



Comptroller and Auditor General
Report on Value for Money Examination

Department of Public Enterprise

Met Éireann

April 2000

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The report was prepared on the basis of information, documentation and explanations obtained from the bodies referred to in the report.

The draft report was sent to the Department of Public Enterprise and to Met Éireann and comments were requested. Where appropriate, comments received were incorporated in the final version of the report.

Report of the Comptroller and Auditor General

Met Éireann

I have, in accordance with the provisions of Section 9 of the Comptroller and Auditor General (Amendment) Act, 1993, carried out a value for money examination on Met Éireann.

I hereby submit my report on the above examination for presentation to Dáil Éireann pursuant to Section 11 of the said Act.

A handwritten signature in black ink, appearing to read 'John Purcell', with a large loop at the top and a long horizontal stroke at the bottom.

John Purcell
Comptroller and Auditor General

12 April 2000

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Glossary of Terms

Climatology	The study of the general characteristics of the atmosphere, their geographical variations and their statistical properties.
Environmental Protection Agency	A statutory body whose responsibilities include promotion of environmental protection and monitoring of environmental quality.
Geomagnetic data	Data about the magnetic field of the earth.
HIRLAM	High Resolution Limited Area Model: a computer model of the atmosphere, used for short-range prediction. The model has been developed in an international collaborative research project called the HIRLAM project.
IAA	Irish Aviation Authority: a statutory body whose responsibilities include the provision of air traffic management and communications in airspace controlled by Ireland and the provision of related air traffic infrastructure.
ICAO	International Civil Aviation Organisation.
LAPEM	Limited Area Primitive Equation Model: the computer model used up to 1994, the predecessor of HIRLAM.
Mean sea level pressure	Over sea: the surface pressure. Over land: extrapolation of the surface pressure to mean sea level.
Meteorology	The study of the earth's atmosphere, especially of weather forming processes and weather forecasting.
Seismic waves	Shock waves relating to or caused by earthquakes or artificially produced earth tremors.
SIGMETS	Significant weather conditions which may affect the safety of air traffic.
Synoptic weather station	Meteorological observing station reporting a comprehensive range of weather parameters at regular intervals, usually hourly.
TAFs	Terminal aviation forecasts: forecasts of weather conditions for use by pilots planning to use specific airports, including forecasts of wind direction and speed, gust, visibility height of cloud cover and the presence of active thunder clouds.
WAM	A computer model for prediction of sea waves and swell, derived from wind forecasts generated by the HIRLAM model.

Summary

Met Éireann is a division of the Department of Public Enterprise but operates relatively independently within the terms of an administrative budget agreement.

The mission of Met Éireann is to meet the national requirement for high quality weather forecasts and associated services, with optimum efficiency and value for money.

This examination was concerned with the techniques used to determine the accuracy of weather forecasts and with the arrangements between Met Éireann and the Department for the management of the performance of the service.

Accuracy of Weather Forecasting

The accuracy and timeliness of weather forecasts are key performance criteria for Met Éireann. Accuracy is considered for three different kinds of service – the underlying computerised weather prediction model, general weather forecasts and specialised forecasts of particular aspects of weather such as wave height and severe weather events. A weather forecast is based on predictions of a number of weather elements including pressure, temperature, humidity and wind speed.

Data reviewed in the course of the examination indicates a significant improvement in weather predictions since the introduction of the current prediction model in 1994.

Over 120 general weather forecasts are issued each day through radio, television and the press, and through a telephone and fax service known as *Weatherdial*. The examination findings are

- General forecasts (for example, the weather forecast broadcast at 7:55 a.m. on RTÉ Radio 1) are typically given in non-numeric terms which limits the scope for assessing their accuracy.
- During this examination, a special exercise was performed to measure the accuracy of minimum and maximum temperature forecasts given over a three-month period on the *Weatherdial* service. The results indicated that almost half of the temperature forecasts were within one degree of the temperature observed while three quarters were within two degrees.
- A comparison of the accuracy of actual weather forecasts with persistence forecasts (i.e. forecasts based solely on weather conditions in the previous 24 hours) generally confirms that the skill exercised by forecasters significantly improves the level of accuracy.

Specialised weather forecasts are provided for aviation services (e.g. wind direction and speed, visibility and height of cloud cover), for coastal shipping (sea area and wave height forecasts) and for local authorities (road ice warnings).

There is no standard method for measuring the accuracy of aviation forecasts. For this reason, international comparisons of accuracy are difficult. However, Met Éireann monitors the accuracy of its own aviation forecasts and has estimated that, in 1998, the internationally agreed standards of accuracy were achieved more than 90% of the time.

Data is collected on wave height from six buoys located around the Irish coastline. For the purpose of this examination, a comparison between actual recorded wave height and wave forecasts for a six month period in 1999 was made. This indicated that the forecasts were reasonably accurate with a slight tendency to under estimate the wave height.

For ice warnings and severe weather alerts, there are three possible outcomes which can be monitored

- **a hit:** where the forecasted weather actually occurs
- **a miss:** where the forecaster fails to predict an exceptional weather event
- **a false alarm:** where adverse weather is forecast but fails to materialise.

Met Éireann is developing an accuracy verification scheme based on the analysis of hit, miss and false alarm rates. Data for the winter of 1998/99 for forecasting road ice indicates a hit rate of 71% and a false alarm rate of 16%.

A special exercise to consider the accuracy of severe weather alerts (fog, wind, snow and rain) in the period November 1998 to January 1999 indicated a hit rate of 92%. However, this analysis includes warnings which were issued later than the targeted advance notice periods for weather alerts. For consistency over time, it would be preferable to include in the accuracy analysis only warnings issued within a predetermined lead time.

Met Éireann provides a range of non-forecasting services which are mainly concerned with the provision of data to international agencies. Some external reviews are made which give reasonable confidence of the accuracy of the data supplied. The continuing acceptance by the international agencies of the data is also considered to provide some reflection of its accuracy and acceptability.

Managing Performance

In recent years, Met Éireann has operated through an administrative budget agreement with the Department and has published customer service plans, statements of strategy and business plans. While these documents are very useful, there are a number of limitations which restrict the proper assessment of performance. These include

- The high level objectives focus more on how the mission will be achieved rather than on the outputs and impact which is sought from its activities.
- No measurable benchmarks are in place for the range of outputs (e.g. forecasts), the volume of each output or the accuracy of the output.
- There is a lack of clarity in separating services which are to be provided on a commercial basis (like aviation forecasts) and those which form part of the publicly funded service.
- There is implicit prioritisation of services to meet the competing demands of clients. The strategic statements and business plans should make the prioritisation more explicit.

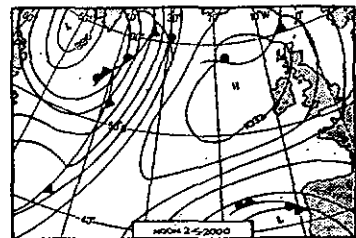
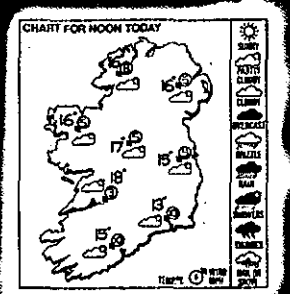
Met Éireann has had a general mandate to develop its commercial services since the mid 1980s. These activities should be underpinned by financial targets for turnover and profit and by a management accounting system. However, such a system is not in place. The accounting function is performed by the Department and is limited to the normal expenditure recording system for producing the Departmental appropriation account. The absence of a more developed accounting system means that the pricing of commercial services is based on estimates of the percentage of time spent by each division on the relevant services and an ad-hoc apportionment of overheads. Met Éireann is aware of these accounting limitations and is in the process of obtaining advice on the type of accounting system which would best serve its needs.

Some performance information has been included in Met Éireann's annual reports since 1995 but the information provides a selective picture of efficiency and effectiveness as different services have been highlighted in each year. It is intended from the 1999 report onwards to present accuracy scores on data produced by the prediction model, the aviation forecasts, temperature forecasts for Dublin and Cork and road ice predictions. It is desirable that performance reporting should be further developed to cover all services. Other aspects of performance such as cost and timeliness indicators and customer satisfaction measures should also be considered.

Met Éireann



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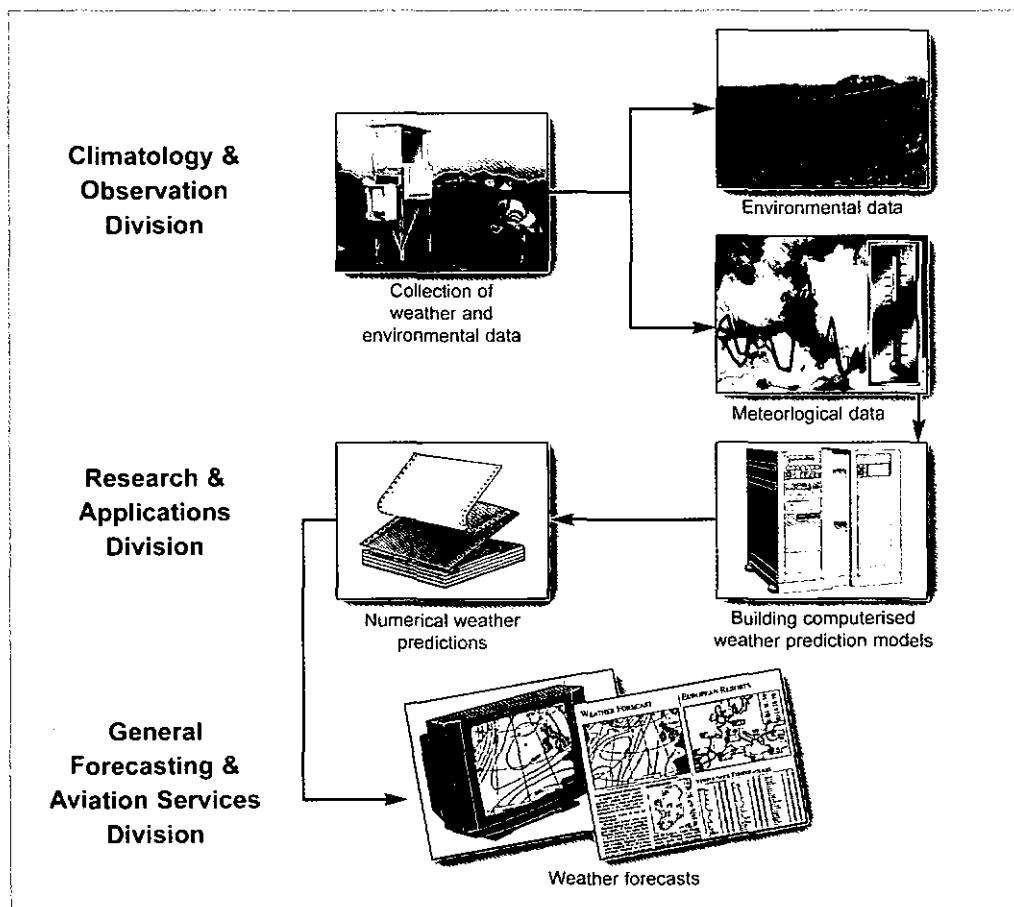
WEATHERDIAL

1 Introduction

1.1 Met Éireann is the main provider of meteorological services in Ireland. The services most familiar to the general public are the weather forecasts which are published in daily newspapers and broadcast at regular intervals on radio and television. In addition, Met Éireann provides a range of specific forecasts and tailored meteorological reports for various clients, including the aviation and navigation sectors, the farming community and some industrial companies whose production is sensitive to weather conditions. Met Éireann also maintains an extensive database of climatological information and monitors certain aspects of the natural environment. The information gathered by Met Éireann has many potential users and uses, including environmental and agricultural research, engineering and infrastructural and spatial planning.

1.2 Many of Met Éireann's outputs are interrelated, as indicated in Figure 1.1. The meteorological data gathered (which includes the most recent weather observations) is of interest to many users, including research organisations and scientists and particularly meteorological services in other countries. Data shared between meteorological offices is used, often through collaborative projects, to construct and run computerised weather prediction models, typically covering very large areas. In

Figure 1.1 Met Éireann's activities and outputs



turn, weather predictions generated by the computer models are interpreted and refined by weather forecasters as the basis for more localised weather forecasts, including forecasts for the general public.

1.3 To fulfil its various roles, Met Éireann has developed an extensive network of stations dispersed throughout the country. This comprises thirteen manned and three fully automated weather stations, 80 climatological stations and more than 600 rainfall stations. The administrative headquarters for the service is located in Dublin.

1.4 Met Éireann currently employs a staff of 226. Of these, 30 are employed in general forecasting, 57 in the civil aviation sector and 66 in the collection of meteorological data. The remainder are engaged in management, research and internal support services.

1.5 Met Éireann is a division of the Department of Public Enterprise (the Department). Its total expenditure for 1999 amounted to £10.5 million, of which just over 70% related to staff costs. Revenue amounted to £5.6 million. Most of the revenue (£4.6 million) represents income from the civil aviation sector.

1.6 While Met Éireann is legally part of the Department, it operates relatively independently on a day-to-day basis, within the terms of an administrative budget agreement. This agreement specifies the level of resources which will be made available for the provision of meteorological services. It also provides for the setting of performance targets to be achieved by Met Éireann over the period of the agreement.

Measuring Performance in Met Éireann

1.7 Met Éireann's stated objective is to meet the national requirement for high quality weather forecasts and associated services with optimum efficiency and value for money.

1.8 The level of efficiency that Met Éireann achieves in providing meteorological services is concerned with the relationship between the quality and quantity of the outputs produced and the costs involved. Improvements in the quality and range of outputs produced without proportionate increases in costs would represent an improvement in value for money. Reliable measurement and monitoring of outputs and costs are essential management tools for achieving improvements in efficiency.

1.9 The reliability and timeliness of weather forecasts and warnings are the aspects of the efficiency of Met Éireann which are of most concern for its various clients, who may make significant business decisions based on the forecasts provided. For example, ferry sailings may be cancelled if rough sea area weather is forecasted or

farmers may commence harvesting if the forecast is for good weather. In such cases, unreliable forecasts could have substantial cost or safety implications. Individuals may also make personal decisions based on weather forecasts, such as deciding whether or not to undertake a car journey or to engage in a weather-dependent sporting activity. In those situations, reliable forecasts help to reduce the risks of death or personal injury. The accuracy of weather forecasts is a key measure of their reliability and therefore of Met Éireann's performance.

Objectives and Scope of the Examination

1.10 This examination was carried out to assess how Met Éireann's performance is measured, in the context of its stated objective and the existence of the administrative budget agreement. The examination focused in particular on how the accuracy of weather forecasts can be measured and on the systems in place for managing organisational performance at Met Éireann. It concentrated primarily on the current situation but, where possible, trends over recent years are also presented.

1.11 The examination findings are presented in two chapters. Chapter 2 deals with the systems used to measure the accuracy of weather forecasts and the reliability of meteorological and environmental databases. Chapter 3 examines the output costing systems for Met Éireann services and the extent to which the Department and Met Éireann monitor its performance in delivering services.

Examination Methodology

1.12 The examination was carried out by staff in the Office of the Comptroller and Auditor General. Information was obtained from the management information system at Met Éireann, review of other documentation and from detailed discussions with the relevant personnel in the Department of Public Enterprise and in Met Éireann. The performance measurement system used by the UK Met Office was also reviewed.

2 Accuracy of Weather Forecasting

2.1 Accuracy is a key determinant of the quality of weather forecasts. While complete accuracy in forecasting is desirable, it is impossible to achieve in practice and most users of weather forecasts recognise that they are subject to a degree of imprecision. Also, since there are many elements of weather (levels of sunshine, wind, precipitation, etc.) and there can be significant variations in weather over short distances and over short time intervals, measurement of the accuracy levels achieved in forecasting is a complex process.

2.2 This chapter considers how the forecasting accuracy of each of the main weather predictions and forecasts produced by Met Éireann is (or could be) measured. It also reviews the processes used by Met Éireann to ensure that the meteorological and environmental data it produces is accurate and reliable.

2.3 The forecasts issued by Met Éireann on a regular basis fall into three main groups

- broad-ranging and detailed forecasts produced by computer-based weather prediction models
- general weather forecasts, delivered through broadcast and print media and Met Éireann's premium rate telephone service, *Weatherdial*
- specialised forecasts, focusing on particular aspects of the weather or of interest to specific groups of users, including forecasts for aviation, wave height forecasts and advance warning of icy road conditions and extreme events such as storms, snow or very heavy rain.

Weather Prediction Models

2.4 Met Éireann relies mainly on the High Resolution Limited Area Model (HIRLAM) as a basis for its weather forecasts. HIRLAM was introduced by Met Éireann in 1994 and is continuously developed on a collaborative basis by the national meteorological services of Finland, Sweden, Norway, Denmark, Holland, Iceland, Spain and Ireland. The model constructs a three dimensional picture of the atmosphere from the east coast of America to Russia and then predicts what the atmosphere should look like in the hours and days ahead. The model is in the form of a computer programme and is based on precise and fundamental principles of physics.

2.5 The predictive ability of the model is constantly monitored and on-going research is undertaken to improve its reliability. For this reason, Met Éireann has a commitment to provide the equivalent of two full-time scientific staff for its development. Accuracy is assessed by comparing HIRLAM predictions against actual observations at weather stations. The model produces predictions over a range of forecast lead times. Predictions in relation to the following weather elements are verified

- pressure
- temperature
- humidity
- wind speed and direction.

2.6 The HIRLAM predictions for all the major meteorological elements are expressed in terms of numerical values. These numerical values lend themselves to a statistical evaluation of accuracy. The accuracy of the predictions is assessed by measuring the difference between the forecast values and the observed values (the 'error' of the forecast). Of the different methods available, Met Éireann measures accuracy mainly in terms of

- the root mean square (RMS) error, which is a measure of the size of the errors
- the mean error, which indicates the extent of bias in the forecast estimates.¹

2.7 The accuracy of Met Éireann's weather predictions has improved significantly since 1994. Until then, Met Éireann relied on an earlier numerical weather prediction model called LAPEM. The scale of the improvement in prediction accuracy resulting from the change-over to HIRLAM is illustrated in Figure 2.1. This shows that the error in mean sea level predictions over the whole geographic area covered by the models decreased significantly between 1993 and 1995.² There has been relatively little further improvement in the accuracy of the predictions since the introduction of HIRLAM.

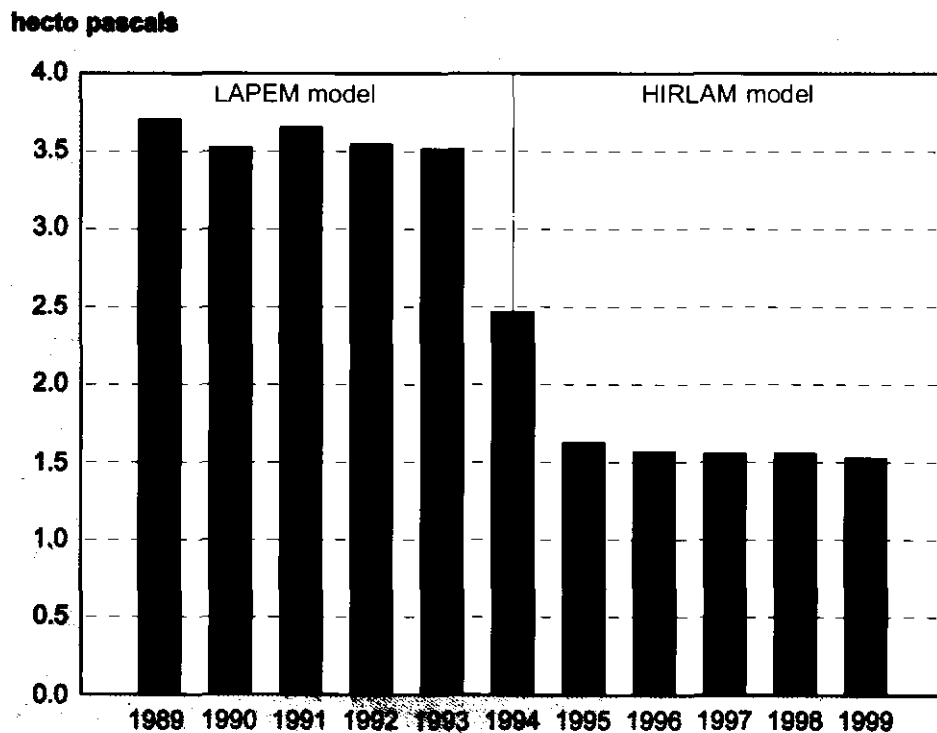
2.8 HIRLAM's ability to predict weather conditions varies from one geographic area to another. Predictions in relation to individual variables (e.g. wind speed) tend to be less accurate where the particular weather features are most changeable. For example, in 1999, surface wind speed predictions for Ireland were less accurate than the average for Europe as a whole. Because of this local variation, international comparisons of accuracy levels are difficult to interpret.

2.9 Accuracy levels in weather predictions can fluctuate from year to year due to variations in the overall level of activity of the atmosphere. For this reason, trends in accuracy levels over a number of years are more informative than year-on-year changes in accuracy levels. Furthermore, because the accuracy levels of the weather predictions produced by HIRLAM are already relatively high, there is a limit to how much further improvement can be achieved. Improvement in accuracy levels is likely to be slow and gradual, as has been the pattern in weather forecasting internationally.

¹ *Appendix A provides a more detailed explanation of the measures used to calculate the forecast error.*

² *A decrease in values of root mean square error indicates an improvement in forecast accuracy.*

Figure 2.1 Root mean square error in surface pressure predictions by LAPEM and HIRLAM numerical weather prediction models, 1989 to 1999



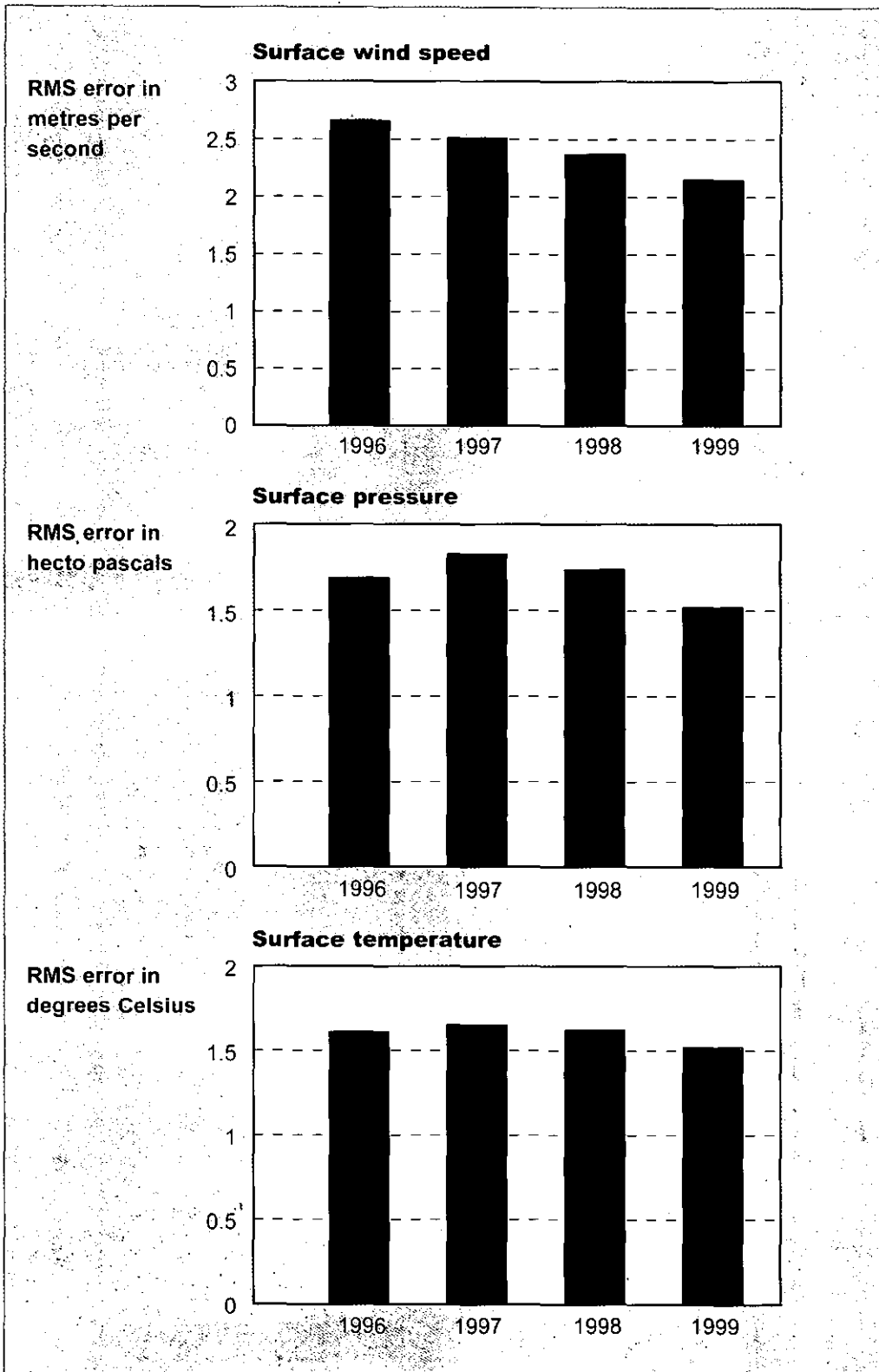
Source: Met Éireann

2.10 Figure 2.2 shows the trend in HIRLAM forecast errors for wind speed, surface pressure and surface temperature for Ireland between 1996 and 1999. The model has improved at predicting wind speed over the four years. By contrast, surface pressure predictions initially deteriorated between 1996 and 1997 and improved thereafter. Overall, there was a small improvement in the accuracy of the predictions. There was a similar small improvement in the accuracy of surface temperature predictions. It is noteworthy that the forecasts for 1999 were the most accurate ever.

2.11 Met Éireann has procedures in place for monitoring the accuracy of the model. A large variety of data sets is analysed using an array of measures. The procedure is designed to enable improvements to be made to individual aspects of the model. However, this type of analysis is too detailed for use in the measurement of organisational performance.

2.12 The challenge facing Met Éireann is to devise a measure of performance which incorporates the comprehensive statistical analysis of all data sets predicted by the model. A composite index could be used to measure the accuracy of HIRLAM's predictions, with the more important elements being given extra weight, if necessary.

Figure 2.2 Accuracy of HIRLAM predictions for Ireland, selected weather features, 1996 to 1999



Source: Met Éireann

General Weather Forecasts

2.13 Predictions from the computer model are interpreted by weather forecasters and used, together with information from other sources, to produce general weather forecasts which should be more accurate than the predictions and easier to understand. Met Éireann issues more than 120 different forecasts each day. The most prominent forecasts are those broadcast on television and radio, which reach a wide audience. The accuracy of these forecasts is difficult to verify because

- the bulk of the forecast is non-numeric
- the forecast may be interpreted subjectively
- information is often too general to extract specific and measurable elements
- the amount of detail possible is limited by the broadcasting time available.

Broadcast Weather Forecasts

2.14 The General Forecasting Division started a project in 1997 to verify the accuracy of the weather forecast which is broadcast on RTÉ Radio 1 at 7:55 a.m. each morning. This is one of the most detailed forecasts and is prepared in such a way as to provide a forecast for the whole country on roughly a province-by-province basis. An assessment of the accuracy of this service would indicate the accuracy of all forecasts that are provided on radio and television by Met Éireann.

2.15 The aim of the project was to verify forecast accuracy by comparing the forecast for each province against conditions that were actually recorded at weather stations within the relevant province. Met Éireann developed software to automate the verification procedure. However, the system has not been implemented, mainly because the way the forecast is presented is too general to extract specific and measurable features which can subsequently be verified. This is clear from the text of a sample broadcast, presented in Figure 2.3.

2.16 Verifying the accuracy of broadcast general forecasts is a problem recognised by all national meteorological offices. If forecasts are made more numeric in content to aid accuracy verification, they may be less easily understood by the general public. To get over this difficulty, a numerical record backing up each forecast could be created for verification purposes while the form of presentation of the forecast would remain the same. Introducing a verification system of this kind would represent a major change in forecasting procedures and may have significant resource implications.

Figure 2.3 Text of the weather forecast broadcast on RTÉ Radio 1 at 7:55 a.m. on Thursday 19 August 1999

There were some severe thunderstorms yesterday with some heavy downpours and some local flooding too. And while some showers are likely today as well, they shouldn't be as widespread nor as severe.

There are some pockets of mist and fog around at the moment but they should clear shortly to give a bright fresh day. Some sunny spells will develop as the day progresses, but showers are likely too. Most of them will probably appear over Munster and also over parts of South Connacht and South Leinster where a few will be heavy with the odd thundery one. Any showers elsewhere will be scattered and mostly light.

Top temperatures will range 16 to 19 degrees Celsius in a moderate to fresh north to northwesterly breeze.

The outlook is for another bright fresh day tomorrow Friday. Cloud will vary in a moderate, locally fresh north to northwest breeze, but all areas will have some sunny spells though some scattered showers are likely too. Top temperatures 15 to 18 degrees and feeling rather cool and autumnal in the breeze.

A good deal of dry and rather fresh weather is expected over most of the country, over the rest of the weekend and on Monday. There is likely to be a good deal of cloud generally, but some sunny spells should develop each day with just a few light passing showers on the east and northeast coasts. Also, at this stage, it looks as if it will be windy, misty and overcast much of the time along the southwest and south coasts, with some showery rain pushing in from the sea at times.

Top temperatures will be in the range 16 to 19 degrees Celsius but, with a fresh and gusty northeast to easterly wind, it will feel quite cool at times, especially in the duller areas and on the exposed coasts.

The nights will be cool this weekend, with lowest temperatures in the range 6 to 9 degrees, and a few mist or fog patches are possible also.

Recap on today's weather again: a bright fresh day with sunny spells. Some showers also, most frequent over the South and Southwest, where there is a risk of thunder. Top temperatures 16 to 19 degrees Celsius.

Source: Met Éireann

The Weatherdial Forecast

2.17 *Weatherdial* is a weather forecast service which is provided through a premium rate telephone service offered by Met Éireann. The services are available by telephone or fax. Forecasts are available for each of the four provinces, the greater Dublin area, Irish coastal waters and the Irish Sea. These forecasts are more detailed than the general weather forecasts available on radio and television.

2.18 For the purpose of this examination, the accuracy of maximum and minimum temperatures forecast daily for Munster, Ulster and the Greater Dublin Area for the three-month period May to July 1999 was determined. The results of the assessment are summarised in Table 2.1. Since the assessment was based on temperatures extracted from free-format text forecasts and since the three-month period covered

Table 2.1 Accuracy of Weatherdial forecasts of maximum and minimum temperatures, selected regions, 1 May to 31 July 1999

Forecast	Accuracy level achieved
Maximum temperature ^a	50% of forecasts were within ± 1 degree of actual
	79% of forecasts were within ± 2 degrees of actual
Minimum temperature ^a	47% of forecasts were within ± 1 degree of actual
	71% of forecasts were within ± 2 degrees of actual

Note: a The forecast often includes a range of temperatures. (For example, on 5 May 1999, the forecast for Munster was that minimum temperatures would be between 6 and 10 degrees.) The temperatures recorded for that day ranged between 10 and 12 degrees. The average forecast temperatures were therefore compared with average observed temperatures.

Source: Analysis by Office of the Comptroller and Auditor General

is rather short for a verification exercise, the results must be treated with a certain degree of caution.

2.19 Almost half the temperature forecasts were within one degree of the temperature observed. Almost three-quarters of the forecasts were within two degrees of the temperature observed.

2.20 The effort and skills deployed in producing forecasts should make a significant contribution to the accuracy levels achieved. One way of assessing this contribution is to compare the forecast accuracy levels with the accuracy of forecasts based simply on the persistence of existing weather conditions. For example, a persistence forecast of temperature would assume that the expected temperature in the forecast period would be the same as that observed during the previous 24 hours. Comparing the RMS error scores for the actual forecasts and persistence forecasts indicates that the forecasters' skills significantly improve the level of accuracy.

Specialised Forecasts

2.21 Met Éireann produces a range of forecasts and weather warning services which are designed to meet the needs of specific users groups or which concentrate on particular weather-related conditions. These include services required for aviation and navigation and warnings about extreme or unusual weather events, such as icy road conditions and storms, which may cause particular hazards.

Bord Gáis

2.22 Met Éireann carried out a detailed verification exercise for temperature forecasts issued under contract to Bord Gáis at 6 a.m. each day over the period 1994-

1999. The forecasts include expected maximum and minimum temperatures for Cork and Dublin during the current day and the following two days. As may be expected, this showed that forecast accuracy declines the further ahead forecasts are prepared. The accuracy levels achieved were similar to those relating to the *Weatherdial* forecasts for the period May-July 1999. The analysis showed an improving trend in the quality of the forecasts over the six-year period. Also, the forecasts were an improvement on the accuracy levels achievable through temperature forecasting based on persistence, or on the expected average temperature for the time of the year.³ Met Éireann calculated that looking at the whole series of forecasts, the Dublin forecasts were 57% more skilful than climatology while the Cork forecasts were 46% more skilful.

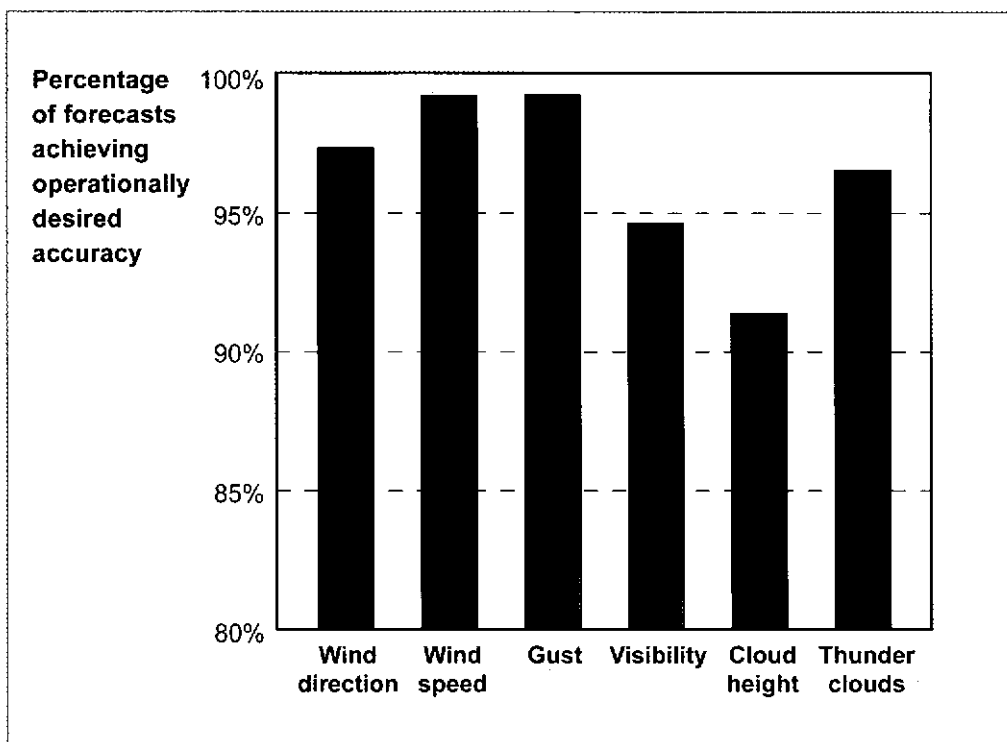
Aviation Forecasts

2.23 Under the 1944 Chicago Convention on International Civil Aviation, the State is obliged to provide certain services to aviation. Met Éireann is charged with satisfying the meteorological information requirements of the convention including the provision of 'Terminal Aerodrome Forecast' (TAF) reports. These reports contain all the meteorological information that a pilot requires. The information is presented in alphanumeric code used by pilots worldwide. The content is specified by the International Civil Aviation Organisation (ICAO). The main weather elements included in the forecast are wind direction and speed, gust, visibility, height of cloud cover and the presence of active thunder clouds. The ICAO specifies, for each weather element, the level of accuracy that is desirable. There is no standard method of scoring the accuracy of a TAF. Various national meteorological offices use different methods. For this reason, international comparisons are difficult.

2.24 In assessing the accuracy of the various elements of the TAF reports it provides, Met Éireann awards a score of one to a forecast which meets the ICAO 'operationally desired accuracy' and a score of zero to one that does not. Figure 2.4 shows Met Éireann's success at meeting the desired level of accuracy between January and December 1998, for the six main elements of the forecast.

2.25 Met Éireann (at Shannon) is also a designated Area Meteorological Watch Office and is required to maintain a constant observation of weather conditions in all Irish air space. It must report to aviators any significant weather conditions (referred to as SIGMETS) which may affect air safety. These may be observed by pilots who come in contact with the significant weather condition, or forecast by Met Éireann. The accuracy of these warnings is not formally assessed. The main difficulty in assessing the accuracy of forecasted SIGMETS is the lack of technology to verify if conditions subsequently prevailed. There are some moves to set up a global turbulence database which may assist with accuracy verification.

³ This is referred to as a climatology-based forecast.

Figure 2.4 Accuracy of terminal aerodrome forecasts, 1998

Source: Met Éireann

2.26 The Aviation Services Division of Met Éireann also provides an aerodrome warning service. Warnings are issued if weather conditions are within certain specified parameters, which could affect the safety of an aircraft if the pilot was unaware of them and failed to take appropriate action. The conditions could also affect the operation of certain aerodrome services. The accuracy of these warnings is not currently assessed.

Wave Height Forecasts

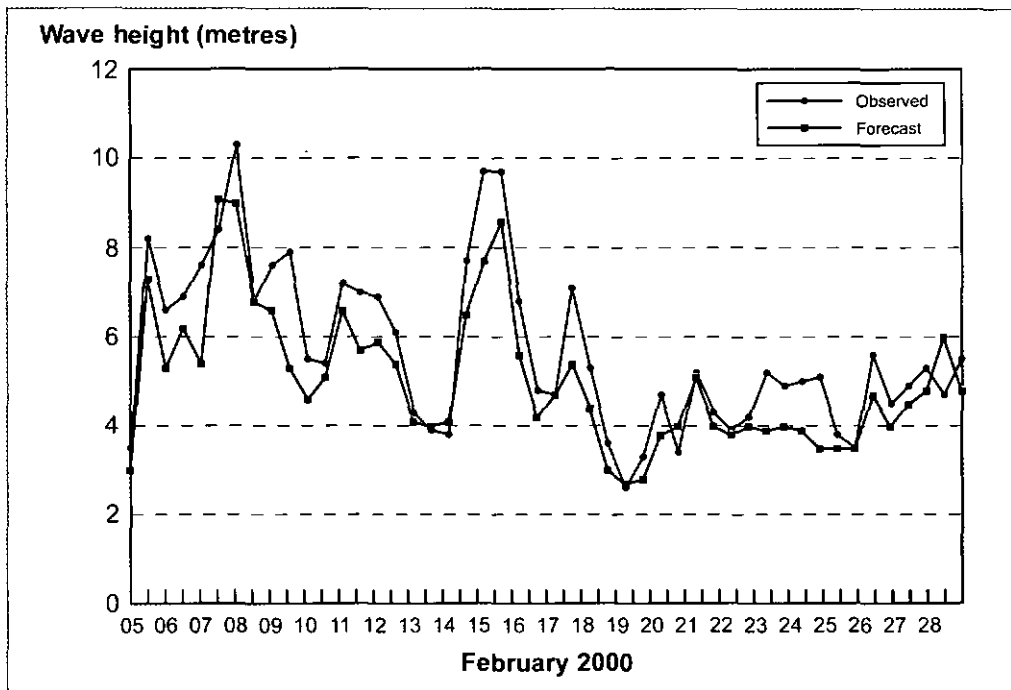
2.27 A number of forecast services for users of Irish coastal waters have been developed by Met Éireann based on wave height predictions which are produced from a numerical weather prediction model, referred to as the Wave Model or WAM. These include general sea-area forecasts for broadcast on national radio and on coastal radio and forecasts which are tailor-made to meet specific customer needs e.g. ferry companies and oil rigs.⁴

⁴ Information is also supplied directly to clients through the Weatherdial fax service. Information available on this service includes

- 24 hour forecast of height and period of waves (presented graphically)
- 24 hour forecast of mean sea level pressure and 10-metre wind (presented graphically)
- 2 to 5-day planner showing 10 metre wind, sea direction, swell direction, sea height and swell height.

Model predictions are also supplied to a private company in the marine sector in electronic format.

Figure 2.5 Forecast and observed wave height at buoy number 62081, at midnight and midday, 5-28 February 2000



Source: Met Éireann

2.28 The accuracy of the WAM predictions is monitored by Met Éireann. The accuracy verification procedure is limited by the number of observation buoys located around the Irish coastline. Currently, there are six buoys (owned by the UK Met Office) continually recording actual conditions. Therefore, only forecasts for these locations can be verified. There are plans to place a new buoy network around Ireland which should improve both the forecasts and the ability to verify wave height predictions.

2.29 At present, Met Éireann regularly compares observations at each of the six buoys against wave height forecasts produced by the WAM model. Extensive data is generated which is used to improve the model's predictive ability. Figure 2.5 compares predicted and observed wave heights for February 2000 at the buoy moored off the south west coast. This suggests that the forecasts were reasonably accurate. Estimated accuracy levels are different when forecasts are verified against observations at other buoys because different buoys measure to different levels of accuracy.

2.30 For the purpose of this examination, wave forecasts for the period May to November 1999 were compared with the observed wave heights at each of the six buoys. The analysis indicated that, on average, the forecasts of wave heights were reasonably accurate but that the model has a slight tendency to under estimate the height of waves.

Road Ice Warnings

2.31 For many years, Met Éireann has provided support to local authorities in their efforts to keep major roads ice free. In the past, information on potential icy weather conditions was disseminated in a number of forms. Some local authorities received information from a forecaster in terms of a four-category 'ice index'. The categories ranged from 'ice very unlikely' to 'ice likely'. Others subscribed to a telephone consultancy service whereby they could get a complete meteorological briefing at any time. Other authorities arranged for detailed forecasts to be faxed to them routinely during winter.

2.32 In 1995, in conjunction with the National Roads Authority, a new Road Ice Prediction System was put into place. This involved installing automatic roadside weather stations at various locations. About 1,500 kilometres of road was thermally mapped and a new computer model with the supporting infrastructure was installed.⁵

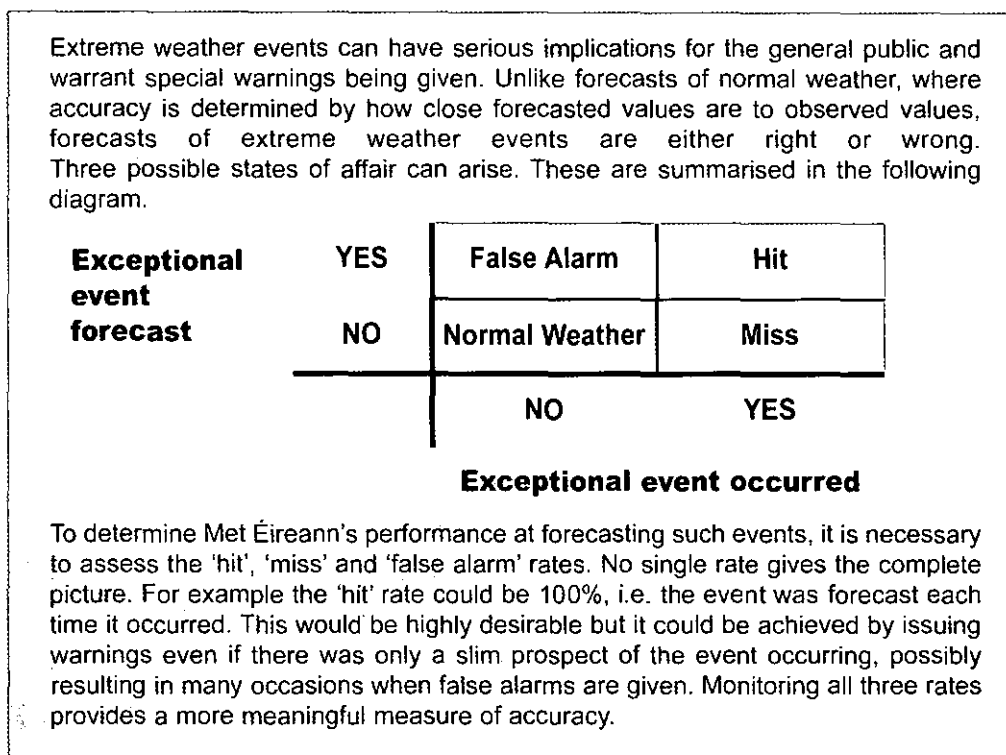
2.33 The computer model has a number of limitations and requires significant forecaster input. A forecast is produced, both in text and graphical form, showing the predicted variations of the road surface temperature and whether or not ice is expected.

2.34 A range of outcomes is possible in relation to ice warnings (see Figure 2.6). Ideally, each time icy conditions occurs, an ice warning will have been issued (i.e. a 'hit'). Local authorities can then take appropriate preventive measures such as salting or gritting of roads. However, the warning system can fail in two ways.

- The system may fail to anticipate ice which subsequently occurs (a 'miss'). This can have serious implications for road users and may also result in higher costs to local authorities since road treatment in reaction to icy conditions is usually more expensive than preventive treatment.
- Ice warnings may be given, triggering preventive road treatment, but icy conditions may not subsequently occur (a 'false alarm'). This has relatively few implications for road users but increases costs for local authorities and can result in unnecessary environmental damage.

2.35 Met Éireann is developing a forecast accuracy verification scheme based on the analysis of hit, miss and false alarm rates. Rates are only available for winter 1998/1999. Table 2.2 summarises the data available for forecasting road ice for this period.

⁵ *The computer model takes into account the fixed characteristics for a particular site, the starting conditions, the forecast meteorological factors and the physics of the road (heat conduction from below and radiation from the surface) to produce a road state for the guidance of the road maintenance personnel.*

Figure 2.6 Forecasting exceptional weather events

2.36 During the period examined, ice was forecast on 71% of the occasions it occurred. The forecast accuracy for some stations was considerably lower. At onestation, more than half the incidents of icy conditions were not predicted. On the other hand, on one day in six when frost did not occur, a false alarm warning was issued.

Table 2.2 Accuracy of road ice predictions, November 1998 to April 1999

Accuracy measure	Most accurate station	Least accurate station	Average for all stations^a
Hit rate (ice forecast and occurred)	100%	46%	71%
Miss rate (ice occurred but was not forecast)	0%	54%	29%
False alarm rate (ice forecast but did not occur)	0%	34%	16%

Note: ^a Thirty roadside automatic weather stations were included in the verification calculations.
Source: Met Éireann

Weather Warnings and Severe Weather Alerts

2.37 An important part of Met Éireann's public service role is the issuance of weather warnings to specific interested parties and to the public in general. Two types of warnings are issued to the general public: weather warnings and severe weather alerts. Both apply only to land areas of Ireland and may relate to any one of five weather conditions: wind, rain, snow, fog and frost. For each weather condition, a threshold criterion is specified (see Table 2.3). If conditions are expected to be more extreme than the threshold level, the weather is deemed exceptional and an appropriate warning or alert is issued.

2.38 Met Éireann does not have a system in place to assess the accuracy of its weather warnings or severe weather alerts. Consequently the hit, miss and false alarm rates for weather warnings are not calculated.

2.39 For the purposes of this examination, weather warnings issued between November 1998 and January 1999 were reviewed. The sample comprised all fog, wind, snow and rainfall warnings issued during the period. Of the 62 occasions when extreme weather occurred, warnings had been issued for 57 (a hit rate of 92%); no warning was issued on five occasions (a miss rate of 8%). There were only four false alarm weather warnings or alerts over the period.

2.40 The target minimum time for the issue of weather warnings is 24 hours in advance and warnings may be given up to 48 hours in advance where forecast confidence is high. The target for severe weather alerts is 12 hours. Warnings and

Table 2.3 Threshold criteria which warrant a weather warning or severe weather alert

Forecast element	Weather warning criteria	Severe weather alert criteria
Wind	Gusts > 60 knots	Gusts > 70 knots
Rain	> 50mm in 24 hours	> 30 mm in 6 hours > 45 mm in 12 hours > 65 mm in 24 hours
Snow	Any snowfall below 250m above sea level	Snow showers likely to cause accumulations of more than 2.5cm below 100m
Fog	Widespread and dense	–
Frost	Widespread road ice	–

Source: Met Éireann

alerts are given only when forecasters feel there is at least a 50% chance of the event occurring.

2.41 Weather warnings are issued later than the target advance notice periods if the perceived likelihood of occurrence increases. Because of the limitations on the data available, it was not possible to examine the lead time between the issue of the warning and the commencement of the phenomenon in question. Consequently, a 'hit' was counted whenever a warning was issued, regardless of the amount of lead time given. In practice, the amount of advance warning of extreme events is important so that preventive action can be taken by users of the forecast. In a correctly designed verification scheme, such as Met Éireann intends to put in place, a 'hit' should be counted only when the lead time exceeds a certain target which will depend on the weather element in question.

Non-Forecasting Services

2.42 Met Éireann is involved in many non-forecasting activities. These centre around the collection, analysis and archiving of a variety of data sets, including an archive of past weather observations, ozone measurements and chemical analysis of air and rain. The data produced may be further processed by Met Éireann, transformed into a service or supplied to other organisations which require it for research and other purposes. Appendix B describes the range of activities undertaken and indicates the main applications for the data collected.

2.43 In the majority of cases, the output of these non-forecasting activities is the data itself. Met Éireann's ability to accurately record the various data elements is a primary measure of its performance in these activities. However, as the data is recorded for a unique event at a specific time and place and there is usually only one recording of the event, it is difficult to verify the accuracy of the data directly. As a proxy, confidence in the data's accuracy may be established by assessing the quality of the collection and recording systems.

2.44 The collection of data is complicated by two factors. Firstly, there are three different types of weather stations, synoptic, climate and rainfall. Synoptic stations are the only stations manned by Met Éireann personnel. Secondly, there are many different data sets collected. The equipment, level of training, documentation, and quality assurance procedures associated with each data set varies greatly.

2.45 An adequate collection system requires the following quality controls

- standards for the specification and siting of all equipment
- clearly documented operating procedures
- adequate training

- schemes for the calibration and maintenance of equipment
- quality inspection procedures.

2.46 Data, once collected, must be accurately entered into Met Éireann's database. This may occur either automatically or manually. Where data is automatically entered (e.g. automatic weather stations), accuracy is wholly dependent on the collection system. However, the accuracy of manually entered data may be further compromised during the entry process. This risk is controlled by entering the data twice. Any anomalies are checked by a software programme which identifies any entry mistakes which are then corrected by the person responsible for data entry.

2.47 All data, whether inputted manually or automatically, is subjected to a number of automated checks. These ensure the readings collected are theoretically possible, reasonable and consistent. Information is not currently available on the percentage of each data set discarded during these quality checks. Information of this nature would assist in highlighting areas where data collection is weak. Furthermore improvements in collection systems would be indicated by decreases in the percentage of data rejected.

2.48 The data collection and recording systems, for all the major data sets, were reviewed during the course of this examination and no significant defects were apparent.

2.49 Confidence in the quality of the data is reinforced by the continued acceptance of it by world research data centres, like the Voeikov Geophysical Observatory in St. Petersburg (data on solar radiation), Thessoloniki in Greece (data on ozone) or the International Seismology Data Centre in Newbury (data on seismic waves). The European Centre for Medium-Range Weather Forecasts continuously monitors upper-air reports, by agreement with the world Meteorological Organization. Furthermore, many respected research programmes continually use data provided by Met Éireann, for example the European Stratospheric Experiment 'THESOE' (using upper air measurements).

2.50 Other assurances of the high quality of certain non-forecasting data sets produced by Met Éireann are provided by independent organisations. The chemical analysis of air and rain samples by Met Éireann is subjected to audits by the Environmental Protection Agency's national quality assurance manager to ensure data quality objectives are met for both sampling and laboratory control. The Norwegian Institute for Air Research also verifies the accuracy of the data by analysing samples supplied by Met Éireann. Geomagnetic data recorded by Met Éireann are submitted on a monthly basis to the International Service of Geomagnetic Indices. The German Geographical Institute requests spot values for particular dates for quality control purposes.

Conclusions

2.51 The main conclusions are

- It is technically possible to measure the accuracy of many of Met Éireann's weather forecasting systems. In some areas, where computerised systems are producing forecasts on an automatic basis, Met Éireann is already assessing accuracy levels routinely.
- For most areas of the service it provides, including the broadcast forecasts and weather warning systems which are of most interest to the general public, accuracy levels are currently not assessed.
- The quality control systems in place in Met Éireann for the collection and maintenance of climatological information give reasonable assurance that the data produced is accurate and reliable. This is confirmed by periodic quality assessment by external agencies which rely on data produced by Met Éireann.

3 Managing the Performance of Met Éireann

3.1 The Strategic Management Initiative (SMI) which commenced in 1994 has shifted the emphasis in public sector management from the traditional focus on inputs and the availability of resources to a system which concentrates more on the performance of public sector bodies in terms of the outputs they produce and the impacts they achieve. The change in emphasis prompts questions about the suitability of traditional organisational, management and reporting arrangements for ensuring that the best possible performance is achieved by public bodies.

3.2 This chapter describes the current organisation and reporting arrangements for Met Éireann within the Department. It then examines the process for setting strategic and operational objectives and targets for Met Éireann. The extent of the development of performance monitoring and reporting arrangements is also examined.

The Relationship between Met Éireann and the Department

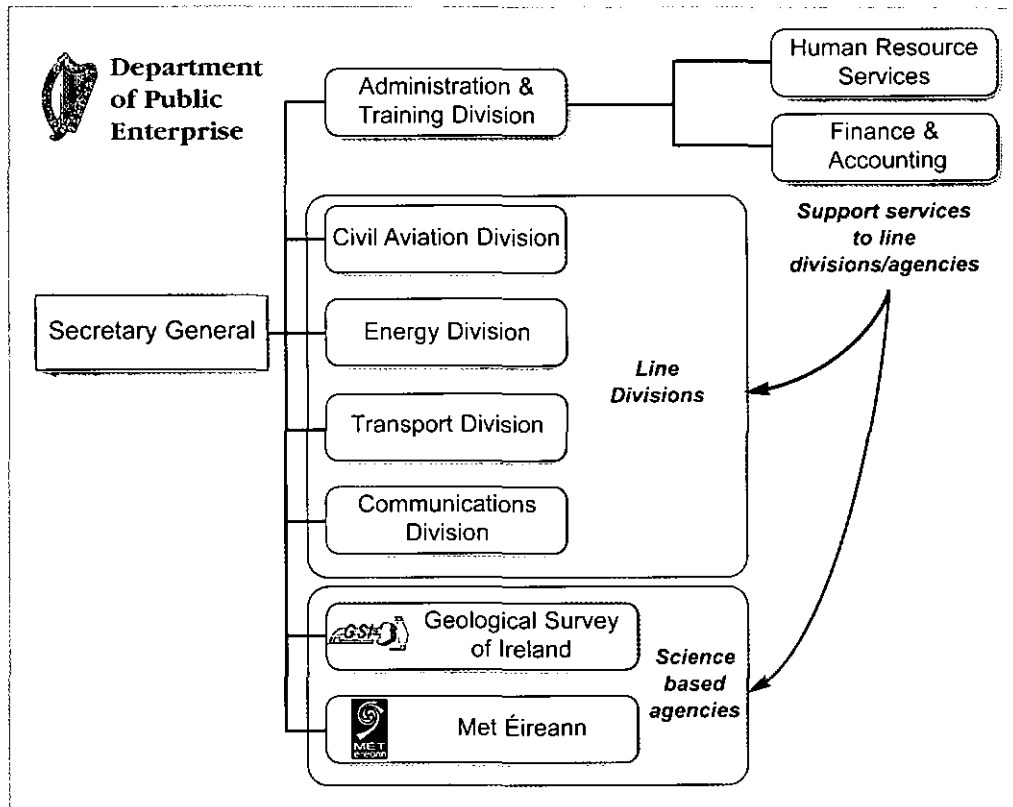
3.3 In legal terms, Met Éireann is a division of the Department. Met Éireann's staff are civil servants and the Division is bound by the general human resources and public financial procedures and regulations for the civil service. However, within the Department, a distinction is drawn between the 'line' divisions (which deal with policy for a range of public enterprise areas and the oversight of many semi-state bodies), and the two 'science-based agencies', Met Éireann and the Geological Survey of Ireland (see Figure 3.1). Human resources, budgeting, finance and accounting functions for Met Éireann are shared with the Department's central administration division.

3.4 The Director of Met Éireann reports directly to the Secretary General of the Department. They meet on a regular basis to discuss operational matters relating to Met Éireann but there is no formal performance reporting mechanism between them, such as a periodic written report on outcomes in relation to an agreed set of performance measures.

Defining Objectives and Setting Targets

3.5 The Public Service Management Act, 1997, requires departments to draw up statements of their strategic objectives and the setting of related operational targets. In order to set targets, there should be agreement on how performance is to be measured in each of the areas relevant to the agencies' objectives. In practice, the definition of objectives, the selection of performance measures and the setting of

Figure 3.1 Organisation of the Department of Public Enterprise



targets is often performed simultaneously. The process is also refined as successive planning cycles are undertaken.

3.6 The need for Met Éireann to define its objectives and to set operating targets has been addressed under a range of initiatives since 1995. These include a formal administrative budget agreement between Met Éireann and the Department covering the years 1995/1996, the publication of a customer service plan in 1997 and statements of strategy published in 1996 and 1999. A business plan for Met Éireann, covering the period 1999-2001, was issued in February 2000.

Strategy Statement

3.7 The 1999 statement of strategy, on which the business plan is based, identifies Met Éireann's mission statement and six high-level objectives to be achieved over the years 1999 to 2001 (see Figure 3.2).

3.8 In the business plan, the high level objectives are linked to specific projects, activities and outputs, and will be further elaborated in divisional plans. The administrative budget agreement between Met Éireann and the Department of Public Enterprise has provision for the setting of lists of 'service outputs' but these are at an

Figure 3.2 Met Éireann's mission statement and high level objectives, 1999 to 2001

Mission statement

Our mission is to meet the national requirement for high-quality weather forecasts and associated services, with optimum efficiency and value for money

High-level objectives

- to provide a comprehensive range of high-quality meteorological services to the Irish people and to all sectors of the Irish economy
- to ensure the long-term sustainability of meteorological services in Ireland through adequate infrastructural investment
- to help reduce public Exchequer costs (of Met Éireann's service) by engaging in profitable commercial activities, while maintaining a constructive relationship with the private sector and always conforming fully with competition law
- to obtain optimum benefit from developments in meteorological science by prudent utilisation of modern technology, by a well focused research programme and by collaboration with relevant bodies
- to utilise fully the talents and potential of all staff by pursuing a humane and effective human resource policy, and by according high priority to training, communications and participation
- to examine the current clerical, technical and professional grade structures with a view to matching individual skills to work requirements, and to promote overall staffing flexibility

Source: *Met Éireann Strategy Statement, March 1999*

early stage of development. It is important that a distinction is made between what Met Éireann is trying to achieve - its outputs and impacts - and how it intends to achieve them. Reporting on performance should focus more on the achievement of outputs and impacts than on the nature and scale of the activities undertaken.

3.9 Examination of the full series of Met Éireann's strategic planning documents produced in recent years reveals recurrent references to the need to provide high quality meteorological services and accurate weather forecasts to meet national requirements in an efficient and economical way. Met Éireann is also required by the Department to increase its commercial revenue, but the practical implications of this have not been articulated. Any performance agreement between the Department and Met Éireann should therefore define objectives and set targets in relation to such issues as

- What range of outputs should Met Éireann provide over the medium term, and how should changes to the range of outputs be decided?
- What volume of service should be provided for each output?

- What level of accuracy of weather forecasts should be achieved?
- Within what cost or efficiency constraints should the agreed outputs be provided?
- Which of the outputs should be provided on a fully commercial basis and which should be provided as publicly-funded services (free of charge or on a subsidised fee basis)?

Defining the Range of Outputs

3.10 The needs of client groups should be reflected in defining the range of outputs to be provided by Met Éireann. In weather forecasting, the range, timeliness and presentation (language and format) of the forecasts should reflect the context in which the client groups use the forecasts and their level of familiarity with meteorological terminology. For example, ferries and fishing fleets may require detailed sea-area forecasts 24, 36 and 48 hours in advance. By contrast, the airlines and aviation sectors require forecasts over much shorter time frames, a range of altitudes and possibly over longer distances. In these cases, the users are usually familiar with meteorological terms and understand the degree of precision attaching to forecast details. The requirements of members of the general public are much different. Typically, they require reliable forecasts to be delivered in plain language and would be concerned about major forecast failures. They are usually less concerned about the precise degree of accuracy of general forecasts or the amount of advance notice given for forecasts of normal weather conditions.

3.11 The forecasting requirements for aviation are fixed under international agreements, which oblige the contracting states to ensure that agreed outputs are provided. In this case, the level of service to be provided by Met Éireann is clear. The requirements of clients who have contracts with Met Éireann for the provision of specific services are also relatively clear.

3.12 Outputs and requirements, in terms of timeliness of forecasts and methods of presentation for other client groups, including the general public, are less clearly defined. Representatives of these groups should be involved in defining the range of outputs to be provided. This could be done periodically by means of targeted surveys and consultations with client group representatives. Met Éireann has carried out a limited amount of research of this kind in the past. For example, a small scale survey of farmers' requirements for weather forecasts, carried out in 1998, is described in Case Study 1.

3.13 There is a limit to the range of outputs which Met Éireann can provide, given the available resources. Consequently, prioritisation of client demands is required. The range of outputs currently provided contains an implicit prioritisation of demands. The agency's strategy statement should set out clearly the current operational priorities.

Case study 1

Survey of farmers requirements for weather forecasts

A general survey of farmers carried out by the Agri Awareness Trust in 1998 included three questions about weather forecast requirements drawn up by Met Éireann. Respondents were asked

- how often they needed to know the latest weather forecast for their work on the farm (several times a day; daily; a few days each week; occasionally)
- what weather forecast period is most important to them (less than 12 hours ahead; 12 to 24 hours ahead; 2 to 3 days ahead; 4 to 7 days ahead)
- what is the most suitable way for them to get their weather forecast (television; national radio; local radio; *Weatherdial* voice; *Weatherdial* fax; Internet; newspaper).

The results of the survey, analysed by type of farm, are presented in Appendix C

Commercial Operations

3.14 Met Éireann earned revenues of around £5.6 million in 1999. Most of this (£4.6 million) consisted of fees for aviation services. The balance (around £1.0 million) was in respect of fees for the provision of forecasts to other clients, including fees earned through the *Weatherdial* service. Revenue represents 53% of the cost of the organisation.

3.15 Met Éireann has had a general mandate since the mid-1980s to increase commercial revenue but a clearer definition of the extent to which Met Éireann is to operate commercially is required. This definition should provide some means of distinguishing between outputs which are supplied as 'public goods' (free of charge or charged for at a subsidised rate) and outputs which are to be supplied on the basis of full cost recovery or at a profit. Once this definition is in place, relevant financial targets should also be set.

Aviation Forecast Fees

3.16 The provision of services to aviation is a non-profit making activity for Met Éireann. Under the International Civil Aviation Organisation rules, it is permitted to recover the full cost of providing the prescribed services from commercial airlines. Met Éireann estimates the cost of providing the services at the beginning of each year and notifies the Irish Aviation Authority (IAA) accordingly. The IAA arranges for the collection of the funds through the levying of en-route charges on commercial aircraft overflying Irish territory.⁷

3.17 Met Éireann does not have a management accounting system so there is no mechanism for directly determining the cost of each service to aviation. The overall

⁷ The en-route charges also cover the IAA's own costs of providing air traffic control services.

cost is calculated by estimating the percentage of each division/unit's activity which is devoted to aviation.

Revenues from Non-Aviation Commercial Services

3.18 In the context of the 1995/1996 administrative budget agreement, a mechanism was introduced to give Met Éireann an incentive to increase the amount of revenue earned. It was agreed that if Met Éireann increased revenues from non-aviation commercial clients above a target level of £0.5 million, half of the extra revenue above the target could be spent on the provision of the service e.g. for extra investment in technology.

3.19 As a mechanism to encourage a more commercial approach to its activities by Met Éireann, the revenue-sharing formula is a crude instrument. It ignores the costs involved in initiatives designed to generate additional revenue. Met Éireann staff perceive that the additional revenue the organisation might retain from certain commercial initiatives would not be sufficient to cover the incremental costs of providing the services. It would be more meaningful to frame incentives in terms of sharing profits from any new commercial initiatives.

3.20 Staff shortages are cited by Met Éireann as a further restraint on commercial activity. It argues that budgetary constraints and civil service recruitment policies prevent it from recruiting additional staff. Even when new staff posts are sanctioned, the civil service recruitment process causes significant delays in appointing staff. The option of separating Met Éireann formally from the Department by giving it a distinct legal identity would give management greater control over staffing. This has been considered by the Department and Met Éireann, but no firm decision has been taken.

Pricing Decisions

3.21 Purchasers of weather forecast services have a choice of suppliers. For example, Irish television and radio stations can buy information for use in weather forecasts either from Met Éireann or from forecasting agencies outside Ireland, including the Met Office in the UK and a number of private sector suppliers. Clients of Met Éireann who have contracts for specific services (such as Bord Gáis or the National Roads Authority) could also use these other suppliers. Users of premium rate telephone forecasts currently have a choice between Met Éireann and another Irish private sector operator. In making a choice of supplier of forecasts, purchasers typically make a decision based on the quality of the service offered (which is determined by the accuracy, timeliness and format of the forecast) and the cost of the service.

3.22 Met Éireann currently has a range of fixed prices which relate to the standard services it provides. For example, it has a telephone consultancy service where a

client can have direct access to a forecaster on a 24-hour, year-round basis. Prepaid calls are available in blocks of ten, with prices ranging from £120 for one block to £630 for seven blocks.

3.23 The price of services tailored to meet the needs of individual clients (for example, forecasts or weather warnings for weather-sensitive industrial processes) is partly related to the amount of development time required to set the system up and to the amount of routine operational work required each time the service is provided. In arriving at a price, the other major considerations are what Met Éireann believes the client would be willing to pay (i.e. a market-based approach) and what is deemed to represent a fair price.⁶

3.24 A market-based approach to pricing requires routine market research to inform management of the probable demand for services at the different price ranges and also to provide information on the prices charged by comparable service providers. As the market is continually changing, this type of market research is required at regular intervals. No such research is carried out by Met Éireann and it is unclear how they currently assess what price the market is willing to pay for the various services which are provided. This research would have to be justified on cost/benefit grounds.

3.25 The 1999-2001 business plan includes a commitment to conduct cost analysis and market research in 2000 and to restructure the price list on this basis.

3.26 There is a lack of clarity in Met Éireann surrounding what constitutes a public service – to be provided free or at a subsidised price – and what may be considered commercial – and consequently be priced at the market rate. Met Éireann points out in its 1999 strategy statement that it is undermined operationally by the ‘lack of an authoritative statement as to its public service obligations.’ Some clarification of this issue is desirable. The consequences of not clarifying the situation are that revenue may be lost to the Exchequer because of inappropriate pricing or that Met Éireann’s clients may be charged for services that should be considered to be part of its public service role.

Measuring Performance

3.27 Met Éireann’s obligations under the SMI and the Department’s requirement that it should increase commercial revenue require it, if possible, to have systems in place which allow it to measure its performance in terms of outputs and costs. Although Met Éireann is a data-based organisation, its systems are not designed to provide it with information on outputs and costs which would allow it to report on the efficiency of its operations.

⁶ *In practice, products are priced on the basis of cost of production plus what is regarded as a reasonable margin of profit.*

A System to Measure Outputs

3.28 Outputs need to be measured from two perspectives.

- the quantity of outputs, in terms of the volume of services provided and
- the quality of these services.

3.29 Measuring quantity involves setting targets for the volume of each particular service category and then counting the number actually supplied. The measuring of quality is more problematic. The key determinant of quality is forecast accuracy, which is amenable to measurement as discussed in Chapter 2. However, choices are required to be made about which measures should be used and how they are defined. An accuracy measurement system should meet the criteria outlined in Figure 3.3. Furthermore, all measures should be agreed in advance with all concerned parties.

3.30 The existing accuracy measurement system at Met Éireann does not meet the criteria outlined in Figure 3.3 in a number of ways.

- Accuracy is not measured for all its major services. Table 3.1 summarises the extent of accuracy verification at present.
- For services where accuracy is assessed (output from HIRLAM, aviation forecasting, forecasts for the energy sector and wave forecasting), the measures applied are not considered representative of the accuracy levels achieved across all forecast elements.
- With regard to the accuracy verification of HIRLAM's and WAM's predictions, the amount of data available and its level of detail obscure the overall picture of performance.
- There are no accuracy targets for any of the forecasting services.

Figure 3.3 Key characteristics of a forecast accuracy measurement system

Comprehensive	The accuracy of all major services should be measured.
Concise	The information provided should centre around a small number of the most significant performance factors. Otherwise there may be too much information to absorb or act upon.
Valid	The measures selected should represent the aspect of accuracy to which they relate.
Consistent	Definitions of indicators should be consistent over time.
Target setting	Target values should be specified.

Table 3.1 Progress towards accuracy verification of the major forecasting services

Service	Status of accuracy verification scheme
General forecasts	No accuracy verification scheme for broadcasts
Aviation forecasting (three main services)	<ul style="list-style-type: none"> ● Accuracy of one service continually assessed ● No accuracy verification scheme for two services
Weather warnings	No accuracy verification scheme
Road Ice predictions	Accuracy verification scheme under development
HIRLAM	Accuracy of model assessed
Wave forecasting (WAM)	Accuracy of model assessed

3.31 Met Éireann is a data-rich organisation and has the capability to dramatically improve its accuracy measurement system. It is making progress in developing such a system. A key step required to prevent information overload for users of the measurement system is to reduce the number of indicators to manageable proportions. There are two main strategies for doing this.

- Select measures of accuracy for one or two forecast elements for each service which can be regarded as representative of the accuracy levels achieved across all the forecast elements
- Combine all the main forecast elements into an index value (which may be weighted to reflect the relative importance of individual forecast elements, if necessary).

3.32 The UK Met Office currently operates an index-based performance measurement system. It has a single index value for each of the main numerical weather prediction models, which incorporates measures of the accuracy of a number of weather features predicted by the model. Another index incorporates the accuracy of the main forecasting services. Each index has associated with it a document which explains in detail how each element of the index is measured and is subsequently incorporated into the index. The basis of measurement, assumptions and method of reporting are all captured in the documents which help to ensure accuracy is measured consistently from one year to the next.

A System to Measure Costs

3.33 Met Éireann has no formal system to generate information on the cost of providing each of its existing services or to determine the additional (or marginal) cost of providing any new service. The Administration and Training Division of the Department is responsible for the accounting function for Met Éireann but its role is limited to accounting for expenditure under the standard civil service vote sub-headings.

3.34 Management require information on the unit cost of each service for a variety of reasons, in particular for assessing and monitoring levels of efficiency. Furthermore, information on costs could be used by management to improve pricing decisions, to allocate resources more efficiently and to consider the viability of commercial services. Inevitably, some element of notional allocation of costs will be required in developing such a system, but so long as this is done systematically and comprehensively, useful costing information should be provided.

3.35 It is equally important for management to be aware of the cost of providing each public service. Met Éireann should weigh up the benefit derived from each service against its cost. From such an analysis, the optimum service mix, given the limited resources available, can be formulated. This may result in the efficient allocation of resources to the services that best fulfil the public service role.

3.36 Met Éireann is aware of the limitations of its current accounting systems. In 1998 and 1999, provision was made in Met Éireann's budget to hire consultants to advise on the type of accounting system that should be adopted. A request for tenders for this project was issued on 7 February 2000.

3.37 The requirement to have a reliable costing system in place is reinforced by European Commission rules. In 1995, it imposed an obligation on all national meteorological services to introduce 'financial accounting systems which would allow confirmation that no cross-subsidisation (of the cost of commercial meteorological or forecasting services) has taken place'⁹, within one year of non-aviation commercial receipts exceeding one million euros. This threshold was exceeded by Met Éireann in 1999.

Performance Reporting

3.38 Met Éireann has, since 1995, provided some information on the accuracy of its services in its annual reports. However, the information presented has not provided a comprehensive picture of accuracy because the annual reports have focused on different services each year.

⁹ *Official Journal of the European Communities of 29 August 1995.*

3.39 Met Éireann has stated that the reporting of accuracy verification work in different areas was preparatory to the regular inclusion of accuracy verification scores from the 1999 report onwards. The intention for the 1999 report is to include accuracy scores for

- the HIRLAM weather prediction model
- terminal aviation forecasts (TAFs)
- forecasts of maximum and minimum temperature for Dublin and Cork
- road ice predictions.

3.40 The annual report should detail all relevant performance measures across the full range of Met Éireann's services, rather than just a selection. They should include cost indicators as well as accuracy measures. The number of measures presented should be small enough to be comprehended. In addition, there should be consistent definitions of performance measures from year to year. If definitions change (as may occasionally be required to reflect changes in the services provided by Met Éireann), measures should be recalculated retrospectively, where possible, and the results presented over suitable time frames. Finally, the performance that is reported should be capable of independent verification.

Conclusions

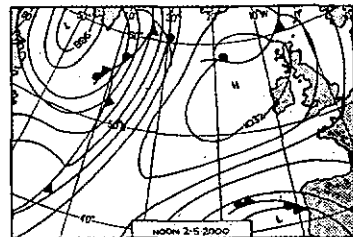
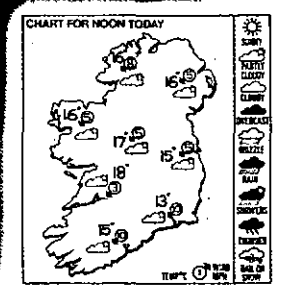
3.41 The main conclusions are

- There is no service level agreement between the Department and Met Éireann.
- A comprehensive and reliable performance measurement system would contribute significantly to the management decision making process within Met Éireann. It would also help to define more clearly the level of service which Met Éireann is expected to deliver and provide a sound basis for the process of accountability between Met Éireann and the Department.
- Met Éireann's public service and commercial roles are not clearly defined.
- Many of the elements required for performance measurement are in place but they have not been brought together into a coherent performance management system, despite recognition over many years that such a system is required.
- There has been little progress in the development of a suitable costing system, which would be central to any performance measurement system.

Appendices



MET éireann



WEATHERDIAL



Appendix A Measures of Error in Forecasts

Many aspects of weather, such as temperature, wind speed and atmospheric pressure, are measured on continuous numerical scales. In practice, observed values usually vary to some degree from what is forecast. The accuracy of the forecasting process is assessed by the extent to which the values observed differ from those forecast. A range of measures is required to give a reliable representation of accuracy levels.

The error in a forecast is the difference between the forecast value and the observed value. The average value of the error over a period is called the *mean error* or *bias*. The mean error or bias indicates if there is a tendency for the forecast to under or over-predict the variable in question. A positive mean error (or positive bias) means that the forecast is on average too high; a negative mean error (or negative bias) means that the forecast is on average too low. A large bias indicates a consistent problem in the forecasting system.

Since the forecast error may be positive on some days and negative on others, there is a possibility that large errors may cancel each other to give a small mean error. To estimate the overall size of the forecast error, the positive and negative signs have to be ignored. This is done by calculating the *root mean square* (RMS) error for the forecasts.

The RMS error is an estimate of the typical error size. It would be unusual for the error on a given day to be more than twice this value and very rare for it to exceed three times the RMS value.

Appendix B Non-forecasting activities in Met Éireann

The most important non-forecasting activity of Met Éireann is the compilation and maintenance of an archive of past weather observations – the climatology database. Work on this archive includes the collection of the data from networks of weather stations and observing systems, its quality control and storage on computer media. The database itself constitutes a resource for the description of the climate of the country and for the study of climate change. More specific outputs from the database include the Monthly Weather Bulletin, climatological normals and statistics of weather extremes used in engineering and architectural design. It also enables Met Éireann to answer enquiries about past weather conditions from official and legal sources and from commercial customers.

Besides its contribution to forecasting, research work in Met Éireann also produces output of direct benefit to the public e.g. studies on atmospheric pollution and the relationship of weather to animal and crop diseases.

Met Éireann is also responsible for monitoring relevant parts of the natural environment. The following table gives a summary of the environmental monitoring activities of the organisation and of the uses to which the resulting data may be put.

Description	Applications
<p>Measure and record solar radiation (global, diffuse, direct and infra red radiation and turbidity)</p>	<ul style="list-style-type: none"> ● Climatology ● Botanical/agricultural research ● Research into renewable energy
<p>Ozone Measurements Ground level ozone and a vertical profile of the amount of ozone in the atmosphere</p>	<ul style="list-style-type: none"> ● Meteorology ● Climatology ● Atmospheric research
<p>Chemical analysis of air and rain</p>	<ul style="list-style-type: none"> ● Research, data users include <ul style="list-style-type: none"> – Economic Commission for Europe – World Meteorological Organisation – Background air pollution monitoring – Norwegian Institute for Air Research – Environmental Protection Agency – Environmental Monitoring and Evaluation Programme
<p>Measure, record and map variations in the Earth's magnetic field Phenomena monitored include</p> <ul style="list-style-type: none"> ● absolute magnetism ● regular variations ● secular variations ● magnetic disturbances (sudden storm commencements) ● magnetic storms ● solar flare effect 	<ul style="list-style-type: none"> ● Geomagnetic Research ● The Ordnance Survey require magnetic survey data to produce maps ● The Irish Aviation Authority use data to update lines of equal declination on aviation maps ● Data used to survey and calibrate compass calibration circles at airports (the circles in turn are used to calibrate aircraft instruments) ● Compass calibration for the Air Corps and private aviators ● Other industrial users require the data, e.g. <ul style="list-style-type: none"> – prospecting companies (surveying) – power companies (to investigate power failures) – telecommunication companies (to reduce communication difficulties)
<p>Monitor seismic waves These are produced by movements of the earth and may cause earthquakes.</p>	<ul style="list-style-type: none"> ● Seismologic research ● Global Monitoring Programme
<p>Observe and record the cycle of nature for certain species of flora</p>	<ul style="list-style-type: none"> ● Phenological research

Appendix C Results of 1998 survey of farmers' requirements for weather forecast services

A total of 243 farmers were surveyed. Three questions were asked about weather forecast service requirements.

Q: How often do you need to know the latest weather forecast for your work on the farm?

	Dairy	Beef	All other areas
Several times daily	21%	15%	8%
Daily	39%	55%	47%
Few days a week	27%	23%	40%
Occasionally	13%	7%	5%

Q: What weather forecast period is most important to you?

	Dairy	Beef	All other areas
Less than twelve hours	12%	13%	21%
12 to 24 hours	21%	40%	38%
2 to 3 days	38%	31%	29%
4 to 7 days	29%	16%	12%

Q: What is the most suitable way for you to get your weather forecast?

	Dairy	Beef	All other areas
TV	21%	40%	27%
National radio	38%	19%	19%
Local radio	25%	17%	13%
<i>Weatherdial</i> voice	16%	14%	31%
<i>Weatherdial</i> Fax	–	–	–
Internet	–	5%	7%
Newspaper	–	5%	3%

Source: Agri Aware Survey, 1998

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