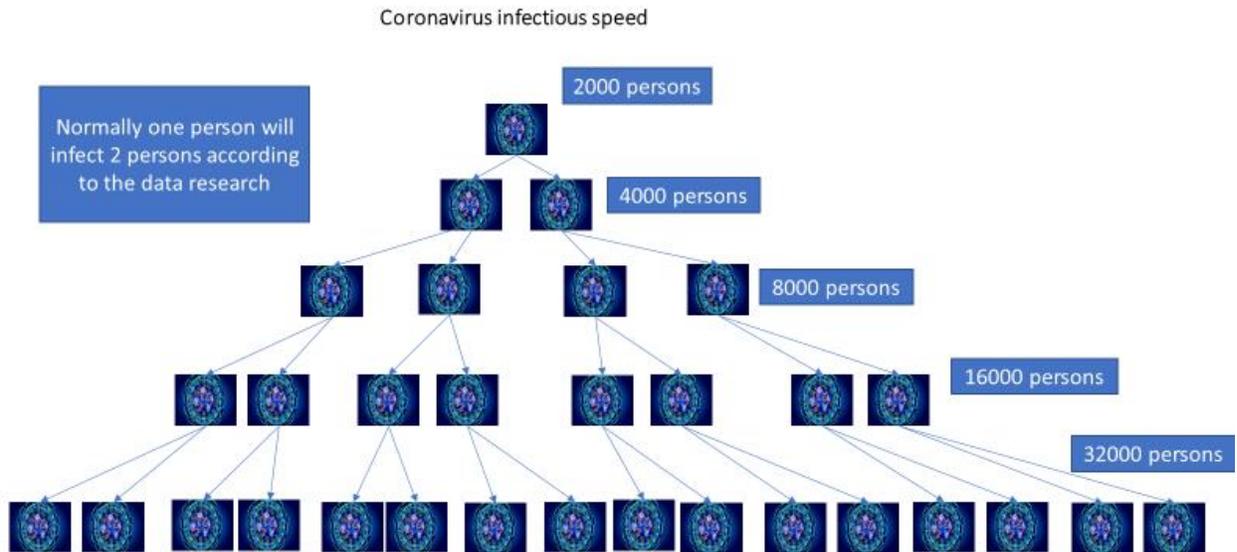


Figure 3: The NCIP spread speed in the calculation

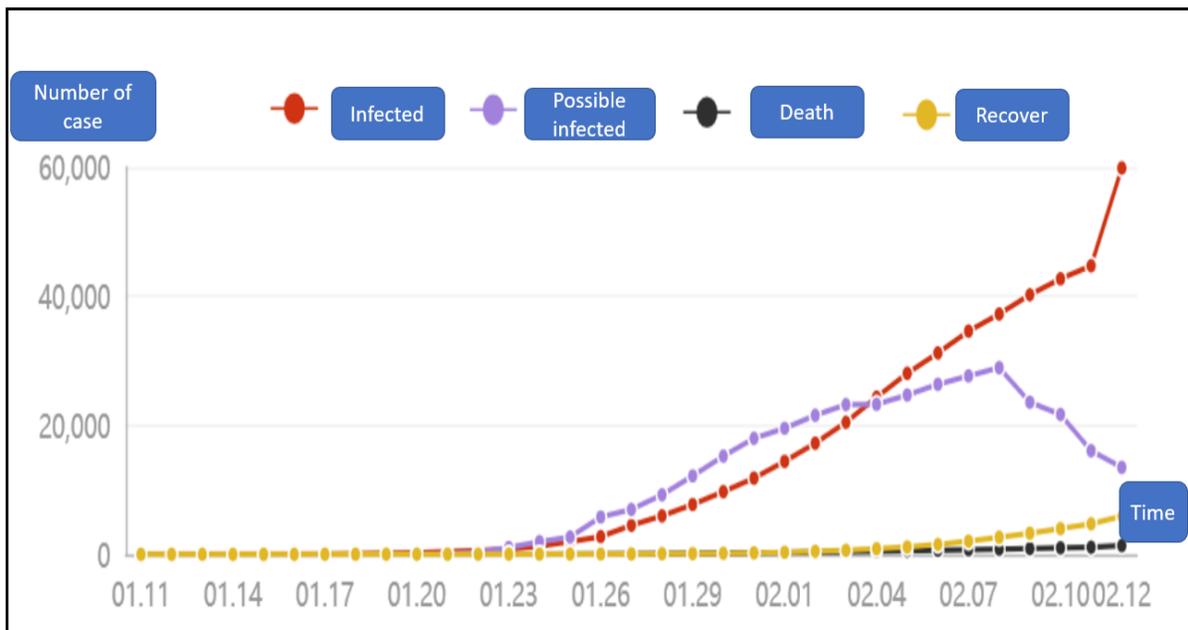


Figure 4: Infectious persons and health status [7]

Table 1. Wuhan's needs [19-21]

	Number of professional medical Dr. and Nurse	Medicine and equipment O2	Beds	rooms	ECMO ¹	Cube Hospital or the similar
Available	6000 (12070 beds)	1,460,000 m3	12,000	12,000	Estimated 100	11
Required	20,000 or more	15,000,000 m3	50,000	50,000	2,000 or more	30 or above

key resources needed in the supply chain	daily
Food	11,000,000 kg
Drinking water	20,000,000 kg
Clean water	400,000,000 kg
Meat & legume	5,000,000 kg
Medical mask	10,000,000
Medical clothes & glovers	200,000
Medical cover	200,000
Medical glasses	200,000

Table 1. is an actual resource according to the government data in about 30 hospitals. Currently, there are more than 12070 beds for infected persons. Now infected persons are over 50,000 and are increasing, more cube hospital, Drs. and nurses are an urgent need. As well, other resources as ECMO, beds, and rooms are necessary as the first aids.

The following types of transportation are considered for Wuhan city which can transfer products from outside. Table 2 shows a comparison between a plane, ship, train, truck [22].

Table 2: Comparing the Wuhan's transportation systems

	Plane	Ship	Train	Truck
Speed	The fastest way in a certain distance	The slowest approach	Quick than ship and truck in a certain distance	In short distance: fast and flexible
Cost	The highest cost	Cheaper than truck and plane in a large quantity	Cheaper for long-distance	Cost-effective for short distances
Load	Only load 2000 kg - 20,000 kg per time	Load 1000 kg to 1000000 kg	load 2,500,000 kg or above	50,000-100,000kg/per truck
limitation	Need airport	Need port	Need station and deliver from station	Just in time delivery, door to door service

Assumption 1: Now some hospitals use off masks that protect people from infection. Therefore, it is an emergency to support the first humanitarian aid and daily supply in later. Now one case is that one Dr. has checked 350 patients in a day. Some nurses and Drs can only have 2-3 hours rest in 24 hours. Even, one Dr. has been worked for 4day/96hours with little rest. At least four hospital centers are constructed up to now in the Wuhan area for an emergency, from beginning to end for one hospital center, including all telecommunication, electricity, foods, medical machines, water, and all other in six days.

The supply chain for resources could be modeled as follows 3 methods:

1. By the importance of methods into the city from outside:

A. The first aids:

175 trains

=14.6 trains/hour if 12/24 hour supply

B. The daily aids:

45000 trucks load/day if 10000kg/truck

=6300 tanks of train

=158 trains

=13.2 trains/hours if 12/24 hour supply

It is impossible for a city that there are so many trains that stop in a station or two stations.

2. By people's demands:

A. 11,000,000 persons:

10,000,000kg food/day

=1000 trucks/day if 10000kg/truck

20,000,000kg drinking water/day

=2000 trucks/day

400,000,000kg cleaning water/day

=40000 trucks/day

B. 60,000 patients and potential demands in future

2500000 tents

= 30,000,000kg

=3000 trucks

1,000,000kg medical resources, cotton, alcohol

=100 trucks/day

Others resource such as clothes, electricity, fuel, ... etc.

=1000 trucks/day.

3. Transfer by trucks in city area:

A. First aids:

50000 trucks

=14.6 trains/hour

=2.1 trains/hour if five stations for supply chain

B. The daily aids:

45000 trucks load/day

=1.6 trains/hour if five stations for supply chain

It is possible for a city that five stations deliver resource 1.6 trains/hour for people in a city.

For the river, a ship normally can load about:

1,000,000 kg. load/ship=100 trucks.

The shipload can satisfy the transport for a city if there is a river near or cross the city.

Assumption: truck unit: x / train unit: y / plane unit: z / ship unit: m

Load:

$$\text{Load}=10000x+2800000y+20000z+1000000m$$

$$=450000000$$

Cost:

$$\text{Cost}=2000x+40000y+20000z+30000m$$

$$0 \leq x \leq 45000$$

$$0 \leq y \leq 158$$

$$0 \leq z \leq 100$$

$$0 \leq m \leq 450$$

The optimization is to satisfy the above function and conditions and make the minimal cost.

For the first humanitarian aid supply chain, the quickest method is to apply for an airplane to support transportation; the cost will be the second important factor in that people's life is the first important factor that needs aids. After daily assistance, the trains will be the lowest cost of humanitarian aid, the ship, truck, and plane cost will follow one by one. It needs to balance its cost and load in the crisis logistics. Those values in Table 3 are calculated according to the number of 11,000,000 people living in Wuhan city. For example, one person may consume 1 kg of food per day, and by the aids resource, it can calculate how many trucks, trains, ships, and airplanes are need in crisis logistics.

Table 3: Resource for crisis logistics 2019-nCoV

	Load/unit	maximal	cost	Cost/unit load	
Truck (x)	10,000kg	45000	2000/truck	0.2	The third choice
Train (y)	2,800,000kg	158 / 5 stations	40000/train	0.014	The first choice
Plane (z)	20,000kg	100 times limited	20000/time	1	The fourth choice
Ship (m)	1,000,000kg	450 /5 ports	30000/ship	0.03	The second choice

Above, it is the actual situation model for crisis logistics. Given the history, the virus becomes more and more infectious than before. If its power of infection increases several times, it could make a substantial disaster for the human being. The crisis logistics should deal with this situation, otherwise, it probably happens again in the future.

Assumption:

A: The power of human-human transmission is that one person can infect four persons, about two times as the current situation (figure 5).

B: The period of infection is three days, about two times in this case (figure 5).

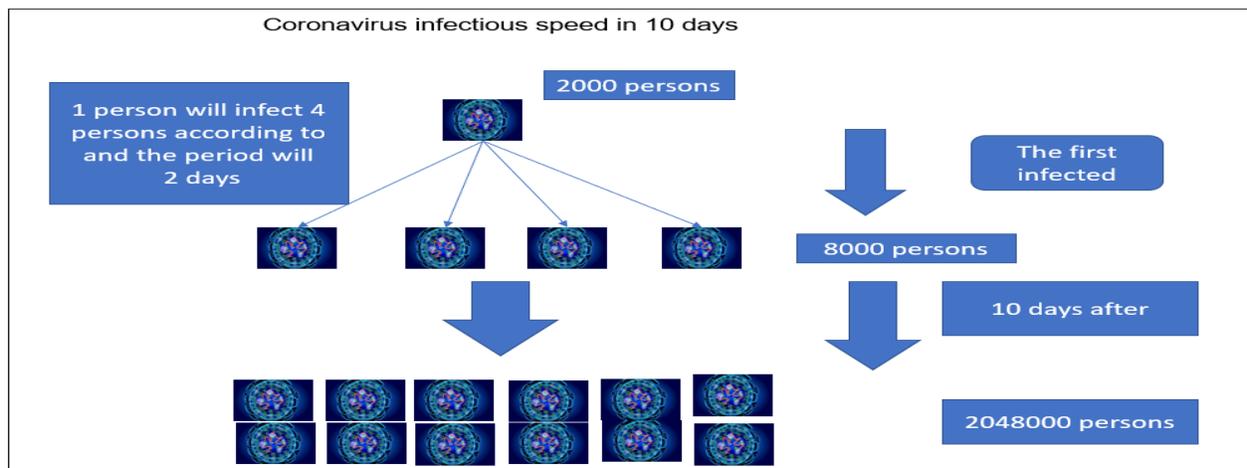


Figure 5: Virus spread speed under four-time in 2 days.

In this model, more than 2 million people will be infected by the virus under this condition, and there are about 40,000 people may be killed in 10 days, which is very horrible and unimaginable, which is a big problem for people do more research. 2019-nCoV was five times than Sars infectious speed in 2003. In the future, there is a high probability of happening a virus whose rate of infection spread is more than that of 2019-nCoV. Crisis logistics will become very difficult in that condition. Considering there is half of the number of people infected as an above assumption, it is about 1 million people affected. Table 4 shows the daily demands for infected persons (1,000,000) that can be provided

by each mode of transportation, which is a severe crisis in humanitarian aid. It does not only need several countries to help but all over the world should take measures to coordinate with the crisis logistics of humanitarian assistance.

Table 4. Resource for crisis logistics in the assumption

	Daily	High speed train	Truck	Ship	Plane
Foods	11000000 kg	Could satisfy the load for a crisis if there are enough stations and if there is a short time to unloading from a train on the station.	May deliver resources from the train station to people in the city.	Could load a large number of resources to port.	Help load the first aid and the urgency needs.
Drinking water	20000000 kg				
Clean washing water	400000000 kg				
Meat, legume	5000000 kg				
Medical clothes	2000000 unit				
Medical mask	2000000 unit				
Medical cover	2000000 unit				
Medical glasses	2000000 unit				
Medical gloves	2000000 unit				

4. Conclusions

To conclude this work, we have proposed a model to compensate for the damages caused by Coronavirus in Wuhan, China. In particular, in the first period of the epidemic, the speed criteria had the highest priority, and the cost was ignored; therefore, the airplane was the optimum solution to maximize the transfer speed. In the second period, the cost and speed were the two factors considered in the optimization problem. The best solution turned out to be the train according to the considered criteria. It is interesting to mention that by considering both factors, ships, trucks, and airplanes represent the alternatives, respectively. More researches will focus on cases of quicker spread of the virus in the future.

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