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CRITICAL INFRASTRUCTURE IN YANGON, MYANMAR, IN CASE OF DISASTER: THE READINESS OF PROVIDERS*

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Abstract

Resilience has become a very important concept in disaster research and disaster management. In this context, critical infrastructures are important elements to support and protect a society and strengthen its resilience. Critical infrastructure, defined as physical structures, facilities, networks and further assets, provides services essential to the functioning of a community or society. The paper gives an overview of critical infrastructure arrangements in Yangon in case of disasters. It examines the awareness and preparedness of providers of these infrastructures in the face of disaster situations. The research also looks at how the administration assesses the situation of critical infrastructure in case of a disaster. Additionally, it examines to what extent and how critical infrastructure is interconnected in order to meet the needs of society in a disaster. A special focus is on identifying gaps and shortcomings with regard to critical infrastructure failure, including cascading effects caused by interconnections of infrastructures. The research mainly employs a qualitative approach. Institutions in Yangon involved in critical infrastructures were asked about their arrangements and for an evaluation of their preparedness and awareness.

Keywords: Critical infrastructure, Yangon City, awareness, preparedness, resilience

Introduction

With the Hyogo Framework for Action 2005-2015 (UNISDR 2005), subtitled “Building the resilience of nations and communities to disasters”, the concept of “resilience” became an inherent part of disaster risk reduction and management. The same holds true for the concepts of adaptation, coping capacity and bounce-back-better, which are now used in various disciplines (Dahlberg et al. 2015: 44).

Since Cyclone Nargis hit Myanmar disastrously in 2008, particularly the Ayeyarwady and Yangon Regions, the country has much intensified its efforts to implement measures to reduce disaster risks and to make society more resilient. New legal frameworks have been established, above all the Natural Disaster Management Law of 2013 (Republic of the Union of Myanmar 2013), the Disaster Management Rules of 2014 (Republic of the Union of Myanmar 2015) and the Myanmar Action Plan on Disaster Risk Reduction (NDMC 2017, latest version). Based on these laws, Disaster Management Committees have been introduced for all five administrative levels

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(national, state/region, district, township, ward/village tract). These committees are responsible for coordinating activities in disaster risk management and for operational disaster control measures before, during and after a disaster. These achievements can be seen as milestones to make Myanmar society more resilient to disasters. They set a clear framework for government and administration, society and individual people to manage disasters.

Critical infrastructures play an important role in making society more resilient. Infrastructures such as electricity, health services, water supply, communication or transportation have to function or at least must be promptly repaired in case of a disaster in order to maintain vital support and supply processes for society, neighbourhoods and individuals to overcome the effects of the disaster as soon as possible. Thus, critical infrastructure has to be resilient to disasters.

On the one hand, in a disaster situation, resilient critical infrastructure means that it has to stay "functional" or "its functionality can be restored quickly" in technical, mechanical and physical terms (e.g. water pipes must function well and reliably, bridges must have sufficient shock stability). On the other hand, it is evident that functionality can only be secured if the institutions in charge of the critical infrastructure and services, the so-called providers, are aware of disasters, anticipate their infrastructural effects, try to be prepared for disaster cases and thus keep infrastructure resilient. Based on this interrelation, the paper analyses the situation of critical infrastructure in Yangon and investigates the strength of awareness and preparedness among providers.

Resilience and infrastructure – a conceptual framework

Although the term "resilience" has gained wide acceptance in research and in reports on (human-made and natural) disasters, it has to be underlined that the term has had a range of different meanings in its etymological history, as Alexander (2013) demonstrates. Moreover, as he critically mentions, nowadays the perceptions and meanings of the term may differ according to different research traditions and concepts on disasters. However, Alexander acknowledges that the term "… shows promise in that it encourages the researcher to bridge the "shear zone" between (dynamic) adaptation and (static) resistance" (Alexander 2013: 2714). The definition of the United Nations Office for Disaster Risk Reduction (UNDRR/formerly: UNISDR) is probably the most appropriate, as it underlines: "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management" (UNISDR 2017b).

Studies on critical infrastructure have increased in particular since the early 2000s (Garschagen and Sandholz 2018). According to UNDRR/UNISDR, critical infrastructure comprises "(t)he physical structures, facilities, networks and other assets, which provide services that are essential to the social and economic functioning of a community or society" (UNISDR 2017b). Taking this definition, it becomes immediately evident that the term covers a variety of different issues, which also might – at least partly – be different from society to society, even from county to county as NACO (2014) points out, e.g., for the United States. Additionally, the list of infrastructure perceived as "critical" might change over time (O'Rourke 2007, DHS 2019).

Instead of critical infrastructure, the term "lifeline" is often used with a similar meaning, although it is not mentioned in the UNISDR (2017b) terminology. An early study using the lifeline concept investigated the vulnerability of business in case of lifeline disruptions (Tierney and Nigg 1995). NACO (2014: 2) points out four defining characteristics which distinguish lifelines from other sectors and services, namely: (1) Lifelines provide necessary services and goods that support nearly every home, business and county agency; (2) They deliver services that are commonplace in everyday life, but disruption of the service might develop into life-threatening situations;

(3) They involve complex physical and electronic networks interconnected within and across multiple sectors; (4) A disruption of one lifeline may effect or disrupt others in a cascading effect. According to O'Rourke (2007: 23), the term is used to "evaluate the performance of large, geographically distributed networks during earthquakes, hurricanes, and other hazardous natural events. Lifelines are grouped into six principal systems: electric power, gas and liquid fuels, telecommunications, transportation, waste disposal, and water supply." It should also be mentioned that in general many publications in the field are related to technical aspects, in particular when connected with the term "lifeline".

Turning to studies related to Myanmar, only very few articles have been published on critical infrastructure and lifelines. One article by Phongsapan et al. (2019) describes a flood risk decision-support tool, which may help to support critical infrastructure activities in case of a disaster. Second, Khin Aye Mon et al. (2017) looked into seismic risk analysis at a medical centre in Yangon, checking the functioning of critical infrastructure (in particular the water supply system). Without doubt, more research in the field of critical infrastructure in Myanmar is required.

As argued in the introduction, resilient critical infrastructure is an important element to render a society resilient to disaster. This is also strongly pointed out by the UNDRR/UNISDR with an emphasis on making cities resilient in the "My City is Getting Ready!" campaign. One of the ten essentials to make cities resilient is the increase of infrastructure resilience through the development of a strategy for the protection, update and maintenance of critical infrastructure and through developing risk-mitigating infrastructure where needed (UNISDR 2017a: 32).

Following O'Rourke (2007: 25), four requirements are important to make critical infrastructure resilient: (1) Robustness, which means the inherent strength or resistance of a system to withstand external demands without degradation or loss of functionality; (2) Rapidity, which refers to the speed with which disruption can be overcome and safety, services and financial stability restored; (3) Redundancy, which refers to the system's properties that allow for alternate options, choices and substitutions under stress; (4) Resourcefulness, which relates to the capacity to mobilize needed resources and services in emergencies. The latter in particular includes the capacity to identify problems and establish priorities.

O'Rourke (2007) takes these four requirements and elaborates how they are connected with technical, organizational, social and economic activities. Curt and Tacnet (2018: 2447) propose adding "protectiveness" of the system against threats as a fifth requirement. This might be useful, although "protectiveness" can also be seen as an aspect of "robustness".

Following the argumentation in the introduction, all these requirements have to be fulfilled on the technical and mechanical side of the infrastructure, but this can only be achieved if the providers are aware of a disaster, anticipate the effects of a disaster and try to be prepared for a disaster.

Against this background, this article focuses on the providers' management of critical infrastructure in Yangon City and tries to investigate their disaster awareness and preparedness. Consequently, the key questions of this research are:

- To what extent are providers of critical infrastructure aware of disasters and their effects? How do they try to integrate such cases into their future plans?
- Are providers aware of potential loss of function – at least partly - in their services in case of disasters? Do they see solutions for it and do they try to implement such solutions?

As the disaster management committees mentioned in the introduction are essential for disaster response from the administrative side, they are also intensively linked to the issue of critical infrastructure, at least in collaborating with the providers in their areas of accountability.

Therefore, the investigation also examines the situation of critical infrastructures from the perspective of the committees with the question:

- How is the situation of critical infrastructure perceived and evaluated by township officers as heads of the Township Disaster Management Committees?

In the following, after describing the material and methods, the results of the investigations are elaborated. Thereafter, they are discussed with respect to the above-mentioned requirements in order to highlight how strongly the awareness and preparedness of providers in Yangon are developed and how this contributes to the resilience of critical infrastructure in Yangon.

Material and methods

The research is mainly based on information from 18 expert interviews (with a length of 25-75 minutes), which were conducted in spring 2020 and analysed with qualitative methodological tools (e.g. MAXQDA). All interviews have a unique code number, thus direct or indirect quotes and information of the interviews are cited in the text with the code system (e.g. Interviewee-01). 13 interviews were held with representatives of institutions in Yangon which provide critical infrastructures or are involved in related services. The experts were asked about the arrangements of the services and how they evaluate the awareness and preparedness of their agencies in case of disaster. Additionally, five interviews were conducted with representatives from administrative institutions who were engaged in disaster topics mainly on township level (e.g. township officers). Furthermore, information from the 2014 census and from a household survey conducted in early 2020 is used as well as some specific literature on Myanmar.

In the following, the situation of six critical infrastructures will be elaborated, namely: food supply, water supply, wastewater disposal, electrical power, traffic and transportation, and healthcare.

The situation – awareness, anticipation, preparedness, readiness

Food supply: With regard to food supply two things have to be pointed out. First, only the Department of Disaster Management (DDM), a governmental agency on the district/region level, is active in the field of food relief. But the food stocks are only very small because the rules stipulate that the department is not allowed to spend money on food storage in advance of a disaster. Thus, DDM proceeds as follows: in case of a pending disaster DDM asks merchants to keep food in stock and then buys it when the disaster starts. Additionally, purchased food is mainly reserved for disaster victims who are evacuated.

Second, there is no plan for food relief on township level in case of a disaster. Thus, storage of food is not initiated here. Basically, it is the task of the households to have food in stock. A township official describes the situation:

"If I have to tell the truth, we don't have any plans about it. We are in the downtown area and the residents may have their own collection of food for themselves. Otherwise, we do not store massive amounts of food for earthquakes or any other disaster." (Interviewee-08)

According to a household survey of 2020, just about 80% of households have dried food in stock (Heinkel et al. 2022). Only a small portion (8.8%) of these households store sufficient food for just a few days. More than 90% have enough dried food in stock for at least a week and about 60% even for two weeks or longer. Households which do not store food cite "lack of money" as one of the main reasons.

Water supply: In the outer city townships, tube wells are the main water source, supplying about 55% of Yangon households (Myanmar Census 2014). Only about 35% of the households are connected to the public water supply system. This is in particular the case in the central city townships. According to the 2014 census, only about 50% of these households use piped water for drinking. In general, about half of the Yangon households use purified water (sold by private companies) for drinking. But the sources suggest that quite huge differences exist between townships regarding both drinking water and household water.

The piped water supply in Yangon is under the responsibility of the Water Resources and Water Supply Authority (nowadays: Engineering Department (Water and Sanitation)) of the Yangon City Development Committee (YCDC). The water is delivered by four main reservoirs, located in the northern part of Yangon Region. From here the water is distributed to smaller reservoirs in Yangon City. Each of the four main reservoirs has its own system of pipes but the systems are interconnected. So, in case of disaster there is quite a high probability that not all main reservoirs will be unable to function. On the other hand, nowadays not all areas can serve 24 hours a day. Households are informed by newspaper and TV about the time of breaks in supplies and are asked to store water in advance and reduce their usage.

There is no priority plan for supply in case of disaster. The plan is to supply water via water bowsers owned by the department, if piped supplies fail. Even now, sometimes there is an electricity shortage or the pipelines are under repair and water supplies may be limited for one or two days. Then replacements with better supplies from the network are provided or sometimes water is distributed with bowsers. Water supplies in the whole of Yangon can be affected by an electricity power cut because all pumping stations rely on electricity. Here, an improvement in the security of water supply was made in 2019 when the pumping stations were equipped with backup generators.

At present, probably the most important activity regarding disaster preparedness is the construction of alternative intakes at the main reservoirs:

"Alternative intake should be considered as a second intake to be prepared if any problems arise." (Interviewee-02)

The interviewed experts concentrate very much on supply in general, while the local supply conditions (such as the local pipeline network) are less of a focus. A report by Khin Aye Mon et al. (2017) on the resilience to an earthquake of infrastructure (in particular water supply) for the medical centre in Thingangyun, a township in the eastern part of Yangon City, shows quite critical results in particular regarding the local network. Four points may be mentioned here: (1) Neither of the two underground tanks for water is vulnerable, but the elevated water tank is most vulnerable and should be retrofitted, as should the pump house; (2) The mechanical pipe joints of the supply system on the hospital campus are the weakest points in the system with a failure probability of more than 80%; (3) Additionally, the supply network is very vulnerable because it is a series system; (4) All mechanical pipe joints of the network from the reservoir to the hospital have a failure probability of 100% in case of an earthquake. Thus, the pipe joints need to be replaced by newly developed ones based on seismic design guidelines.

Government officials evaluate the situation in the townships differently. Some mention that in terms of drinking water almost all the households in their townships use purified water and are thus not dependent on piped water or water from wells. But other township officers expect a problematic situation in case of a natural disaster, in particular if cuts in supplies continue for a longer time (Interviewee-05). In some areas it will even be difficult to guarantee a supply by water bowsers because road access is difficult (Interviewee-01). The results of Groot and Bayrak (2019) in their research on water security in the Hlaing Thar Yar Industrial Zone (HTIZ) underline the concerns of the officials. Even in normal circumstances there is not always guaranteed water security, neither in terms of quantity nor quality, in particular in areas with informal settlements.

Basically, it is a recommended obligation of the households to have purified water in stock. The households themselves also display very different reactions in terms of being prepared for a disaster, as the results of the survey show (Heinkel et al. 2022). About 10% of the households have less than 2 litres per person in stock and just over 15% of the households store between 2 and 4 litres per person, which underlines the earlier statement that problems may arise if there is a longer cut off.

Wastewater disposal: Wastewater disposal is the task of the Drainage and Sewerage Management Department (today: Engineering Department - (Drainage Management) and - (Water and Sanitation)) of YCDC. The disposal system is completely separated into two parts, the drainage water system and the sewage water system. In the central city area, the sewage system is an underground pipeline system which was built in British times. In the other areas the buildings have or should have their own septic tanks, which are emptied and cleaned by vacuum trucks. The above-mentioned separation of the system will continue in the future. The interviewees from the department responsible for disposal evaluate the system as quite safe from disasters like earthquakes and storms. Some of them are a little more sceptical in relation to floods but they are not very worried. One interviewee even evaluates the situation for wastewater treatment in a treatment plant in case of disaster as:

"Since the beginning of the installation, there has been 'over' installation to use as an alternative. If the plants do not operate, the system will work through this 'over' and supply the treatment plant. The treatment plant has to be stimulated by machines but there is never a time that we have to directly dispose of the sewage." (Interviewee-06)

However, people of the local administrations in the township have a more sceptical view when septic tanks are involved in the disposal procedure. One officer of a fringe township explains:

"There can be challenges here. There are many places at which the wastewater disposal does not follow the YCDC regulations. ... most of the houses do not have systematic septic disposal. During flooding, health can be very much affected." (Interviewee-05)

If old houses are renovated, a septic tank system is installed according to the regulations. But it is not easy to persuade the owners of existing houses to build the system according to the law. One reason is that the owners fear the costs of installing an adequate septic tank system.

Another officer of the administration complains further about management of the wastewater in the drains:

"If we go to see at the back there, the water is opaque and very dirty. ... There is no wastewater management here. There is the drainage system but the wastewater cannot be managed." (Interviewee-01)

Such problems become even more severe with floods because in cases of *"water overflows, this septic water flows into the drains."* (Interviewee-01)

To date the systems have not been very dependent on electrical power because the floodgates or sluice gates are operated manually and there are no pumping stations. But this situation will change in the near future. Funded by the World Bank, the underground drainage system will be upgraded and a high-capacity pumping station as well as floodgates managed by a SCADA (Supervisory Control and Data Acquisition) system will be installed. This system will comply with international standards and depend on electricity. Therefore, the supply of electric power will be a crucial element in the future (Interviewee-07).

Electricity: The electricity supply is managed by the Yangon Electricity Supply Corporation (YESC) under the Ministry of Electricity and Energy. The electricity is produced outside Yangon and then transferred to the 230 Yangon substations, from where the power is distributed to the customers. Currently about 86% of households in the City of Yangon are connected to the electricity system, which means that these households have at least electric light (Interviewee-18). The 14% of households that are not yet connected are mainly located in settlements in the urban fringe. Here some townships have only about 50% power coverage, whereas in the central part of the city the coverage is almost 100%. It was planned to connect the rest of the households by the end of 2020 (Interviewee-18). According to the 2014 census, about 50% of households use electricity for cooking. Variations between the townships are quite distinct. In some of the central townships more than 80% of households use electricity for cooking, in contrast to which in Dala, a township at the southern fringe, only a little over 20% use electric power. Additionally, to some extent the households have adjusted to interruptions in electricity supplies because power cuts are more common at certain periods of the year, partly due to the vulnerability of the system. Such interruptions last mostly up to an hour and are thus only short-term.

There is a list for priority supply in cases of disaster with main priority given to hospitals and authorized organizations, furthermore schools, fire stations and police have high priority.

In cases of locally concentrated disasters, replacements and repairs are taken over by the substations. If the whole of Yangon is affected, help from outside – i.e. from other cities, regions and states – is needed for immediate and fast repair. In particular, depending on financial shortages, the amount of spares in stock for repairs only amounts to between 5% and 10% of the total parts, which would not be enough in the case of a severe disaster.

The experts point out that flooding, e.g. caused by high tides or heavy rainfall would particularly affect the transformers in the substations near the river banks. The transformer body itself can be submerged about halfway without causing problems, but the cables and breakers are not protected enough. Thus, the transformers have to be switched off to prevent danger.

In the downtown townships, the main supply lines are underground (a practice which started in the British era), whereas in most of the other townships supply lines are overground. The experts agree that underground systems would be less vulnerable in particular during storms. But a very important constraint is the budget situation as underground systems are more expensive and need more maintenance. Additionally, one of the experts mentioned that an overground system can be repaired much more easily and quickly in case of a disaster, because more time is needed to locate the problem in an underground system. One of the interviewees summarizes:

"We cannot say definitely whether there is advantage or disadvantage. The definite answer is we need budget." (Interviewee-18*)*

While hotels and cinemas have their own generators in case electricity supplies fail, police stations are not always equipped with such facilities, furthermore police stations do not always have priority for power services, as a police spokesman (Interviewee-16) confirmed − in contrast to statements by the experts from YESC.

Traffic and Transportation: Within this sector, the following aspects were the focus of consideration in case of a disaster: (1) The control of traffic in general, which is mainly the task of the traffic police and the traffic control centre; (2) The upkeep of the traffic system, maintenance and repair of streets, for which the traffic police and Engineering Department (Roads and Bridges) of YCDC are responsible, (3) The organization and upkeep of public transport which is conducted by the Yangon Region Transport Authority.

For the control centre, the traffic police and the Engineering Department (Roads and Bridges), the functioning of the traffic lights at the big junctions is of eminent importance in order to keep the traffic moving. Probably the biggest threat here is the cut-off of electricity. The installation of an uninterruptable power supply (UPS) is planned for about 150 junctions (about 10% has been completed), but the batteries can supply enough power for only about 2 to 3 hours. This is in particular a major problem for the high-capacity junctions, because they are particularly vital in an emergency situation. Some experts are thinking of installing a solar system at the junctions, but such systems can produce electricity only during the day unless storage with batteries is available. Moreover, such an investment needs additional funds, which are not available.

The data unit in the control centre is fully backed up as it is supplied by a generator which automatically starts within 5 seconds after power is cut off. However, stores of diesel fuel for the generator only cover about 24 hours, which shows a lack of preparation for a severe disaster. But the control centre is high priority for electric power supplies in case of a disaster.

In respect of spares and replacements for traffic lights, the experts very clearly declared that the institution is not prepared in case of a disaster.

"We are always busy with doing the daily ad-hoc works … but we haven't thought about what we will do to prepare for the disaster. … We know it is important, but we could not even solve our daily difficulties which is critical too." (Interviewee-09)

Even in normal times the supply of spare parts is insufficient, so that sometimes parts are taken out from less busy junctions and replaced in the lighting systems of the busy ones. The main reasons for this are the inadequate quality of the parts and the budget limits that do not allow higher quality components to be ordered or stores to be built up.

Difficulties also exist related to the workforce. The control centre is, for instance, understaffed and only can operate during office hours. And not all of the staff are highly motivated and often are narrowly focused on their fixed duties without keeping in mind the wider situation. Here raising a spirit of initiative is an important issue, but incentives like awards or increases in salary are not possible.

Regarding the traffic police, the main obligation in case of disaster is to give priority to anyone who has been injured or is facing a life-threatening situation. In line with this, nowadays all members of the traffic police are trained in first aid. But depending on the type and severity of a disaster the tasks may be ranked differently. During floods for instance, the first task will be clearing the roads instead of rescue efforts. But if there are victims they will – according to the main obligation mentioned above – be picked up as a priority and sent for medical treatment (Interviewee-09).

Public transport in Yangon is very important, in particular for citizens with low incomes. It is organized by YRTA (Yangon Region Transport Authority), an institution of Yangon Region. Public transport is almost entirely based on buses. In the city about 6000 buses are registered, about 4500 are active in the daily transportation of citizens. Since some years, the bus fleet has been improved with modern vehicles mostly with air conditioning. This fleet consists partly of diesel powered and partly of CNG (compressed natural gas) powered vehicles, whereby CNG powered buses make up the vast majority. This choice primarily reflects environmental concerns. But it is also an advantage in case of disasters because it helps by offering substitution opportunities. However, an expert mentioned that YRTA does not have high storage capacities for diesel fuel (more or less just for a day) and none for gas:

"Actually, we do not store the CNG. It is always supplied from Nyaungdon. I am worried for one thing. If there is an earthquake and if CNG is not supplied, the transportation will be affected. We will then have to rely on diesel and petroleum." (Interviewee-15)

The same expert is considering also introducing electric or hybrid buses backed by the argument that the bus fleet should rely on different kinds of power in times of a disaster. The purchasing costs are a bit higher, but the technology of electric and hybrid vehicles has much improved. Electric buses, for instance, can operate with one battery set for about 200 km, so they can be used in the daily routine quite well.

In case of a disaster, the buses as well as cargo trucks, which are under the control of the YRTA, are used for transportation purposes, too. Hereby the plan is to use the buses for an evacuation of people while the cargo trucks will be used to transport emergency supplies and goods.

Healthcare: The healthcare system in Yangon consists of a public and a private sector. The public sector is owned by the government and is the responsibility of the Department of Health and Sports. The system of the private sector is similarly structured and in general adjusted to the regulations of the Ministry of Health and Sports. The public sector includes hospitals and township medical centres, while in the private sector hospitals and clinics also exist.

The health experts differentiate a disaster event into four phases, namely pre-, acute-, post- and rehabilitation periods. The experts are aware that it is most important to prepare for the acute phase. One of the activities is that in public hospitals prioritization areas have been implemented in recent years. Here, arriving patients are checked for the severity of their health problem (severe, moderate, mild category) in order to treat the most severely suffering patients first. These prioritization areas are important for the organization of the medical treatment process. But one expert also expressed:

"We cannot expect too much for the triage area to be large and equipped with modern devices at our public hospitals, but we have implemented such areas within the available area we have and raise the awareness of it to our health officials." (Interviewee-17)

Furthermore, ambulances have been improved since 2019 with most hospitals having an ambulance car. Additionally, ambulance cars provided by different charity groups are now available. The Yangon Region Government in collaboration with Emergency Medical Services (EMS) has started

"conducting a network of ambulance cars as to which cars will have to go depending on the location of the incident and categorizing the cars according to their facilities" (Interviewee-17).

The location of the medical centres determines which is responsible if a disaster occurs. In general, the medical centre of the township where the disaster is located is responsible. A second criterion is the distance to the nearest hospital. Therefore, if the centre of another township is closer, the ambulance will transport the patients there.

In general, the experts underlined that the shortage of human resources, budget and material is a problem in the medical sector, as will become evident during a disaster.

"The main thing is HR, human resources. This is one point. Another thing is budget which is one of the main points." (Interviewee-03)

If there is a disaster, the township medical centres will collaborate with auxiliary midwives (AMW), who are responsible for one or two wards in the townships. Community health workers are involved to some extent, too. Additionally, young volunteers are linked to the midwives in the wards. In case of a disaster, volunteers also take over the collection of data about victims. All these people, in particular volunteers, are urgently needed because:

“They are able to communicate with the community more than us. Therefore, just give them the 'right health message' and they will convey the message to the community. We have to send the health message we would like to share through them.” (Interviewee-17)

The “right health message” is given to them in AMW training courses, which are attended by young volunteers, too.

Officially, collaboration with private hospitals is not yet very close. Private medical units need permission from the Ministry of Health and Sports. They are also integrated in the official monitoring system, which is valid for 17 diseases. Concerning the Covid-19 situation, regular collaboration meetings have been established and a reporting of positive cases arranged. Apart from this, an intensive collaboration between the private and the public health sectors is not yet much established. In particular, in case of disasters a plan to join hands seems not yet to exist.

Discussion

The findings described above show quite strong variations in respect to the resilience of infrastructures and the laudable attempts of the service providers to become more resilient. Improvements can be reported but also gaps are evident.

Following the requirements for resilience as stated by O’Rourke (2007: 25), the results can be summarized as follows (see also Tab. 1):

(1) **Robustness of the system**: All the investigated infrastructures have shortcomings, and failures will happen if there is a disaster. Partly the problems are caused by tired and old parts of the networks, as for instance in the case of the water supply network. Partly the quality of the parts is not suitable to withstand disasters. Additionally, the providers try to update their infrastructure, which often leads to higher dependency on electric power. But the electric power system is not always sufficiently stable. This problem can sometimes be overcome by generators producing substitutional power during power cuts. However, in case of a long-lasting interruption, provision with fuel might be problematic. In respect to food supply, there are no official storages. Emergency stock depends on the preparedness of the households (emergency reserves of food) and the availability of food supplies. A similar situation exists for drinking water in the form of purified water. As the results show, quite a number of households do not have enough durable food or water reserves. Here the households must be more intensively informed. Because many households mention a lack of financial resources as a reason for not storing durable food, the government should think about changing its procedure and establish an emergency food storage system.

(2) **Rapidity of overcoming disruption and restoring services:** Because the shortage of spare parts may become a problem in case of disasters, which can lead to further cascading collateral damage, it is advisable to establish a stock of essential spare parts.

(3) **Redundancy of the system (substitution of elements):** The water supply network of the four main reservoirs is interconnected which means that substitutional supply is possible. At the local level, supply with water bowsers is planned for cases of interruptions in supply. However, the narrowness of streets prevents access to certain locations, therefore, a fleet of smaller, more flexible water bowers is recommendable for such areas. Turning to electricity, generators are the solution for essential facilities (e.g. pumping stations), although it is not clear how long fuel provision can be maintained. Collaboration between public and private hospitals currently only exists for some minor health-related fields (e.g. reporting patients with specific diseases), yet there is a lack of formal agreements governing disaster situations, including collaboration or a joint action plan (i.e. ambulance, treatment).

(4) **Resourcefulness in the case of disaster (capacity to identify problems, establish priorities and mobilize resources):** Human and material resources for repairs and reconstruction are not satisfactorily available, the same holds true for financial resources that would enable better preparation. Sometimes plans with priority supply exist, but not yet systematically in key fields.

Cascading and dependency of infrastructures: Almost all infrastructures are highly dependent on electric power supply. Such cascading effects are, in particular, emphasized by the representatives of water supply (pumping stations), wastewater disposal, traffic and transportation (traffic lights) and the health sector. They can even increase if systems are upgraded because the new technologies are heavily reliant on IT elements and electric power. The instalment of automatic floodgates for wastewater disposal is a good example. The experts mainly see diesel generators as a solution to bridge power shortages. For traffic lights at big junctions, batteries are planned to be (and in some cases have already been) installed, but battery power will last only for 2 to 3 hours. Solar energy as an alternative power source for traffic lights seems to have similar time limit problems, if not only used during the day.

Awareness of providers: Many providers are quite well aware of disasters but some have not yet thought deeply and systematically about them and their consequences for infrastructure. In some cases, they only see a small sector of their supply systems. Often, problems in local supply appear to be of minor importance to them. This is different for local administrations. They are aware of the local shortcomings, but they depend on the activities of the providers.

Table 1 Resilience requirements regarding the technical and organizational dimensions of infrastructure

Infrastructure	Requirements			
	Robustness	**Rapidity**	**Redundancy**	**Resourcefulness**
Food supply	Depends on the preparedness of and collaboration with shops as well as on the storage preparedness of the private households	Almost no storage from official side, availability depends on the preparedness of the food suppliers (shops, food chains)		Depends on the storage availability of and the collaboration with shops
Water supply	Main 4 reservoirs with own pipeline systems but interconnections Alternative (second) intakes for main reservoirs Pumping station cannot work in case of floods (power cuts) Low quality of mechanical pipe joints	Diesel generators at the pumping station exist	Main 4 reservoirs with interconnection Water bowsers, but sometimes accessibility is a problem (roads too narrow)	Water bowsers A plan of priority supply does not exist
Wastewater disposal	Treatment plant for the central city area has enough storage capacity Not all households have proper septic tanks		Private septic tanks are not safe enough from flooding	Awareness and legal base for erecting adequate septic tanks for new buildings exist, but house owners do not novate the septic tanks for existing houses for financial reasons
Electricity	Frequent cut offs even in non-disaster times, so people are used to it Cut off of substations in case of flooding: transformer is resistant, but cables and breakers are not protected enough	Shortage of spares	Essential/crucial services/organizations have generators Long-term provision of fuel for the generators is not guaranteed	
Traffic and Transportation	Mix of buses with different engines Fuel storage is a problem Parts for traffic lights often of low quality	Clearing of streets as soon as possible by Roads and Bridges Dept. in collaboration with traffic police	Mix of buses with different engines Traffic lights are independent of electricity (with batteries) for only a short time	Priority repair for intensively used traffic cross sections
Healthcare	Prioritization system established, but only a basic version Ambulance network system is in the making	A system for bringing victims quickly to the nearest hospital has been initiated	Collaboration between private and public hospitals is minor Coordination of emergency transport (hospital and CSO cars) has begun	Shortage of human and financial resources Young volunteers and midwives are active on the ward level

Anticipation of disaster and disaster effects by providers: Not all interviewees have anticipated disasters intensively in a way that allows conclusions to be drawn for their services and functioning in cases of disaster. According to the interviews, the experts from traffic and transportation have tried quite intensively to anticipate what kind of effects disasters could have and what could be done to reduce the risk. In order to intensify the anticipation level, specific courses or workshops would be helpful. Here, exemplary disaster cases and their effects could be presented and potential (re)actions in terms of provision of critical infrastructure services could be developed (including the whole range from the source of generation to the supply to customers).

Preparedness of providers: The providers are facing limitations in preparedness, even if they are aware of and have anticipated disasters. Pertinent reasons are shortages in human resources, in the amount and quality of material and spares, and in finance for investment. Often, budgets do not even cover the needs of the moment. The interviewees in charge of traffic and transportation are good examples. They were quite aware of and had anticipated disaster situations well, but opportunities to get prepared were limited because of restrictions in human and financial resources. The dilemma is apparent: of course, it would be good to be better prepared because this will pay off in case of a disaster, but if the available resources do not even cover the current daily needs then it is not possible to keep them for precaution measures.

Conclusion

There is not always intensive awareness and anticipation of disasters among the interviewees, who are engaged in the management of critical infrastructure. In some cases, the respondents focus narrowly on a small sector of the whole field of their infrastructure (e.g. only on main water reservoirs, ignoring supply on the local level). In contrast, the township administration officers are very much aware of the local shortcomings. Here workshops in which disasters and their consequences are described and discussed, including effects on infrastructure, might be a good measure to diminish this gap. Workshops could improve the awareness of the people in charge and would contribute to a more comprehensive overview of their field. As a result, they would help to anticipate how different kinds of disasters affect infrastructure differently. Thus, a solid base could be laid for thinking of preparedness measures. However, even if the above-mentioned solid base was laid, some constraints concerning preparedness activities remain and might reduce the preparedness progress. In particular, budget restraints hinder improvement of the technical and material facilities and equipment, and shortages of well-trained staff cause further problems. Additionally, better collaboration between the providers of infrastructures and local experts is desirable. Such an exchange of information regarding the local situation as well as ideas about how to prepare for disasters would contribute to the disaster resilience of the infrastructure.

This paper gives an overview about the situation of six critical infrastructure sections in the city of Yangon (Myanmar) and its disaster resilience, in particular as viewed by the service providers. It shows that resilience, awareness and preparedness vary quite remarkably, for instance spatially as well as according to the kind of infrastructure and the type of disaster. This clearly demonstrates that there is a need for more detailed research concerning specific critical infrastructure, specific types of disaster and different spatial contexts. Such research would then provide a better information base for setting up adequate preparedness activities.

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