Criteria for Evaluating the Condition of a Tropical Cyclone Warning System

Dennis Parker
Flood Hazard Research Centre, Middlesex University

This paper evaluates the condition (i.e. health) of a tropical cyclone warning system (TCWS) during a ‘quiet period’ between infrequent intense cyclones. Capacity to make pre-disaster evaluations is important — disaster warning systems need to be in sound condition before, not after, disaster. The research — part of the UK’s International Decade of Natural Disaster Reduction Flagship Programme — focuses upon an evaluatory method first used on flood warning systems. The Criteria-development Matrix comprises social, organisational and institutional criteria by which a TCWS may be assessed using a five-stage development scale. This method is used to evaluate Mauritius’s TCWS using in-depth interview data. Ways to enhance the method and apply it to other disaster warning systems are discussed. The TCWS in Mauritius is a relatively sound one from which others can learn. Weaknesses requiring attention for Mauritius’s TCWS to progress to an advanced level of development are identified.

Key words: warnings, tropical cyclones, dissemination, evaluative criteria.

Introduction

Reliance upon disaster warning systems is increasing globally as development in hazardous zones intensifies and more people are exposed to hazards. This growing reliance is recognised by the United Nations (1995) which calls for better systems of early warning for disasters. There has been growing attention to ‘natural’ disasters within sustainability literature, and disaster researchers and practitioners are increasingly framing their work within the context of sustainable development (Burby, 1998). Sustainable communities adapt successfully to hazards and adopt strategies which increase their disaster resilience. Sound strategies normally combine means for increasing community resilience, disaster warning included. Disaster warning systems have high applicability to most hazards, but are likely to be most effective for ones which normally develop relatively slowly, such as tropical cyclones.

Disaster warning systems may be either effective or ineffective, or anywhere between these poles. In 1991, Andhra Pradesh government agencies evacuated 600,000 people in advance of a tropical cyclone reducing fatalities to one-tenth of the more than 10,000 people killed in a similar cyclone 13 years previously. Timely meteorological forecasts and well-disseminated warnings made this possible (Davis et
Similarly, prior to the eruption of Mount Pinatubo in the Philippines in 1991, more than 350,000 people avoided harm because a warning system translated scientific evidence into commonly understood warnings which triggered evacuation (Davis et al., 1998). However, there are numerous cases where disaster warning systems under-perform or fail utterly (Parker and Neal, 1990). For example, in the Easter 1998 floods in England and Wales flood warnings only reached a minority, and there was complete failure to warn some communities. Approximately 10,000 people were evacuated after flooding in one community because no flood warnings were received (Environment Agency, 1998). During typhoon Sally which struck the south China coast in September 1996, warnings did not reach some in its path (Wills et al., 1998). It is often the warning dissemination process which fails (PAGASA, 1990; Parker and Neal, 1990).

Foster (1980), Williams (1964) and Keys (1997), all emphasise that regular evaluation of disaster warning systems is fundamental. Such evaluations can be undertaken in at least three complementary ways. First, the performance of a system may be observed and monitored during an extreme event (e.g. Wadge et al., 1998). Second, there may be a post-event audit (e.g. Environment Agency, 1998). Unfortunately, both of these approaches are conditional upon a disaster occurring. Extreme events which trigger disasters occur infrequently — say once in 30 or 50 years. Clearly, therefore, it is desirable to develop a means of evaluation which can be applied in the intervening ‘quiet period’ (i.e. the period between disasters or before any disaster occurs for the first time in a particular location) so that the effectiveness of the warning system can be optimised in preparation for a disaster. In practice such a ‘quiet period’ is likely to be punctuated by events of lesser magnitude and experience of these may assist the evaluation, as may rehearsals. This third type of evaluation is under-developed. This paper explains and evaluates an experimental method developed to investigate the ‘condition’ (i.e. health) of a tropical cyclone warning system during a relatively ‘quiet period’ based on an investigation of the TWCS system in Mauritius (UK, NCC for IDNDR, 1998; Parker, 1998a; Parker and Budgen, 1998).

**Mauritius and the tropical cyclone threat**

Mauritius (Figure 1) usually experiences a series of storms ranging in intensity from tropical depressions to tropical cyclones in any single cyclone season, but intense or very intense tropical cyclones are relatively rare (Padya, 1989). The frequency of intense or very intense tropical cyclones centring on the main island of Mauritius is estimated as between 1:8 and 1:15 years.1 Mauritius has a long cyclone history (Padya, 1984). In April 1892 nearly 1,200 people were killed, partly at least attributable to the lack of a cyclone warning system. The cyclone of February 1960 killed 40 people, destroyed 70,000 buildings and made 100,000 homeless. The most recent very intense cyclone (Hollanda) occurred in February 1994, and killed two people; caused extensive damage to urban infrastructure, livestock, sugar production and hotels; and is estimated to have slowed Mauritius’s economic growth rate in that year from 7 to 5 per cent (Parker, 1998). Mauritius also experiences torrential rainfall flooding, riverine flooding, tidal surge flooding and landslip.

The main island of the Republic of Mauritius is Ile Maurice with a population of
1,082,972 (1994 census). The island is small (1,865 square kilometres) with a high population density. However, the maritime jurisdiction of the republic is very large — about 1.6 million square kilometres — and embraces the small island of Rodrigues (population 35,000 in 1995) which is 560 kilometres east of Ile Maurice. There are also other smaller islands with a combined population of a few hundred. Spatial dispersion presents initial complications in responding to the cyclone threat and disseminating warnings. For example, Ile Maurice and Rodrigues may be threatened by different cyclones at the same time.

Over the past 25 years, Mauritius has experienced major structural change from an agricultural, mono-crop (sugar-cane) economy with fast population growth, high unemployment and low per-capita income, to a country with a stable population, nearly full employment, a rapidly diversifying economy and rising per-capita wealth. The emergence of the export manufacturing and tourist sectors has been particularly rapid (Republic of Mauritius, Ministry of Economic Planning and Development, 1993). The population is stratified according to income and there is an evident stratum of poor people in most settlements. This is particularly pronounced in some of the more remote coastal rural locations and urban squatter settlements where social vulnerability to cyclones is likely to be highest. While there is evidence of poor housing (for example, wooden and tin shacks with corrugated-iron roofs) in most settlements, these dwellings are now in a minority. The proportion of dwellings
constructed of concrete walls and roofs has been rising, reflecting government policy of increasing the cyclone resistance of all dwellings. Poverty is greater in Rodrigues than in Ile Maurice (Republic of Mauritius, Central Statistical Office, 1994).

The tourist and tropical cyclone seasons coincide. Tourist arrivals exceeded 400,000 in 1994 and are expected to be 700,000 in the year 2000. Most of the island’s tourists are totally unaccustomed to tropical cyclones. There are 90 hotels on Ile Maurice and approval has been given for another 16.

Mauritius is a multi-racial, multi-lingual society with Hindus, Muslims, Sino-Mauritians and those of African descent living and working together and speaking English, French, Creole, Hindustani and other languages. Racial and linguistic diversity complicates the cyclone warning processes, although in Mauritius many of these complications appear to be minimised because many are trilingual.

The republic’s overall vulnerability to tropical cyclones is a highly complex function of risk, exposure, socio-economic and infrastructural vulnerability, and technological and social adjustment to risk. By virtue of population growth, the main island now has a much larger and more densely packed population exposed to risk of cyclone damage than earlier in the century. Increasing prosperity associated with economic growth is accompanied by a steady increase in the value of property, infrastructure and investment at risk. Some modern technologies are more vulnerable to damage than those they replace — the large rotational, overhead irrigation systems used on sugar plantations are one example. On the other hand, other technologies are becoming less vulnerable: for example, the optical-fibre telecommunication networks being installed. Decisions to locate investments and infrastructure in the most exposed zones — such as coastal storm surge zones — serve to increase exposure. The stratification of society and the continued existence of a poor stratum increases social vulnerability, although the strength of family units provides some amelioration. Whether the risk of very intense cyclones in the south-west Indian Ocean is increasing owing to global warming-induced climate change remains uncertain (Houghton et al., 1996: 334), but sea levels are rising so that the potential impact of storm surges associated with tropical cyclones is increasing.

Preparations for tropical cyclones are the responsibility of the Central Cyclone and Other Natural Disasters Committee (CCC) — a committee of the Prime Minister’s Office and chaired by the home secretary. This committee comprises ministerial heads and representatives of key agencies, including the Mauritius Meteorological Service (MMS). The CCC has played an important leadership role in preparedness planning for those ‘natural’ hazards affecting Mauritius. The Prime Minister’s Office authorises and publishes the ‘Disaster Preparedness, Cyclone and Other Natural Disasters Scheme’ (Prime Minister’s Office, 1995). This is an important, exemplary document which explicitly sets out the administrative arrangements for cyclone warnings, their dissemination and response. The CCC is supported by the work of Local Cyclone Committees comprising district-level officials and chaired by mayors. In the aftermath of cyclones, local level Task Forces are set up to collect information on impacts and relief needs.

Oakley analysed cyclone preparedness in Rodrigues (1991a) and hazard management in Mauritius (1991b). In his analysis of Rodrigues, Oakley reported important equipment and other shortcomings adversely affecting the island’s cyclone warning system. The UN Department of Humanitarian Affairs (DHA) sent a mission to Mauritius and Rodrigues following tropical cyclones Hollanda and Ivy which struck
the islands in February 1994. Their report also identified weaknesses with the cyclone warning and related communication systems which are taken into account in the evaluation which follows.

The criteria-development concept

Research on disaster warning systems remains dominated by technical aspects of forecasting and prediction (Keys, 1997: 15–16). While much of this research may be beneficial, the research reported here stems from a different perspective: that hazard warning systems are primarily social, organisational and institutional processes, which employ technical and other (for example, social, economic and political) means to reduce risk and loss. The effectiveness of disaster warning systems often depends upon the quality of human resources and expertise, social networks and institutional arrangements. Some of the most enduring evaluative methodologies employ a range of criteria by which a policy or process is assessed. Many of these methodologies have their roots in studies of natural resource policy in the 1960s and 1970s (for example, Fox and Craine, 1962; Howe, 1971; Parker and Sewell, 1988). Quarantelli (1997) has recently advocated using evaluative criteria to improve disaster management.

The central concept is a list of criteria and the Criteria-development Matrix (CDM) (see Table 1). This concept was developed to evaluate flood warning systems in the European Union (Parker and Fordham, 1996). In that project 14 criteria were identified but in the present work these have been significantly extended to 27. The criteria are distilled from the key lessons from research, experience and practice with warning systems contained in the now extensive literature on the subject (Drabek, 1986; McLuckie, 1973; Quarantelli, 1983; World Meteorological Organisation, 1989). They are based on those factors discovered to be critically important in designing and operating effective hazard warning systems. For example, Criterion 4 highlights the need for parity of attention between (a) the scientific and technical development of forecasts, and (b) the dissemination of appropriate warnings to warning recipients. Previous research has revealed that often there is heavy attention to and investment in (a) but relative neglect of (b) leading to problems (Keys, 1997). Criterion 8 maintains that hazard warning systems ought to serve the needs of potential disaster victims, rather than some other political purpose, and that the needs of all stakeholders should be included in designing any system. Criteria 10, 11 and 12 relate to those often excluded from hazard warning systems.

The European flood research indicated the possibility of thinking of five levels (or stages) of development on each criterion, and therefore a staged-development model of a disaster warning system. For example, as a disaster warning system is developed from being basic (development stage 1) (or one which is characterised by the most rudimentary or crude attributes conceivable) to being advanced (development stage 5) (that is, fully developed in which the current state-of-the-art is judged to have been reached, and containing no major shortcomings), it passes through intermediate stages of development (development stages 2, 3 and 4). A particular disaster warning system can be assessed against each criterion and each development stage to produce a ‘profile’ of its overall state or stage of development. The CDM then suggests prescriptive paths for improvement. To make the process of evaluation more rigorous, the condition which needs to be met or exceeded at each development stage...
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Development stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Legitimisation and authority accorded to warning dissemination</td>
</tr>
<tr>
<td>2</td>
<td>Legislative foundation</td>
</tr>
<tr>
<td>3</td>
<td>Cyclone warning philosophy</td>
</tr>
<tr>
<td>4</td>
<td>Forecast and warning parity</td>
</tr>
<tr>
<td>5</td>
<td>Application of technology to forecasting</td>
</tr>
<tr>
<td>6</td>
<td>Application of technology to warning dissemination</td>
</tr>
<tr>
<td>7</td>
<td>Geographical coverage (land area covered)</td>
</tr>
<tr>
<td>8</td>
<td>Extent of links with stakeholders</td>
</tr>
<tr>
<td>9</td>
<td>Arrangement for night-time warnings and response</td>
</tr>
<tr>
<td>10</td>
<td>Arrangements for remote areas</td>
</tr>
<tr>
<td>11</td>
<td>Arrangements for social groups with limited resources</td>
</tr>
<tr>
<td>12</td>
<td>Arrangements for groups with special needs</td>
</tr>
<tr>
<td>13</td>
<td>Redundancy in communication networks is developed</td>
</tr>
<tr>
<td>14</td>
<td>Multiple reinforcing sources of warnings</td>
</tr>
</tbody>
</table>

Dennis Parker
| 15 | Content of warning messages to public | Limited with major shortcomings in iconic, factual and/or behavioural content | Improved a little, but still with major shortcomings | Partially developed but considerable scope for further improvement | Partially developed, but with some scope for improvement remaining | Fully developed with little scope for improvement; iconic, factual and behavioural content all sound |
| 16 | Degree of local detail in warnings | None. Highly generalised warnings; problem unrecognised | None. Highly generalised warnings; problem being worked on | Some degree of local detail in warnings, but latent demand exists | A higher degree of local detail in warnings; some needs now being satisfied | A high degree of local detail in warnings; most needs now being satisfied |
| 17 | Extent to which the warning system allows for confirmation processes | None in formal system; problem unrecognised | None in formal system; problem is recognised; problem being worked on | Some good possibilities exist | Well developed | Highly developed |
| 18 | Presentation of messages to the public in broadcast media | Basic methods; many shortcomings affecting communications are unrecognised | Basic methods; many shortcomings, but some of these are recognised and being addressed | Partially developed; many shortcomings recognised and being addressed, but scope for improvement | Partially developed; many shortcomings recognised and addressed, but scope for improvement | High standard taking in results of recent research |
| 19 | Extent of integration of forecast and media agencies | Non-existent; competition and rivalry abound | Collaboration and competition exist side by side; reasonable collaboration at some levels over some aspects | Collaboration is now the rule and competition and rivalry has been eradicated | Collaboration is the norm; explicit measures to reinforce integration are evident | Seamless integration is evident; explicit measures to reinforce integration are evident |
| 20 | Extent of informal communication network activity | Very limited; with no attempt to encourage | Limited; with no attempt to encourage | Evidence of some communication activity; value may be recognised | Well-developed social networks; value recognised | Extensively active informal social networks; value recognised and reinforced |
| 21 | Availability of hazard information | Virtually non-existent or existent but fragmentary and incomplete based only on historic records | Efforts to build a comprehensive database for the first time; updating not well considered; major quality and resolution problems | Less than comprehensive database of hazard zones; irregular updating; some major quality and resolution problems | Comprehensive database of hazard ones; not on GIS; regularly updated; quality and resolution problems | Comprehensive GIS database of hazard zones; regularly updated; high quality and high resolution |
| 22 | Attitudes towards freedom of hazard information | Highly restrictive and secretive | Quite restricted and secretive | Mixed; more openness developing, but in practice confidentiality looms large | Generally more open in policy and practice | Fully open in policy and practice |
| 23 | Public awareness raising about warnings | Non-existent or virtually so | Efforts are apparent to develop awareness programmes | Programmes exist; narrow range of methods; not evaluated | Programmes exist; narrow range of methods; not evaluated; fewer other shortcomings | Comprehensive; regular awareness raising, using combination of methods regularly evaluated |
| 24 | Public education about cyclones and cyclone warnings | Non-existent or virtually so | Efforts to include material in the school curriculum are apparent; other methods are ad hoc | Embedded in school curriculum; linked to some exposure in audio-visual and printed media; unevaluated; special needs and ethnic minorities not distinguished | Embedded in school curriculum; linked to some exposure in audio-visual and printed media; either unevaluated or special needs and ethnic minorities are distinguished | Integrated approach employing school and college curriculum; audio-visual and printed media; effectiveness formally evaluated; ethnic minority and special-need groups given special attention |
for each criterion is specified in the matrix cells — again based upon synthesis of previous research. Clearly, these conditions can be altered and modified over time and this would be expected to happen as the state-of-the-art advances. Equally, other criteria might be added or substituted depending on the emphases of a particular evaluation.

**Stakeholder analysis and key informant interviews**

The data required to evaluate Mauritius’s tropical cyclone warning system were provided by analysing results of in-depth interviews with stakeholders undertaken between 1996 and 1998 (most of them done by the author). The interviews were preceded by preliminary research on different aspects of Mauritius, its institutions and the cyclone forecasting and warning system. The way was paved by an initial visit of a representative of the UK Meteorological Office who began the process of identifying stakeholders in the TCWS.

The formal stakeholder analysis went through five iterations and was then revised after the first main field visit to Mauritius. This analysis categorised and identified the principal stakeholder groups (see Table 2) for interviewing. Research resources did not
### Table 2  Stakeholder groups

1. Central government departments/ministries with responsibilities for some aspect of the cyclone forecasting, warning and response system: **senior civil servants**
   - Prime Minister’s Office
   - Ministry of Housing and Land Development
   - Ministry of Local Government
   - Ministry of Economic Planning and Regional Co-operation
   - Joint Economic Council (JEC)
   - Ministry of Social Security and National Solidarity

2. The cyclone forecasting **providers**:
   - The Mauritius Meteorological Service (MMS)
   - Mauritius Broadcasting Corporation (MBC)

3. **Agency or group** cyclone warning **receivers and responders** including:
   - Civil protection agencies
   - The police: police headquarters
   - Fire services: the government fire service
   - Medical services and hospitals
   - Regional/local governments: mayors
   - Commercial establishments: industry
   - Association des Hoteliéres et Restaurateurs, Ile Maurice
   - Sugar-cane industry: Public Relations Office of the Sugar Industry
   - Public utilities
     - Mauritius Marine Authority
     - Ministry of Energy
     - Water Services and Postal Services
     - Central Water Authority
     - Central Electricity Generating Board
     - Special Mobile Force
   - Housing agencies: self-help
     - Semi-private
     - Central government agency

4. The **Media services**
   - Television and radio: MBC
   - Press/newspapers

5. **Insurers**
   - Agricultural crop insurers
   - Household and other insurers

6. **Receivers who are individuals**
   - Householders
   - Cultivators
   - Other members of the public and tourists (i.e. outsiders without experience)

7. **Consumer groups and associations**
   - Association des Consommateurs de L’Ile Maurice
   - Institute for Consumer Protection
   - Government Civil Servants’ Association
   - Farmers’ Unions

8. **Critical thinkers**
   - University of Mauritius (also warning receivers)
   - Others

9. **Vulnerable, excluded or under-privileged groups**
   - Geographically isolated groups on Ile Maurice
     - on Rodrigues (37,000 pop)
     - on Cargodos Carajos (St Brandon) (c.300 pop)
   - Socially vulnerable groups
     - ethnic minorities
     - the poor
     - the infirm/elderly
     - women and female-headed households
     - those with limited access to TV
     - those from low-quality housing
extend to undertaking a large and representative programme of interviewing of individual householders or cultivators, although further research of this nature can yield extremely useful complementary data (Parker and Neal, 1990). Sampling involved at least two interviews in each of the nine stakeholder groups and gaining data from as wide a range of agencies and individuals as possible. The selection of key informants from each sampled stakeholder organisation/group is crucial. Experienced individuals who through their status, position of responsibility and/or first-hand knowledge and experience, have a strong insight into the development and effectiveness of the disaster warning system were classed as key informants. A list of key informants for sampled stakeholder organisations/groups was drawn up and contacts were made to arrange meetings and interviews. Almost all of those contacted agreed to be interviewed during one of the two field visits. Fifty-two key informants were interviewed during 35 key-informant meetings. In some cases those contacted for interview assembled a small group to participate in the meeting and this proved invaluable. The main example was the Director of the Joint Economic Council (JEC) who assembled four representatives from industry and himself for a meeting which lasted several hours.

Those with whom meetings and interviews were conducted included the director of the MMS, the secretary of state for Home Affairs, the commissioner of police, the director-general of the Mauritius Broadcasting Corporation (MBC), the portmaster and the director of the Ministry of Economic Planning and Development. Interviews were also held with company senior managers including from the State Insurance Co. of Mauritius, the Mauritius Housing Corporation, the Mauritius Export Processing Zone, the Mauritius Chamber of Commerce, Mauritius Telecom, the Munich Reinsurance Company and the Association of Hoteliers et Restaurateurs. Critical thinkers included academics at Mauritius University and a representative from the island’s Town and Country Planning Department. Interviews were also held with a fishermen’s group, several small cultivators, a women’s group, several householders and several of the occupants (in groups) of two squatter settlements. The field visits did not extend to Rodrigues or the other smaller islands but an interview was undertaken with the Minister for Rodrigues. Four of the key informants were interviewed on a second occasion for verification and clarification purposes.

The survey instrument comprised a partly structured, in-depth interview guide (different versions were produced for the various types of stakeholders). The guide included a series of questions, both factual and evaluative, addressed in variable order. Questions addressed the main factors as indicated by the 27 criteria. Interviews were not tape-recorded because it became clear that this might create problems for government officials. Interviewers took handwritten notes transcribed into word-processed reports usually on the evening of the interview day. Interpreters were used in a small minority of cases. As interviews were completed, the opportunities for cross-referencing and for using the process known as ‘triangulation’ (Baxter and Eyles, 1997) expanded, allowing the researchers to focus on strengths and weaknesses of the system and adding confidence to the process. Some conflicting information and views became evident. In cases where conflicting factual information was provided, further questioning took place, usually during the final visit of June 1998, in order to clarify. Some conflicting views could not be resolved since they reflected different perceptions of events. A number of separate investigations were undertaken to verify certain pieces of key information.
The data-collection methods performed satisfactorily. A possible problem with the methodology is the potential for ‘capture’ by the MMS since many interviews were arranged through that agency which might have a vested interest in proving the effectiveness of the TCWS. This could lead to selection and political bias and other problems. The researchers were aware of this possibility at the outset. Research findings are interpreted taking into account these possibilities, and a strategy used to counter this potential problem was to arrange a proportion of interviews without MMS’s knowledge. The researchers formed the view that the director of the MMS valued independent views and this fortunately minimised the possibility of capture and bias. A key issue is whose views were and were not heard. Although the research did not set out to determine the views and experiences of ‘ordinary’ Mauritians (including householders, farmers, poor people, women and Rodriguans), care was taken to include a small number of members from all these groups (e.g., a small number of Rodriguan refugees living in Mauritius was interviewed). The voice of Rodrigues was also partly captured by interviewing the Minister for Rodrigues, but the voice of those occupying the smallest islands was insufficiently captured. The mass of recorded data from the meetings and interviews was interpreted, together with documentary evidence, as systematically as possible to locate according to each criterion the most likely development stage reached.

**Characterising the forecasting and warning system**

MMS is a professional meteorological service responsible for providing the TCWS for the republic, and operating with a 24-hour team. MMS’s staff are well networked into the World Meteorological Organisation, including their Technical Commission. Mauritius is a member of the Tropical Cyclone Committee for the south-west Indian Ocean. These and other arrangements provide for knowledge transfer, training and up-to-date equipment.

The MMS has a mix of state-of-the-art, near state-of-the-art and conventional equipment. It has acquired new equipment under a Regional Project on Meteorology from the Indian Ocean Commission, and by funding from the European Development Fund. The forecast section was computerised in 1997 using a SYNERGIE workstation enabling weather maps and satellite imagery to be visualised. The METEOSAT meteorological satellite which provides hourly images of weather systems is used, together with several complementary systems. Mauritius is on the eastern boundary of the image coverage provided by METEOSAT because of that satellite’s track. There is an area of the Indian Ocean to the east of Mauritius for which satellite coverage is not available to the MMS. Unfortunately, this is also the area where cyclones affecting Mauritius originate and so there is a need for access to another Indian Ocean satellite. A weather radar (non-Doppler) installed in the 1970s is still functioning but will need replacing shortly or complementing by a Doppler radar giving wind velocity as well as rainfall intensity data. During 1996 the MMS confirmed that equipment shortcomings affecting cyclone warnings in Rodrigues identified by Oakley (1991a) had been rectified. However, the need identified by DHA in 1994 for at least one international communication system with high survival capability was still under discussion in the Prime Minister’s Office in mid-1998. There are significant risks to equipment (such as satellite dishes, instrument masts and international communications) during cyclones...
which can reduce the forecasting effectiveness of the MMS. This could be particularly problematic if significant equipment damage occurs early in a very active cyclone season.

The four-class warning system

Since the 1950s, Mauritius has had a formal warning system for tropical cyclones which has four, stepped, coded classes (see Table 3). The coded classes do not indicate the intensity or size of the cyclone, only the extent to which gusts will exceed 120km/h. A formal ‘cyclone watch’ commences when a tropical depression forms, and when this occurs the depression is also named. The system displays evidence of learning. Mauritians have learned that providing people with warnings well ahead of nightfall helps with appropriate damage-reducing response, and that nightfall warnings degrade response capacity. Therefore, as far as is practically possible, warnings are given 12 and six hours ahead of nightfall in the case of Class II and III warnings. The four-class warning system is publicised through a public booklet, media weather presentations, the school curriculum and pre-season cyclone posters.

The cyclone warning dissemination system

The formal warning dissemination system is a well-developed (a) fan and (b) cascade model with the MMS (the ‘Meteo’ locally) at the hub (Figures 3–6). This system is clearly specified in the document issued by the Prime Minister’s Office (1995). Cyclone bulletins are the principal form of data disseminated. They specify the position, intensity and movement of cyclones, with a forecast of the expected changes in conditions of wind and sea, and the expected time of commencement of specified wind speed and gust conditions. The frequency of bulletins is increased as cyclone warning progresses through the classes. A termination bulletin is issued when the MMS Director believes that no wind gusts of more than 120km/h are expected. When sending bulletins the MMS operates rigorous confirmation processes. Cyclone bulletins are issued in four languages and warnings are also disseminated using a system of flags flown from public buildings. Warnings are also issued by TELMET —

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Cyclone warning class system for Mauritius</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class I</strong></td>
<td>is issued 36–48 hours before Mauritius or Rodrigues is likely to be affected by a depression or cyclone</td>
</tr>
<tr>
<td><strong>Class II</strong></td>
<td>is issued so as to allow as far as practicable 12 hours of daylight before the occurrence of gusts of 120 km/h</td>
</tr>
<tr>
<td><strong>Class III</strong></td>
<td>is issued as far as practicable in time to allow six hours daylight before the advent of 120 km/h gusts</td>
</tr>
<tr>
<td><strong>Class IV</strong></td>
<td>is issued when gusts of 120 km/h have occurred and are expected to continue</td>
</tr>
<tr>
<td><strong>Termination</strong></td>
<td>There is no longer any appreciable danger of gusts exceeding 120 km/h</td>
</tr>
</tbody>
</table>
a public dial-up, telephone answering message service in English and French. To date little use is made of the Internet to disseminate cyclone warnings in Mauritius.

Principal findings: the evaluation of the warning system

The evaluation was largely qualitative and judgemental, and based mainly on a synthesis of field evidence (see Figure 7). The reasoning for the development stage categorisation according to each criterion is given briefly below (wording in parentheses refers to the criteria labels in Figure 7) (Parker and Budgen, 1998). Full
details of research findings are provided in Parker (1998a) and Parker and Budgen (1998) with a number of points amplified below.

Criterion 1: legitimisation and authority accorded to warning dissemination (legitimisation). The Prime Minister’s Office Scheme (1995) provides a strong and high level of legitimisation for Mauritius’s TCWS. However, this legitimisation might be further strengthened by fuller reference to the need to integrate the

![Figure 3](https://example.com/figure3.png)

**Figure 3** Cyclone warning dissemination system for Mauritius (see insets on following pages)

![Figure 4](https://example.com/figure4.png)

**Figure 4** Inset A
activities of the media and forecasting agencies in the specific area of warning dissemination.

Criterion 2: legislative foundations (legislation). Mauritius has fragmented disaster prevention and management legislation which constrains the development of disaster mitigation. The current legal status of TCWS is unclear and the boundaries of responsibility of the MMS, and other agencies involved in cyclone warning dissemination, are currently ambiguous.

Criterion 3: extent to which the country has a coherent TWCS philosophy (philosophy). Government has taken a strong lead in explicitly specifying a TCWS philosophy which emphasises integration, coherence and consistency. Less attention has been afforded to consistency by integrating arrangements for the outer islands, and there is some lack of integration of the warning system with arrangements for transport, insurance and schoolchildren.

Criterion 4: forecast and warning parity (forecast and warning parity). There is little evidence that technical and scientific issues surrounding cyclone forecasting have led to warning and warning dissemination not being afforded full and equal attention. However, there is not much systematic attention to the social performance of the TCWS (for example, the extent to which it meets social needs).

Criterion 5: application of technology to forecasting and the availability of detection and forecasting equipment (forecast technology). Mauritius possesses or has access to state-of-the-art — or near state-of-the-art — technology in many parts of its operation, although this is a fairly fast-advancing area of technology. Recent investments have increased capability but there are some obvious equipment-ageing problems.

Criterion 6: application of technology to warning dissemination and the availability of dissemination technology (warning technology). Again, Mauritius possesses or has access to state-of-the-art, or close to state-of-the-art, technology in many parts of its warning dissemination operation. There are, however, some exceptions (for example, the absence of electronic mail networks) and some gaps and shortcomings which can be significant under particular circumstances.

Criterion 7: geographical coverage (geographical coverage). The geographical coverage of Mauritius’s cyclone detection, forecasting and warning is complete. A
high proportion of the population have television, radio and telephone communications and, although there are reception problems in some areas (for example, Rodrigues), coverage by the warning system is high. These findings must be interpreted alongside those for criterion 10 below.

**Criterion 8: extent of dialogue with stakeholders (stakeholders).** MMS is developing relatively strong networks with stakeholders in the TCWS. In some cases, (for example, JEC) a dialogue has developed and there is relatively regular contact. In other cases (for example, the fishermen who were interviewed), contact has been sparse. Overall, there remains considerable potential for extension of dialogue with the full range of stakeholders.

**Criterion 9: arrangements for night-time warnings and response (night-time).** The special problems posed by cyclone warnings during night-time have been well-recognised in the four-class warning system. Even so, class warnings are sometimes issued at night. Provision has been made for warning dissemination at night, although a number of shortcomings were identified (for example, the lack of an up-to-date list of the contact details in the MMS for night-time) and it is believed that arrangements for night-time could be strengthened further (for example, by refurbishing the siren system).

**Criterion 10: arrangements for remote areas (remote areas).** Arrangements for disseminating cyclone warnings to remote islands and sea areas appear to be significantly weaker than for Ile Maurice. Deficiencies were identified in relation to Rodrigues and Rodriguans in Ile Maurice which are indicative of these problems. Work is being undertaken to address these problems but significant improvements may be made.

**Criterion 11: arrangements for social groups with limited resources (limited resources).** Arrangements for disseminating cyclone warnings to socially excluded groups appear to be unsatisfactory. Those with radios appear to be relatively well connected to the warning dissemination system, although their opportunities for receiving warnings from multiple reinforcing sources may be reduced. The poorest of
the poor — for example, migrants occupying squatter settlements — are provided for in terms of post-cyclone shelters but not so much in terms of warning dissemination.

Criterion 12: arrangements for groups with special needs (special needs). Two particular groups were identified to exemplify this issue: fishermen and tourists. Neither are provided with warning dissemination systems and supporting information designed to meet their special needs. Both are highly exposed to tropical cyclones.

Figure 7  Indicators of the condition of the tropical cyclone warning dissemination system in Mauritius in 1998
Criterion 13: redundancy in and robustness of communication networks (communication networks). Mauritius’s communication networks work reasonably securely until intense cyclone conditions are experienced when there is a progressive loss of communications to a point (such as in the case of cyclone Hollanda) when virtually all communications are lost. Agencies are increasing the redundancies within their communication systems so that the network robustness is increasing, but considerable scope for improvement remains. Loss of the electricity supply which underpins many communication systems is a persistent and severe problem requiring urgent attention.

Criterion 14: multiple reinforcing sources of warnings (warning sources). Mauritius has developed a multi-channel/source warning system which includes warning by the broadcast media (television and radio), a flag system, TELMET and warning (in last resort circumstances) by the Police and a Special Mobile Force. Social networks appear to support these formal warning processes. The addition of a siren system would be advantageous. There is evidence that the warning sources are not always consistent, and that TELMET requires enhancement.

Criterion 15: content of warning messages to the public (warning content). The detailed content of cyclone warning messages has not been analysed. However, cyclone warnings include both factual and behavioural information and are relatively well developed. The iconic (attention-getting) aspect may well require further attention because of the frequency of cyclone bulletins and the complacency that emerged during cyclone Hollanda.

Criterion 16: degree of local detail in warnings (local detail). Mauritius has a complex micro-climate which produces quite large differences in weather conditions over short distances. This presents a particular challenge for weather forecasters and for those giving cyclone warnings. Lack of pertinent geographical detail within a warning message is positively associated with warnings being ignored (Burkhart, 1991). Currently, the MMS does its best to present detail but many users would prefer a greater degree of specific detail within the weather forecasts and cyclone warnings. The MMS’s current view is that users should interpret the forecasts in terms of their own geographical location and other circumstances. Improved forecasting capability and greater resolution may in time generate more local detail.

Criterion 17: extent to which the warning system allows for warning confirmation processes (confirmation). Mauritius relies on the broadcast media to disseminate cyclone warnings, and these media do not present many opportunities for rapid warning confirmation. However, the fact that Mauritius has a multiple-source warning system allows for confirmation, as does the presence of strong social networks. The TELMET service is very useful for warning confirmation and should be enhanced in terms of its quality and robustness under intense cyclone conditions.

Criterion 18: presentation of warnings by the broadcast media (broadcast media). Significant problems exist with the current television weather forecasts and cyclone warnings. These stem from the journalistic leanings of the MBC’s operation, from lack of training and/or the non- or limited involvement of weather professionals in presentations.

Criterion 19: extent of integration of forecast and media agencies (integration). Significant problems exist with current arrangements, although this is not to suggest that the two agencies do not co-operate at the moment. There is a degree of competition between the MBC and MMS and scope for much closer integration of activities.
Criterion 20: extent of informal, social communication network activity (social networks). Social networks were well developed within each island community within the country, and this reinforces cyclone warning dissemination effectiveness. MMS officers have extensive informal as well as formal networks, and the compact island feature reinforces this. However, social communications between islands are more tenuous and need reinforcement.

Criterion 21: availability of hazard information (hazard information). Limited availability of hazard information (for example, zones of high risk for cyclone-related flooding) is a constraint on the effective working of a warning dissemination system. There is limited knowledge of hazard zones which can be accurately differentiated by degree of risk: this applies to tidal surge and flood zones. There is considerable scope for improvement here through a mapping programme.

Criterion 22: attitudes towards freedom of hazard information (freedom of information). There is little reason to believe that hazard information is withheld from the public in Mauritius. On the other hand, there is little evidence that the authorities in Mauritius have recognised that making specific hazard information (for example, tidal surge zone, flood zone, highly exposed locations) available encourages public responsiveness to risks and warnings. The MMS and Ministry of Information only provide generalised hazard information and advice for the public.

Criterion 23: public awareness raising about warnings (awareness-raising). This is achieved by pre-cyclone season publicity and through the issuing of a booklet prepared by the MMS and Ministry of Information. The MMS also provides talks to local schools. Some key informants claimed that publicity was too limited and sometimes late. There appears to be considerable scope for improvement here, but with significant resource implications.

Criterion 24: public education about cyclones and cyclone warnings (education). The educational system gives exposure within the school curriculum to weather systems, cyclones and the cyclone warning system. Any weaknesses which exist relate less to curriculum content than to levels of literacy attainment and absenteeism from schools which adversely affects those from vulnerable social groups.

Criterion 25: knowledge of tropical cyclone forecasting, warning and response system (TCFWRSS) effectiveness by agencies (effectiveness). There is general knowledge about TCFWRS effectiveness, especially those elements relating to cyclone detection, monitoring and forecasting accuracy and reliability. There is less systematic knowledge about the effectiveness of warning dissemination including the timeliness of warnings from the recipient’s viewpoint, the proportion of the population penetrated by specific warnings under different circumstances and times and so on. There is considerable scope to extend knowledge about receiving warning and subsequent response.

Criterion 26: performance targets set and monitored (performance targets). There does not appear to be a performance target setting and monitoring philosophy, except with some aspects of cyclone forecasting. For example, there is no evidence of an annual target-setting process in which the number of agencies which receive direct warnings is steadily increased, or the proportion of complaints from the public is recorded and worked upon in order to reduce it.

Criterion 27: organisational culture (organisational culture). There appears to be a disaster culture among many organisations; those examined had prepared their own internal cyclone emergency procedures. There is evidence of a basic customer-
oriented approach within the MMS, as well as evidence of an open-minded approach to improving TCWSs and relationships with other organisations. There is not much evidence of collaborative, contractual service-level agreements between agencies involved in warning dissemination, although a market for such exists in Mauritius. There is some evidence of competition between organisations although this is not particularly strong, except in the case of the MMS and MBC.

**Amplification of the principal findings**

In cyclone Hollanda in 1994, communications suffered a total breakdown. Mauritius was unable to communicate with the outside world for half a day, which could have been problematic had immediate medical and other international assistance been necessary. The vulnerability of the country’s electricity transmission systems to cyclone damage is high. After Hollanda it took six to eight weeks to restore electricity supplies because of damage to overhead transmission cables. Loss of electricity supply eventually closes down the television service during intense cyclones, although radio normally continues broadcasting (Mauritians are used to keeping battery-powered radios).

Mauritius’s TCWS has many features that potentially set the stage for a sound system. In particular, the government has given a high priority to cyclone warning dissemination and mandatory elements of the system are detailed in the Prime Minister’s Office Scheme (1995) which affords cyclone warning dissemination a high degree of legitimisation. Even so the legislative foundation of the service provided by the MMS requires further attention, particularly regarding the boundaries of responsibility and accountability of that agency, and the extent to which it might be sued for negligence. There is evidence of a learning culture. However, the process of stakeholder consultation could be expanded, including more to excluded and remote social groups. The four-class cyclone warning system must be kept under review to ensure that it meets the needs of tomorrow’s Mauritians. The MMS must continue to examine the claims of industry and fishermen that the present system is not attuned to their needs. Factory owners claim that Class-III warnings are issued too early, which leads to disruption of business because employees must leave for home as soon as it is issued (Mauritians are not insured to drive their cars shortly after a Class-III warning is broadcast and public transport also ceases rapidly). There are other problems because many factory workers are mothers who really need to get home after a Class-II warning since schools close then and schoolchildren must leave. Fishermen believe that weather forecasts and cyclone bulletins are given too late for their purposes. Some key informants believe that Class-I warnings are now so routinely ignored by sections of the population, they should be discontinued. Others believe that this warning is crucial to cyclone preparation and the alert associated with such a warning should be increased. The timely cancellation of Class-I and -II warnings is necessary to maintain high levels of public confidence in the warning service. The MMS has a positive public image and is recognised and respected by the people of Mauritius. Maintaining this respected image is important for the continued integrity of the system, and it is important that risks associated with losing this favourable image are carefully identified and countered.

The precise relationship between the MMS and the MBC requires urgent attention. The broadcast media offer the best means of disseminating cyclone warnings, but it appears that this potential is not being maximised. There is a need for better agreement
over the boundary-spanning processes in which journalists and meteorologists are involved and inter-dependent. Encouraged by the UK Meteorological Office and with training from the BBC weather television presentation team and others, the MMS has set up a recording studio and is capable of preparing weather/cyclone forecasts for transmission by the MBC. The MBC claim that MMS video recordings are of too low a standard to broadcast and that their meteorological presenters are insufficiently glamorous or lack the required voice quality. Television could play an enhanced educational role in Mauritius as far as cyclone preparedness is concerned, but so far the potential is not optimised by boundary contests.

Ile Maurice is a small and densely populated island on which there are a multitude of informal communication networks. Such social networks have been shown to be very helpful in amplifying warning transmission (Parker and Handmer, 1998). Informal warning processes operating via social networks appear to work well in reinforcing the formal system. There is little evidence in Mauritius of formal target setting or a regular evaluation process regarding the TCWS. This approach has been adopted by many UK utilities and service providers within a regulated, customer-oriented, value-for-money and customer charter framework. Some aspects of this approach might be applied to good effect in Mauritius. A flood-warning system linked to the cyclone and torrential rain warning systems is certainly required (Parker, 1998b).

Projects likely to generate the greatest improvements in the warning system

The details of the CDM (Table 1) and the profile obtained for Mauritius’s tropical cyclone warning system (Figure 7) provide a prescriptive basis for improving the system because, between them, they indicate where and how improvements might be made. For example, the warning system could become more complete and effective by targeting a project to shift Mauritius from development stages 2 to 5, say on criterion 10. This might involve organisational and technological investment to ensure that all those living on islands distant from Ile Maurice are at least as well served by the warning system as those on the main island. However, for a selected criterion, the beneficial impact of moving from one development stage to the next may not be the same for moves between each of the stages. Furthermore, the impact of making, say, a two-stage improvement on one criterion is unlikely to be equal to a similar improvement on another criterion. Where, then, might the potential for improvement of the warning system be greatest, and where therefore should investments be focused to gain the maximum overall benefit? Through further research it should be feasible to weight the criteria according to their importance in terms of improving the effectiveness of the warning system.

At the present overall level of development of the system in Mauritius, the greatest potential for improvement lies in addressing hazard information inadequacies (hazard zone mapping) (criterion 21); the needs of excluded groups (criterion 1) and those with special needs, including tourists (criterion 12); communication networks, including the robustness of the electricity transmission system on which they depend (criterion 13); improving the public’s awareness of the hazards, related warning system and appropriate responses (criteria 23 and 24); and achieving better integration of the forecast and broadcast services (criteria 18 and 19). Estimating the costs and benefits
of moving from one development stage to another on each criterion requires considerable further research but should be feasible. In practice, it might only be necessary to focus on the costs and benefits of those shifts remaining to be achieved on those criteria with highest weights.

**Conclusion**

Criteria are identified which provide a basis for improving the design of TCWSs. A TCWS designed to levels four and five in the CDM is likely to perform well. The kind of evaluation undertaken for TCWS of Mauritius may be applied to other hazard warning systems in other settings. But to do this requires modifying the CDM and customising the threshold criteria within the cells to specific hazards and cases. However, it is believed that most of the criteria are applicable to most hazard warning systems because previous research has revealed their significance in improving warning system effectiveness. One criterion (9 night-time) is less applicable to diffuse and slow onset disasters, such as drought, and other criteria may be added where necessary. The threshold criteria for levels of development may also be modified in the light of further research and general advancement.

There is much in Mauritius’s TCWS from which others can learn to develop in communities which are sustainable in hazardous zones. Those criteria on which Mauritius is rated four or five in Figure 7 are especially worthy of the attention of others seeking to enhance tropical cyclone and other warning systems.

**Acknowledgements**

The author wishes to acknowledge the assistance of Mr P. Budgen of the UK Meteorological Office; Mr R. Vaghjee and Mr M. Lee Man Yan of the Mauritius Meteorological Service; Dr L. Radwan; and the members of the UK National Coordinating Committee for the IDNDR and the Meteorological Office for funding this research. The author also wishes to thank Professor Ian Davis for his support and friendship.

**Note**

1. Data supplied by A. Purdassy, State Insurance Co. of Mauritius.

**References**


Prime Minister’s Office (1995) Disaster Preparedness, Cyclone and Other Natural Disasters Scheme. Port Louis, Mauritius.

Quarantelli, E.L. (1983) People’s Reactions to Emergency Warnings. Article 170, Disaster Research Center, University of Delaware, Newark.


Address for correspondence: Flood Hazard Research Centre, Middlesex University, Queensway, Enfield EN3 4SF. E-mail: <<D.Parker@mdx.ac.uk>>