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RESPONSE SYSTEM FOR CYCLONE DISASTER MANAGEMENT

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Abstract *Year after year cyclonic storms form over Indian seas and some of them which cross the Indian sea coast cause extensive damage of life and property over the coastal areas. The loss of life and damage is caused by rain accompanying the cyclonic storms. The frequency of occurrence of severe cyclonic storms is more in the Bay of Bengal than in the Arabian Sea. Thus, areas on the east coast face far more risk than those on the west coast. The development and achievement made in cyclone warning and the response system during the past ten to fifteen years are reviewed and prospects for future are discussed.*

INTRODUCTION

Every year some part or other of India is affected by natural disaster like cyclones, floods, droughts, avalanches, land slides and quakes. Tropical cyclones are the worst natural hazards in the tropics and are capable of destroying coastal cities and killing several thousand people. Available statistics show that 64% of the total lives lost the world over are due to cyclones.

The coastal states of India, are severely battered by tropical cyclones almost every year. The cyclones cause damage to different types of buildings and structures, disturb power transmission and communication networks, inundate the fertile land and submerge the standing crops due to storm surge and uproot large number of trees causing disturbance to life line structures. While the occurrence of the cyclone cannot be prevented, the loss of lives and damage could be minimised by appropriate disaster management. Unlike other disasters like flash floods, earthquakes and land slides, in the case of cyclones, they could be located well in advance, their movement monitored, the disaster prone areas could be identified and warnings issued at least 24 hours in advance. Adoption of systematic disaster preparedness procedures could greatly reduce the impact of cyclones on farmers and fishermen.

The impact of tropical cyclones depends not only on its meteorological conditions which control the wind speeds, the rainfall, the tidal waves and the area over which the tidal waves and rainfall have influence but also on the nature of the area affected, density of population, human activities such as fishing, agriculture, level of industrialisation, the timeliness of forecasts and their dissemination, the preparedness of forecasts and their dissemination, the preparedness of the civic administration to cope with the situation etc.

For an efficient hazard management programme it is essential to forecast the effect of a cyclonic disturbance within a reasonable period of time in advance. The advances made in computer and communication technology in India have helped not only in the improvement of forecast accuracy but also in faster dissemination of information to the authorities responsible for disaster management and the public in general. These types of non-structural measures are going to be less expensive and more effective in disaster mitigation and management. The development and achievement made in cyclone warning and the response system during the past ten to fifteen years were commendable and have been able to reduce the loss of life and damage to property. In this paper these are reviewed and prospects for future are discussed.

CYCLONES

Cyclones form in tropical ocean areas where sea surface temperature is 26.5°C or more. The energy of the cyclone is supplied by the sea. Besides the latent heat of condensation of water vapour supplied by the sea to the air above, it also gets heat from the sea. Cyclones form near the Inter Tropical Convergence Zone on its poleward side. The cyclones of Bay of Bengal and Arabian Sea have a shorter life span than their counterparts namely the typhoons of the Pacific and the hurricanes of the Atlantic.

The frequency of occurrence of severe cyclones is more in the Bay of Bengal than in the Arabian Sea. Thus areas on the east coast face far more risk than those on the west coast. The risk of being hit by a severe cyclonic storm on Orissa and West Bengal on the east coast and areas on the west coast is more during the monsoon season, June-September. For coastal areas in Andhra Pradesh and Tamilnadu the risk is more during the post-monsoon season, October-December. The risk of being hit by a cyclonic storm in any year is maximum for coastal Andhra Pradesh followed by Orissa and West Bengal.

DAMAGES DUE TO CYCLONE

The damages caused by cyclones are generally due to high winds, heavy rainfall and storm surges which are generally associated with its landfall. The extent of damages and loss of life due to rains associated with the cyclonic storms is relatively small and less frequent. The cyclonic storms which occur during the pre-monsoon (March-May) and post-monsoon (October-December) are more destructive compared to the storms in the monsoon season. During the monsoon, the strong wind shear in the vertical does not allow them to intensify.

STORM SURGE

There are two types of effects of wind on waves and storm surges. The first is the effect of changing the sea-surface roughness. The second is the effect on storm surges which is a general increase in the mean sea level. Waves from cyclones move out and they are called swell waves. When the high waves reach to the coast they set up or piling up which is generally referred to as the 'tidal wave'.

Storm surge is responsible for nearly 90 per cent of lives lost in tropical cyclones. At the landfall of cyclone, tidal waves of up to 8 meters of height are known to have occurred and depending on the topography of the coast, the sea waters intrude up to 50 km interior from the coast. In the case of December 1993 cyclone over Tamilnadu and Pondicherry, storm surges of 5-6 meters were observed at different locations. The sea water entered up to 20-25 km interior of the coast. In the case of the November 1996 cyclone over coastal Andhra Pradesh, tidal waves of 5 meters height hit the coastal towns of Kakinada and Yanam. The tidal wave has gone up to 50 km interior from the coast in east and west Godavari districts of Andhra Pradesh.

The northern Bay of Bengal especially along the coasts of Bangladesh and India, is subject to the worst storm surge problem in the world. As recently as 1991, nearly 1,50,000 people were killed during a severe cyclone and surge mostly due to drowning. One way to alleviate the problem is to improve the performance of the numerical models for predicting the cyclone in advance.

Ghosh (1977) generated a series of nomograms to estimate storm surge height. Accordingly, the peak surge associated with the landfall of cyclonic storm with maximum winds of 47 knots may not generally exceed 2 meters. Generally, the wind speed associated with the severe cyclonic storms exceeds 48 knots. Mukherjee and Sivaramakrishan (1981) have shown that wave height and wind speed are linearly related in a cyclone field. The approximate relationship is $H = 0.32\ V$, where H is the wave height in meters and V is the wind speed in m/s. It is observed that this equation can not be applied for wind speeds over 10 m/s (Mukherjee, 1991).

HEAVY RAINFALL

Heavy rainfall comes next in the matter of devastation and loss of lives. In case of many cyclonic storms the total rainfall received during a two-day or three-days period is nearly 80 to 90% of the seasonal or annual total rainfall. This is especially true in case of semi-arid areas with annual rainfall in the range of 75 to 100 cm.

Mooley and Mohile (1986) studied cyclones which struck the east coast of India during 1877 to 1980 taking only those storms which hit perpendicularly (+ or – 20^{o}) to the coast. They confirmed the conclusions of Koteswaram and Gasper (1956) that the heavy rainfall area extends more to the right than to the left of the landfall. Rainfall due to the storm, generally, starts two days before the landfall. It is generally known that westward moving depressions and cyclones during the monsoon produce heavy rain always to the southwest (i.e. of left forward) side of its track of movement. Mooley and Mohile (1986) concluded that the rainfall increases from 2^{o} latitude to the south of landfall point up to the point itself. Thus the highest 24 hours intensity of rainfall has a definite bias to the left in the Indian cyclones. However, based on study of six storms over Tamilnadu, Manikiam and Veeraraghavan (1984) concluded that the maximum rainfall area generally lies more to the north of the cyclone track and the extent of rain affected area is also more to the north as compared to the south.

The highest one day rainfall observed on the east coast is less than 60 cm. For example the highest rainfall recorded during the November 1987 cyclone was 52 cm near Nellore on 3rd November 1987. Intensities of 10 cm/hour were recorded at the time of the storm crossing the coast. The estimates of one day point PMP given by IMD (1988) indicate that the values range from 44 cm to 68 cm on the east coast, the higher values being over coastal Andhra Pradesh.

On the west coast the highest one day rainfall observed is 99 cm over Gujarat in July 1941 and 74 cm over Saurashtra in June 1983. The estimates of the PMP values on the west coast range from 36 cm to 84 cm, the higher values are equally distributed in the three coastal States namely, Gujarat, Maharashtra, and Karnataka. Over Kerala, however, they are slightly less.

WIND DAMAGE

The destruction due to high winds is mostly confined to vulnerable structures and the death resulting from high winds is generally due to people getting trapped in collapsed towers and buildings. The behaviour of buildings and structures subjected to cyclonic wind forces would be non-linear with permanent deformations and local failures. All of them are not amenable to mathematical or theoretical modelling. Post cyclone damage surveys conducted on buildings and structures would provide valuable information for improving the existing knowledge on behaviour of structures and their components against cyclones.

The Indian standard code on wind loading (IS:875) recommends a basic wind speed of 50 m/s for the east coast of India. The damage surveys conducted by Shanmugasundaram et al. (1996) and the risk analysis of extreme winds during cyclones out by the Structural Engineering Research Centre, Chennai revealed that extreme speeds were far in excess of the wind speeds recommended in the code.

CYCLONES DISASTER MANAGEMENT

The cyclonic disaster management shall consist of the following:

(i) Necessary infrastructure for locating the genesis of a cyclone, monitoring its intensity and management and issuing timely warnings,
(ii) Communication network for dissemination and receipt of the warnings, and
(iii) Administrative mechanism for implementing various actions relating to evacuation, transportation, rescue and relief works.

CYCLONE FORECASTING SYSTEM

In order to aim at an effective system of disaster prevention and disaster mitigation the first requirement is to locate and forecast the movement, intensity, the probable time and likely places of landfall of a cyclonic storm. Also, forecasts of the associated wind speeds, possible storm surge and rainfall are essential. The system of cyclone warnings started in India in as early as 1865. Conventionally, the cyclones were tracked with the help of the synoptic charts based on observations over land and sea taken at regular intervals as per WMO Standards. The installation of cyclone warning radars along the east and west coasts during the 1970s and the availability of Satellite pictures at regular intervals from the Indian Geostationary Satellites of the INSAT series since 1981 have greatly enhanced the capability for monitoring cyclone genesis, its intensity and movement. It is possible to detect the cyclones from their preliminary stages some times even before their occurrence by monitoring sea surface temperatures through satellite data.

In spite of the lot research that has gone into the development of numerical models and the improved data availability from land and sea over the region, limitations of cyclone prediction in terms of their intensity, likely movement and place of land fall still persist. These arise primarily due to data paucity and partly due to computational instability. Hence forecasts based on numerical weather prediction models cannot be considered to be in any way superior to those based on conventional analysis of synoptic weather charts.

Against this background, the cyclone disaster response system has to be structured to cover relatively large risk prone areas though the cyclone may affect only a limited area. The same thing is true in case of time also as the duration of the cyclone near or over the coast and its crossing the coast are generally variable and difficult to forecast with a degree of accuracy.

VULUNERABILITY AND RISK ANALYSIS

One of the important requirements of cyclone disaster management is proper risk assessment in coastal areas. One important question is as to how much risk a coastal station faces from the severe cyclonic storms. Based on 98 years (1891-1988) of data, Raj and Jamadar (1994) computed the distribution of number of severe cyclone storms affecting the coasts of Bay of Bengal and Arabian Sea. The information is presented in Table 1.

Table 1 Seasonwise frequencies of severe cyclonic storms affecting Bay of Bengal and Arabian Sea (1891-1988).

Season	Jan-Feb	Mar-May	Jun-Sep	Oct-Dec	Total
Bay of Bengal	5	43	29	102	179
Arabian Sea	0	19	15	36	70

Source: Raj and Jamadar (1994).

Identification of the vulnerability zones and preparation of maps of vulnerable areas shall be an important part of disaster preparedness. Vulnerability is the degree of proneness or potential of losses of a given place resulting from the occurrence of a natural hazard of a given intensity. Vulnerability can be broadly classified as intrinsic vulnerability and extrinsic vulnerability (Muthukumar et al., 1996). Intrinsic vulnerability results from factors which are inherent in the system or area. These include, physical, social, economic and occupational factors. On the other hand the extrinsic vulnerability results from factors external to the system; these are:

(i) The physical vulnerability includes damages, mainly, infrastructural related such as, damages to dams, irrigation tanks, power houses, factories, off share and onshore oil platforms, railways tracks, roads, buildings, etc,
(ii) The social vulnerability relates to poor living conditions, lack of literacy, lack of disaster awareness etc,
(iii) The occupational vulnerability relates to damages due to human activities such as fishing (Prawn culture), salt preparation, poultry, animal husbandry, agriculture, plantations, etc, and
(iv) The economic losses are related to (i) to (iii) above namely, the losses incurred due to the loss of cattle, crops and infrastructure and the money to be spent by Government and individuals on rebuilding and restoring some of the infrastructure.

The extrinsic vulnerability in the context of cyclones comes mainly from the winds, rain and tidal waves associated with the cyclone. While the identification of vulnerability zones and preparation of maps of cyclones hazard prone areas rests with civic authorities, the analysis of vulnerability due to cyclone has to be done by experts dealing with meteorology and weather forecasting. Vulnerability and risk analysis provides an analytical procedure to identify and quantify hazards. Also, the genesis of cyclones could be identified, their movement monitored, the disaster prone areas could be demarcated and the warnings issued. Such a study, if integrated with storm surge models, would improve the efficiency of disaster management.

COMMUNICATIONS

Dependable means of communication are crucial for data collection, for dissemination of forecasts and for implementing evacuation of relief works. Conventional means of communication were known to fail during bad weather. With improved methods of VHF and satellite communication, these problems have been overcome to a great extent. The satellite based Disaster Warning System (DWS) which enables warning to be transmitted directly to numerous points on the coast has been reported to be very successful (Raghavan and Sen Sharma, 1989). Radio amateurs and hams could play a crucial role in communications. Railways could stop trains at major railway stations and junctions to ensure food and medical and to minimise hardships to passengers.

Before the occurrence of a cyclone, it is imperative that disaster management teams have a contingency plan to operate with. The main focus of the plan shall be preparation of a list of actions to be performed and their schedule. It should be obvious that disaster mitigation plans would be different for different places. Some places are more prone to disaster due to geographical, habitation, cultural, economic and infrastructural factors.

ADMINISTRATIVE MACHINERY

A major step taken in India was to organise the response system by way of establishment of cyclone distress mitigation committee in the coastal states. These brought together at the official level, the disaster manager, civil, police and military officials, communication managers and the meteorologists. Manuals for disaster management were prepared. Cyclone shelters in vulnerable areas have been constructed in the coastal areas of some of the states affected by cyclones. Also, publicity material like posters and pamphlets were printed in the local languages and circulated. However, it is generally the experience that it needs an actual disaster to occur to galvanise every one into action.

Although, the technological improvements were the basis for the greater accuracy, timeliness of forecasts and credibility of warnings it was the response and timely action of the State Government which could minimise the damage due to the cyclones in May 1990 and November 1996 in Andhra Pradesh. While the Chief Minister assumed the leadership and supervised evacuation and relief measures, the administration at the district and taluk levels also geared themselves adequately and appropriately with arrangements for transport, shelters, food and medical facilities for the evacuated people.

PUBLIC AWARENESS

The satellite pictures would provide information about the intensity and the movement of the cyclone which could be shown over different channels of Television. These would help to enhance people's awareness about the devastating aspects of the cyclone and would alert them to respond and cooperate with the authorities in evacuation and other measures. Non-governmental organisations could also help the administration in the rescue and relief operations.

OUTLOOK FOR FUTURE

There may be many technological development and improvement in the future. At many places Automated Weather Stations (AWS) and Data Collection Platforms (DCP) are functioning from which information could become available in real time. Also, the IMD is in the process of obtaining the Doppler Radars which could help in assessing the wind speed in the core of the cyclones much more accurately. Figure 1 illustrates a response system for effective cyclone disaster management.

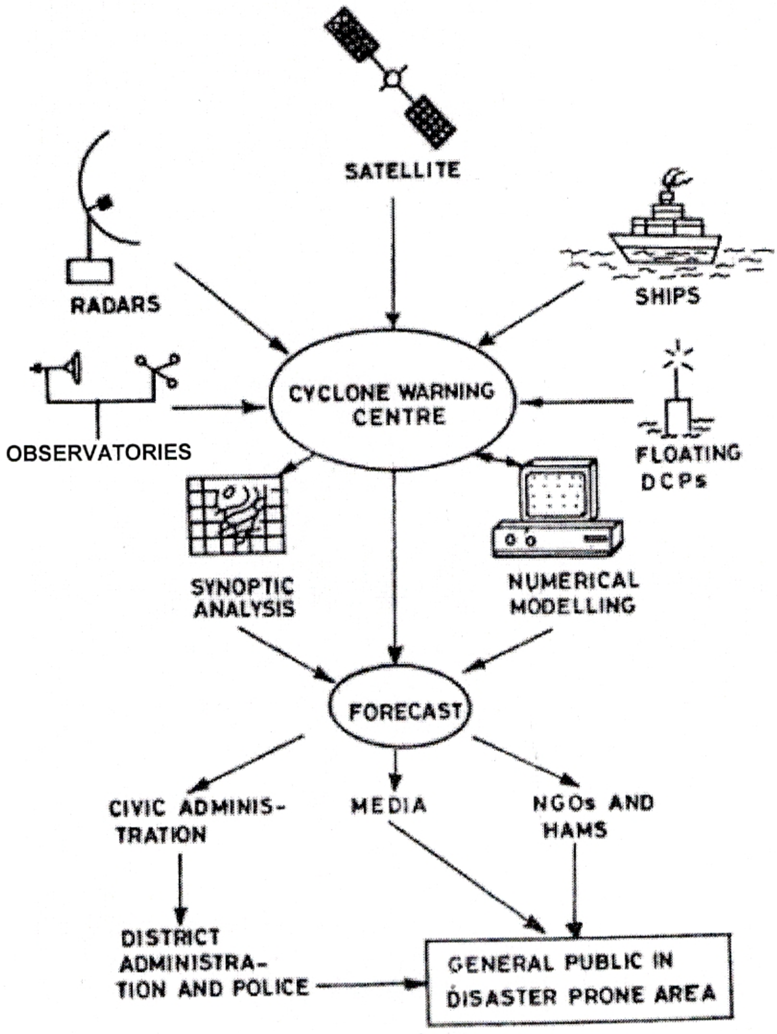

Fig. 1 Response system for cyclone disaster management.

Perhaps the most important subject for future improvement in models for surges in the Bay of Bengal is the inclusion of wave field calculations. The extremely strong winds produce very high waves and their propagation needs to be modelled properly. Topography is a more significant factor in determining where the surge height would be greatest. They are not so sensitive to the cyclone parameters namely the track and timing.

At present because of the uncertainty involved, the forecasts generally indicate a wide area to be affected by the cyclone. This makes the disaster management not only difficult but also involves avoidable expenditure. It is, therefore, necessary that suitable techniques be developed to forecast the place of landfall of the cyclone more accurately and if possible also indicate the places which are likely to be affected by the storm surge. Also, it is necessary to forecast with a certain degree of accuracy both in time as well as in space likely to receive heavy rainfall.

With the communication technology and computer networking in the country developing rapidly, the Disaster Warning System (DWS) is expected to improve further. All these are expected to improve not only the disaster management but would also help in establishing the credibility of the management system. Great progress could be achieved by developing better co-ordination between various governmental agencies namely, the India Meteorological Department, the District Civil and Police Administrations, the Public Works Department, the District Communications Department, the Television, All India Radio and where necessary the three Wings of the Defence Service. A Cyclone Management Centre (CWS) should be established in each State Secretariat under the direct supervision of the Chief Secretary of the State. This would enable pooling of the resources and also detaining some essential facilities in case of emergency.

An essential component of disaster management is disaster preparedness. Disaster management should be treated as a separate component in the plan allocations of concerned Union and State organisations and adequate funds should be earmarked for disaster management during the 9th plan. Programmes of training for disaster management organisers and education of the vulnerable public should be drawn up and implemented systematically at regular intervals. It is also necessary to involve non-governmental organisations (NGOs) to help in educating and creating awareness about the disaster preparedness among the public. For this purpose, it is desirable to constitute village/town level committees involving officials, ham radio clubs, media representatives, etc. These type of non-structural measures would be less expensive and more effective in disaster mitigation and management. If the disaster measures of the cyclones are managed effectively there are some benefits from cyclone such as increased fish catch and above normal rainfall which come in the wake of the cyclones (Jayanthi, 1989).

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