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ALEXIOS: Transporting disaster relief, power supply system in urban flooding

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By

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Abstract:

Due to the terrain and river distribution, floods occur in China every year. The Yangtze River and the lower plain of Yellow River in eastern China are flood-prone, especially in urban areas. Whenever a flood comes, a lot of material and human resources are invested in the affected areas. However, there are some potential hazards in the existing flood control methods and related resettlement and management modes.

In this paper, the author of this article will attempt to design a conceptualized urban flood relief and management system with a focus on the near future. the system will take use of a piece of multi-functional placeable equipment to improve the existing flood control methods, and adopt a modular method so that the joint step such as sandbag and placeable equipment transportation, power supply, and disaster area data collection can be implemented more systematically and conveniently. This system will greatly improve the safety and efficiency of flood management, and reduce the possibility of accidents for disaster relief personnel.

Introduction:

For flood rescue personnel, the problem that needs attention in the flood disaster relief is that the filling, installation, and transportation of sandbags are very inconvenient because in most cases, making sandbags in advance to deal with future floods lacks timeliness and is unrealistic in relation to space for storing sandbags. In general, when the rescue personnels arrive at the disaster site, the local flood control departments will provide them with a large number of bags for making sandbags, they start to make sandbags for rescue and put them into the severely affected flood area for the use which has many inconveniences in the process. At the same time, these rescue servicemen need to carry heavy sandbags to each region of the city to resist flood, which is also very inconvenient and difficult.

For the servicemen involved in the rescue, the implementation of the flood control work was also very difficult and dangerous. In the process of using sandbag stacks to create a flood barrier, the first group of them to go into the water were required to line up in the water and fill with sandbags in the water to resist flooding and again time for subsequent servicemen. In a turbulent flood, they are likely to be washed away by the current. In addition, prolonged

immersion in water, stacking sandbags, and rescuing people who fall into the water will cause them to be damaged by a large number of bacteria and pollutants in the water.

Servicemen involved in the rescue also shoulder the task of exploring the flood situation in the city. Servicemen who enter the city in the first rescue batch for resisting flood and disaster relief need to investigate the flood situation in various areas of the city, such as water level, whether residents have evacuated, etc; When servicemen of subsequent rescue batches enter the corresponding area, they will give a detailed description of the subsequent work with the new servicemen. The whole exploration process may have potential security risks for servicemen, and the exploration results may not be totally complete. Once the hidden danger in the existing management system occurs due to negligence or accident, it is likely to lead to the delay of rescue work and be life-threatening.

In addition, there are some areas that can be improved in the guidance of residents in disaster areas, the resettlement of residents, and the use of disaster relief equipment. It is understood that residents lack effective and comprehensive survival knowledge when the flood comes. They may not know whether the surrounding escape routes are safe and where is the location of temporary settlements for residents. Without knowing the surrounding details, rash action is likely to threaten their lives.

The conceptual design of flood rescue and governance will summarize the existing technologies and governance methods and provide new and more advanced governance equipment, means, and mechanism for flood disaster relief to make urban flood control more standardized, safe, and Convenient. In addition, this conceptual design can also free people from the shackles of existing governance concepts, think about flood control measures from a new perspective, and improve existing governance methods.

Design Research:

Due to the terrain and river distribution, floods occur in China every year but less in the northwest and southwest. The seven major river basins in the territory (Yangtze, Pearl, Yellow, Huai, Hai, Songhua, and Liao rivers) and the inner city are the main areas where catastrophic floods occur. These areas are all populated and urbanized in China, with a relatively high degree of industrialization. Once these places are damaged by floods to the city, it will cause great economic losses and safety losses.[1]

[1] (Lu et al. 2020)——Lu, Ming, Xiaohan Liao, Huanyin Yue, Yaohuan Huang, Huping Ye, Chenchen Xu, and Shifeng Huang. 2020. “Optimizing Distribution of Droneports for Emergency Monitoring of Flood Disasters in China.” *Journal of Flood Risk Management* 13 (1): e12593. https://doi.org/10.1111/jfr3.12593.

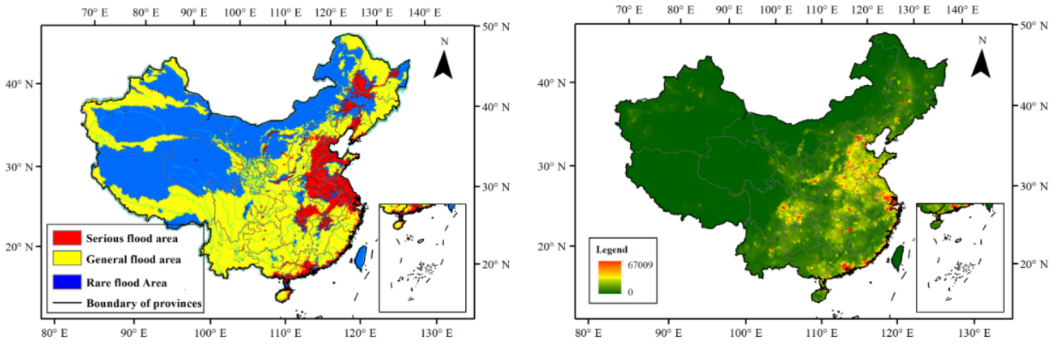

Fig 1. Flood prevention level distribution and One-kilometer grid population distribution data map of China

As a country with frequent floods, China has suffered huge economic losses and human casualties in large-scale floods. It is understood that the total number of deaths caused by floods in China since 1950 is about 280,000. Since 1990, the average annual economic loss is 139 billion, and the average annual death toll due to flash floods is about 984.[2]

Making sandbags for a dam is an important part of flood discharge. So far, in addition to using sandbags to make flood dams, there are many other options, such as cylindrical and tubular structures that can be used for resisting floods. After filling, the flood wall can be assembled and disassembled easily, and is free-lifting, etc.; compared to sandbags, these alternative options can save a lot of time when installing and building a flood barrier. The use of sandbags creates enormous logistical challenges when filling, transporting, and constructing the dam.

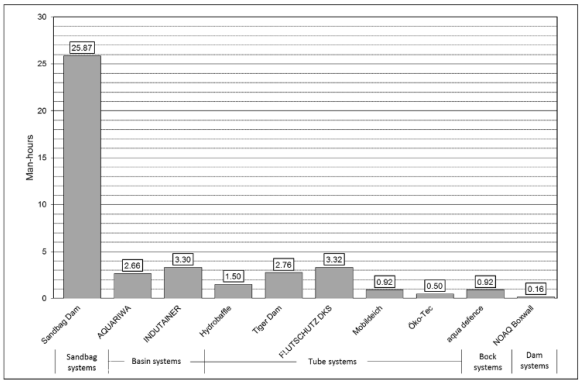

Fig 2. Time required to make a flood dam with different materials

[2] (He et al. 2018)——He, Bingshun, Xianlong Huang, Meihong Ma, Qingrui Chang, Yong Tu, Qing Li, Ke Zhang, and Yang Hong. 2018. “Analysis of Flash Flood Disaster Characteristics in China from 2011 to 2015.” *Natural Hazards* 90 (1): 407–20. https://doi.org/10.1007/s11069-017-3052-7.

But overall, sandbags are still the better option. It becomes heavy enough to have almost no gaps after being soaked in water. Sandbags are very inexpensive to produce and can effectively intercept floodwaters in all terrains without extensive maintenance costs. In the relevant flood resistance test, the flood control wall encountered problems such as flood infiltration and compression deformation of metal supports.

Fig 3. Problem result from using flood walls

In addition, according to research, when the surface of the sandbags dam is covered with a layer of the protruding plastic apron, the flood retention effect of the dam will be improved greatly, which can also greatly reduce the speed of flood infiltration into the sandbags, and the flood infiltration rate will decreased from the original 17.0 dm3/min/m dropped to 0.17 dm3/min/m.[3]

Fig 4. Sandbags dam be covered with a protruding plastic apron

When using sandbags to make a sandbag dam, the stacking method of the sandbags is very important, otherwise, it will not be able to effectively stop the flood. The scientific placement method is a 'mound type'. Because the lower part of the sandbags dam is relatively stressed and the upper part is relatively small, this arrangement can effectively block floods. Specifically, when laying each sandbag, there are generally two methods: 'V type' and 'Bricklaying type'. Additionally, according to research, when the filler in the sandbag is coarse sand, its blocking effect on the water flow is the best. While In reality, flood control work is very urgent. If sandbags are loaded and then transported to the flooding area, the cost will be too high and the timeliness is difficult to guarantee. Therefore, except that some staff will drive

[3] (Massolle, Lankenau, and Koppe 2018)——Massolle, Christopher, Lena Lankenau, and Bärbel Koppe. 2018. “Emergency Flood Control: Practice-Oriented Test Series for the Use of Sandbag Replacement Systems.” *Geosciences* 8 (12). http://dx.doi.org/10.3390/geosciences8120482.

the sand to the site, the currently common practice is that the flood control department will convey the bag to the place in advance, and then the personnel will take materials locally, and shovel the soil 3 (Massolle, Lankenau, and Koppe 2018)——Massolle, Christopher, Lena Lankenau, and Bärbel Koppe. 2018. “Emergency Flood Control: Practice-Oriented Test Series for the Use of Sandbag Replacement Systems.” Geosciences 8 (12). http://dx.doi.org/10.3390/geosciences8120482. into the bag. For the content of the sandbags, it should be sand. For other areas, the sandbag is likely filled with soil, stone, and so on, which may reduce the blocking effect of sandbags on water flow.[4]

Fig 5. Images of Mound type, V type, Bricklaying type

Interview:

I separately conducted an hour-long video interview with the servicemen who participated in the flood rescue and the people who experienced the flood:

Fig 6. Photos of interviewees

The servicemen in the interview had participated in flood relief work in China during their service. I learned about the content and details of the servicemen in the rescue process:

- Flood control includes four steps: rescue, flood discharge, resettlement, and post-disaster dredging. In the rescue process, the work of the servicemen is very important. They should be responsible for the rescue, flood discharge, and post-disaster dredging.

[4] (Is the sand bag used for flood control really useful?- China Meteorological Administration n.d.)——“Is the sand bag used for flood control really useful?- China Meteorological Administration.” n.d. Accessed October 19, 2021. https://www.zhihu.com/question/51406471.

- Before the flood infiltrates the city, the local government will notify the residents in advance and cut off the power to prevent leakage from causing greater difficulties to the following work.
- The local government also needs to provide the first batch of soldiers who come to the rescue with the layout and situation information of the city.
- For flood discharge, one task is to stack sandbags, which can block floods and guide water to other directions to avoid residential areas.
- It is the most difficult for the first batch of servicemen to stack sandbags in the flood. They need to carry sandbags and line up in the water to act as a human wall to gain time for subsequent batches.
- Flood discharge will last for a period of time. During this period, a 24-hour safety inspection will be carried out, especially to check the position of well covers.
- During the post-disaster dredging work, some electrical types of equipment may be used, and the local government will dispatch some on-board generators to supply power for the related equipment.

The interviewed flood witnesses experienced relatively severe flooding in the summer of 2021 in Zhengzhou City, Henan Province, China. Through the interview with him, I learned about the reactions of ordinary residents and the specific measures they took when they encountered floods:

- Residents are sent to temporary resettlement sites, which are usually located in high-lying, open plazas, and parks.
- Because there is a lot of garbage and bacteria in the flood. After being sent to the resettlement site, residents need to take off their existing clothes and disinfect them. Relevant staff will also always disinfect the venue.
- The local government will send on-board diesel generators to the resettlement sites to provide electricity for living and related equipment through diesel generators.

Problem Statement:

Based on the information above, the existing flood fighting measures have potential safety hazards for rescue personnel. The usage of sandbags has problems of inconvenience and low efficiency. The detection of flood conditions in cities will also endanger the safety of the personnel, and the detection results may not be completely accurate. For the local residents, when a flood comes, they are not familiar with the surrounding conditions and do not know how to evacuate to safe settlements.

According to these problems, I propose to design a system that can be utilized during floods, which can make urban flood relief control be more effective and convenient, Reduce the dangerous behaviors that rescue workers need to take while resisting floods, make the flood monitoring in the city more standardized and accurate, enable residents to get effective reminders and guidance when evacuating.

Through the design research and interviews with rescuers and flood victims, the following questions are summarized:

Sandbags

Flood control work is very urgent. Sandbags are made from local materials after rescuers are rushed to the affected area. If the filling is not sand or mixed with other materials, it may reduce the blocking effect of sandbags on water flow. The sandbags were directly discarded after the flood relief, which caused waste and potential health hazards due to the harmful chemicals, bacteria, and other pollutants that would be caught in the sandbags.

Moving

When a flood comes, people need to be very careful and slow to move in the water. They don't know whether the surrounding roads are safe and whether the water level is too deep. There are bacteria in the water, and some manhole covers may have been flushed away by the flood. If they are careless, they may fall or fall into the manhole.

Fixing

According to relevant literature, when making a flood detention dam with sandbags, if a layer of the plastic protruding apron is covered on the surface of sandbags, the effect of the flood depth dam can be improved, which can prevent floods from penetrating through sandbags. How to fix this plastic material to prevent it from being flushed away by the flood is difficult to control.

Safety

In most cases, when the personnel rush to the disaster site, they need to enter the disaster area for rescue and provide information on the specific situations of the disaster area for the follow-up personnel when they arrive at the site. When using sandbags to build a flood detention dam, a group of rescuers needs to enter the water with sandbags, put down sandbags and build the walls hand to hand, and then follow-up staff will stack, reinforce sandbags and complete the stacking of the dam, which is very dangerous for them if water levels keep rising quickly.

Solutions:

Based on the problems above, I designed a multi-part system for floods that will help with safety, efficiency, and cost. Each module in the system is based on the conceptual design of research and functional testing, which can make the design of the system more avant-garde, and make the flood control and rescue work more standardized, safe and convenient.

#1 Manhole Cover

- The manhole cover in the city could lift up to prevent people from falling into the hole.
- When it lifts up, it will work as a base station and start to detect the water level. If the water depth is too high, it will flash red to remind residents.

This ensures that part of the evacuation and evacuation of residents in the city is completed before rescuers and servicemen arrive in the city. When residents in the city see the flashing red lights, they will realize that there are safety hazards there and choose other evacuation routes.

- Flood drains allow water to flow down to relieve the pressure of floodwater pooling on the road.
- Because manhole covers are distributed in different locations in the city, they will upload real-time situation information to the network while detecting flood conditions in different areas. The staff who first entered the city for rescue gave a rough description of the actual disaster situation in the city and took rescue measures. This kind of detailed information and details allows rescuers to take safer rescue measures.

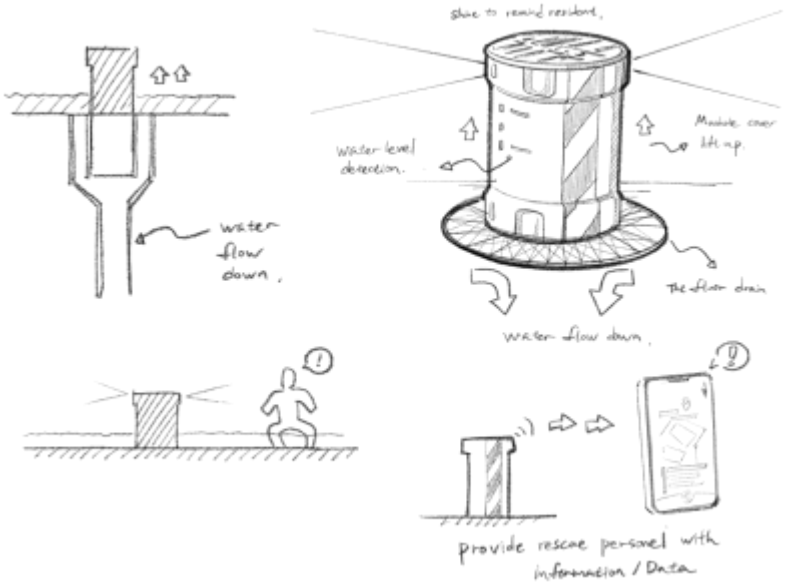

Fig 7. System for manhole covers

#2 Multi-functional Traffic Cones

- The traffic cones are self-weighted and could be filled with sand to ensure that they can still stand stably in the water under the impact of floods.
- Similar to the function of the manhole cover, it can be placed in various locations of the city, especially in low-lying areas where floods are easy

to gather to detect the flood condition and shine red to remind residents if the place has safety hazards.

- The traffic cones could be placed on the ground for fixing the plastic protruding apron covered on the sandbags dam to prevent the apron from being flushed away by the flood. At the same time, it can detect the flood condition around the dam, so that personnel can better decide whether to reinforce the dam or reduce the number of sandbags on the dam.
- The Multi-functional Traffic Cones adopt modular design, which is easy to place, assemble or disassemble and move.
- The Multi-functional Traffic Cones could also upload the detecting information online for the rescuer to check. Compared with the normal manhole cover, the traffic cone is moveable and portable, which allows them to be freely placed in different locations in the city to detect the water level. Therefore, by combining the monitoring and uploading functions of Multi-functional Traffic Cones and manhole covers, rescuers can obtain a more comprehensive and extensive urban flood situation.

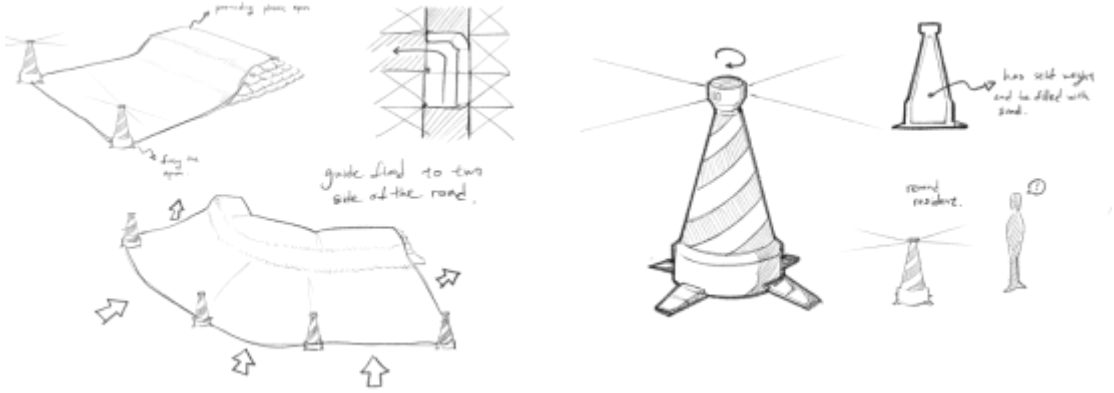

Fig 8. System for traffic cone

#3 Vehicle

- The container of the vehicle adopts a modular design. There are three types of containers with different functions: storing sandbags, storing Multi-functional Traffic Cones, and power supply. According to the actual needs, the rescuers can arbitrarily match the containers carried by the vehicles and drive them to specific areas. It can start the rescue mission from within the city to reduce the pressure of external rescue.

- Storing Multi-functional Traffic Cones Modules and Power Supply Modules requires electricity to work. The vehicle has the On-Board Power Generation System which can provide them with enough power to ensure them to work. When the Power Supply Module's power is used up, the vehicle will replenish it. Likewise, when the Multifunctional Traffic Cones run out of power due to monitoring flooding, personnel can reinstall them in the corresponding modules on the vehicle, and the vehicle will charge them.

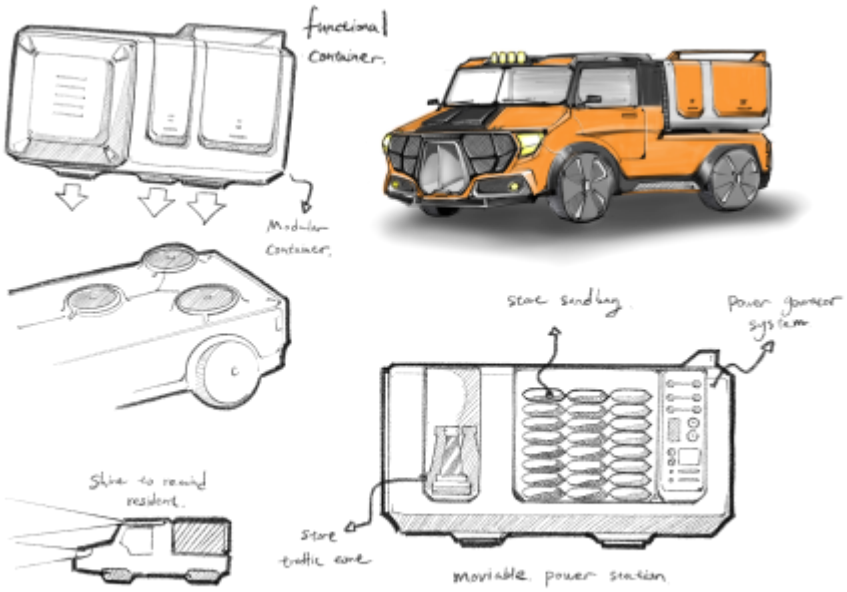

Fig 9. System for transportation vehicle

Project Overview:

As for the design of the manhole, because of the unrealistic redesign of the underground, the function of the Multi-functional Traffic Cones and Manhole Cover is combined.

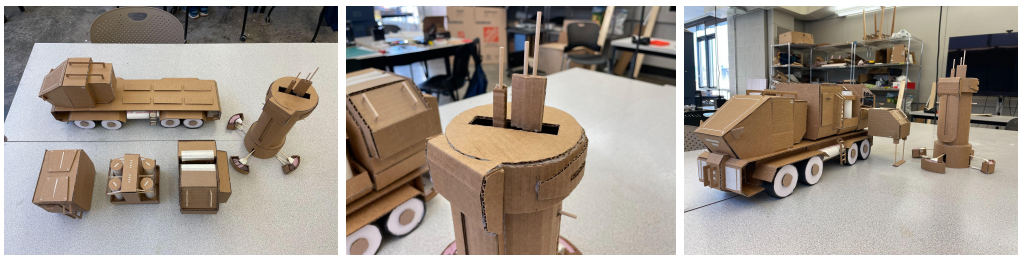

Fig 10. Photos of Prototypes

To test the stability of the Multi-functional Traffic Cones in case of a flood, I made a scaled model to simulate the real flood scenario. In the test, I built a small size sandbag dam and poured down water to verify whether the device can be stably fixed in the water and effectively resist the water to prevent it from penetrating too much into the dam.

Fig 11. Photos of test models

The size of the model of the whole scene is 150*70*20cm, the number of layers of the sandbags dam is three, the size of the model of Multi-functional Traffic Cones is 5*5*11cm, and the weight is 0.5kg. I created two test scenarios, a straight sandbags dam scenario, and a curved sandbags scenario. In two prototype tests, these Multi-functional Traffic Cones can be effectively fixed in the water, preventing the plastic protruding apron from being flushed away by the water, and can effectively block the flood and even change its flow direction under the use of sandbags. In the first scene, the water is effectively intercepted and slowly guided to the sides of the dam to slowly flow out; in the second scene, the direction of the water flow changes but a small amount of water seeps out from the other side of the dam. Only a small amount of water seeps through the bottom of the plastic protruding apron in both scenes, causing it to bulge slightly. Therefore, when installing the plastic protruding apron, some sandbags need to be stacked between the Multi-functional Traffic Cones used for fixing to make it more stable.

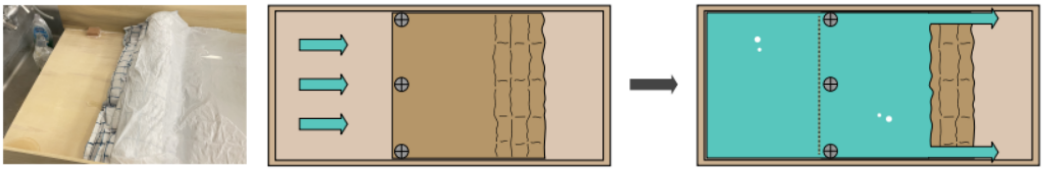

Fig 12. Result of curved line arrangement

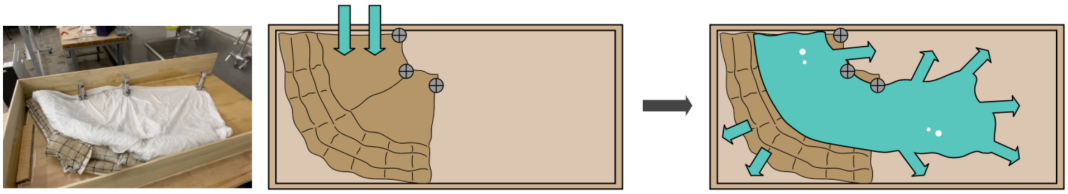

Fig 13. Result of curved-line arrangement

Final design:

I designed a system that makes flood management and monitoring more efficient, safe and convenient. The system consists of a vehicle, three modular containers with different functions, and multi-functional traffic cones.

Fig 14. Rendering of the final design

Multi-functional Traffic Cones

Converted from the previous experimental results, its total mass is about 300 pounds. Usually, it can be folded and stored in the corresponding container module. When it needs to be used, rescuers need to unfold it and install the heavy module on the three fulcrums to reach 300 pounds to ensure that it can be stably placed in the flood for monitoring flood or reinforcing sandbags dam.

Fig 15. Foldable structure

The antenna on its top is used for monitoring and uploading monitoring information. This part also adopts a modular design. They will upload the results online, and rescuers can take safer rescue operations based on the uploaded details. When there is a safety hazard in the area, they will point evacuated residents to alternative routes. The sensors in the middle and upper sections are used to monitor floods. When it detects that the water level in the area is too high or there is a safety hazard (there is a manhole cover nearby), the light on the top of it will flash red to remind residents to pay attention to safety when passing the road section or choose another evacuation route.

Fig 16. Monitoring sensors and modular upload components

The bottom of the device is made of rubber to increase its friction in the water to prevent it from being washed away. The protruding part of the bottom is equipped with swivel wheels, which can make it easier to carry the device.

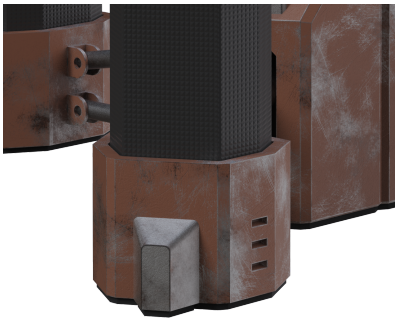

Fig 17. Bottom of the Multi-functional Traffic Cone

In addition, the device can be used to fix the plastic protruding apron covered on the sandbags dam to improve the efficiency of resisting flood or even change the flow direction.

Fig 18. Fixing the plastic protruding apron

Modular Container:

The container of the vehicle adopts a modular design. There are three types of containers with different functions: storing sandbags, storing multi-functional traffic cones, and power supply. According to the actual needs, the rescuers can arbitrarily match the containers carried by the vehicles and drive them to specific areas. It can start the rescue mission from within the city to reduce the pressure of external rescue.

Fig 19. Modules of storing sandbags, multi-functional traffic cones, and power supply

Vehicle:

This is an electric truck and it has an On-Board Power Generation System. Storing the Multifunctional Traffic Cones Module and Power supply Module requires electricity to work. The system can provide them with power to ensure they have enough power to work.

Fig 20. The scenario of Electric Vehicle

There is a storage space under the middle of the vehicle, which is used to store the ramp. Once the foldable ramp is moved out of the space and unfolded, rescuers can easily carry Multifunctional Trac Cones and sandbags. In addition, the installation and removal of modular containers on the vehicle also require the use of this ramp.

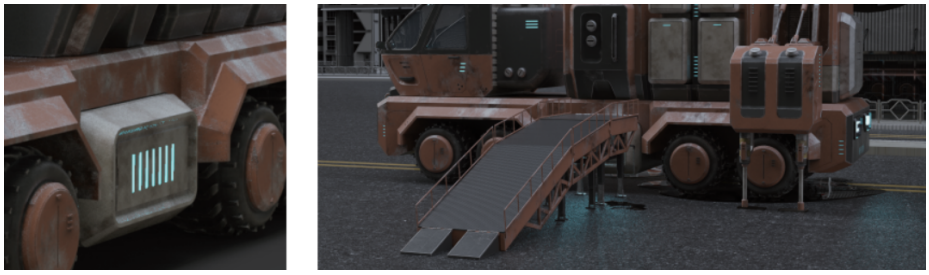

Fig 21. Storage space for the ramp

Conclusions:

Flood governance is a big topic, and it contains problems far beyond what the system I designed can easily solve. There are still many problems in the process of flood control, such as the health problems of rescuers in flood rescue; the layout of temporary resettlement sites the problems of sanitation, and so on. These problems could not be solved by the system designed in this paper.

There are still many imperfections in the design of this system. The vehicle's On-Board Power Generation System is subject to further investigation. In addition, this system may need more testing of prototypes to verify its feasibility.

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[1] Lu, Ming, Xiaohan Liao, Huanyin Yue, Yaohuan Huang, Huping Ye, Chenchen Xu, and Shifeng Huang. "Optimizing Distribution of Droneports for Emergency Monitoring of Flood Disasters in China." Journal of Flood Risk Management 13, no. 1 (03, 2020). doi:http://dx.doi.org/10.1111/jfr3.12593. https://ezproxy.rit.edu/login?url=https://www.proquest.com/scholarly-journals/optimizing-distribution-droneports-emergency/docview/2351299384/se-2.

[2] He, Bingshun, Xianlong Huang, Meihong Ma, Qingrui Chang, Yong Tu, Qing Li, Ke Zhang, and Hong Yang. "Analysis of Flash Flood Disaster Characteristics in China from 2011 to 2015." Natural Hazards 90, no. 1 (01, 2018): 407-420. doi:http://dx.doi.org/10.1007/s11069-017-3052-7. https://ezproxy.rit.edu/login?url=https://www.proquest.com/scholarly-journals/analysis-flash-flood-disaster-characteristics/docview/1975522571/se-2?accountid=108.

[3] Massolle, Christopher, Lena Lankenau, and Bä Koppe. "Emergency Flood Control: Practice-Oriented Test Series for the use of Sandbag Replacement Systems." Geosciences 8, no. 12 (2018): 482. doi:http://dx.doi.org/10.3390/geosciences8120482. https://ezproxy.rit.edu/login?url=https://www.proquest.com/scholarly-journals/emergency-flood-control-practice-oriented-test/docview/2582821053/se-2.

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