The impact of climate and weather on the activities of the building and construction industry in South Africa

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ABSTRACT

This study represents a quantitative survey of the impact of the climate and weather on the activities of the building and construction industry in South Africa. Seasonal productivity problems, the seasonal provision of special facilities and the seasonal use of special techniques are, amongst others, assessed. From these results it is apparent that the building and construction industry has not yet developed a sophisticated response to varying climatological conditions.

The influence of weather variables and weather forecasts are discussed. It appears that most companies are aware of the weather impact, but do not really plan ahead because of doubts about the accuracy of weather forecasts.

Recommendations are made which could improve the productivity in the South African building and construction industry.

SAMEVATTING

Hierdie studie handel oor 'n kwantitatiewe opname van die impak van die klimaat en die weer op aktiwiteite in die bou-en konstruksiebedryf in Suid-Afrika. Seisoensproduksieprobleme, die verskaffing van seisoensgebonde fasiliteite en die gebruik van besondere tegnieke in bepaalde seisoene, word onder andere, bepaal. Uit hierdie resultate blyk dit dat die bou- en konstrukrielbedryf nog nie 'n gesofistikeerde respons tot wisselende klimaatstoestande ontwikkel het nie.

Die invloed van weersveranderlikes en weersvoorspellings word bespreek. Dit blyk dat die meeste firmas bewus is van die impak van die weer, maar dat hulle nie werklik vooruit beplan nie, omdat die akkuraatheid van weervoorspellings betwyfel word.

Aanbevelings word gemaak wat die produktiwiteit in die Suid-Afrikaanse bou- en konstruksiebedryf kan verbeter.

CONTENTS

THE IMPACT OF THE CLIMATE AND WEATHER ON THE ACTIVITIES OF THE BUILDING AND CONSTRUCTION INDUSTRY IN SOUTH AFRICA

HISTORICAL BACKGROUND

Introduction

The building and construction industry is highly dependent on the weather, with for example, approximately 50% of the operations in the U.S.A. sensitive to the weather. This results in losses in that country which vary between $3 billion and $10 billion per year, depending on the severity of the conditions (Smith 1975). In Britain also, the loss in output as a result of the weather is severe. Over the period 1962 to 1970 it varied between £25 million and £200 million per year. The economic justification for a more specific construction-oriented forecast service in these countries has been made by several researchers (Smith 1975).

It is believed that the above also applies to some extent to South Africa, and that a more scientific and dynamic approach towards the weather and climate by the construction industry, together with construction-orientated forecasting could have a pronounced effect on productivity and profits in the building industry.

Statistics compiled by the National Productivity Institute, (Louw 1984), show that construction labour productivity had an average negative growth rate of 0,59% from 1970 to 1982 and construction capital productivity an average negative growth rate of 6,9% over the same period. These figures indicate that a reversal of these trends are imperative for the well-being of the country. Louw (1984) believes that this can be achieved through a study of the measurement of productivity in the South African construction industry. Although productivity is often hard to define and difficult to measure, the rising costs of construction and financing are pushing the issue to the forefront. As labour becomes more expensive and difficult to obtain, labour cost savings can only be effected if an increase in labour productivity is achieved. Louw (1984) also proposes a measurement system which could be applied in the construction industry.

Although the measurement of productivity (which is an effect) is certainly very important, the causes of low productivity should also be considered. In this respect the effect of the weather and climate could be considerable.

Wet weather

Wet, cold weather frequently brings construction work to a standstill in Europe and North America. Although the climate in South Africa is not as severe, cold, and even wet winters do occur regularly, hampering construction activities and affecting productivity. The technical ability to prevent such interruptions exists, but even abroad, precautions are often not taken because the costs seem high. In addition, the increased costs due to loss of production are unclear. Faced with the uncertainty of weather conditions, project managers are reluctant to agree to expenditure in preparing for adverse weather conditions (Harris and McCaffer 1975). Additional costs incurred as a result of preparing for winter activities could be as high as 5% of the total building cost, although extra costs of less than 1% have been recorded (Cekal 1971). In Canada the extra costs are estimated, on average, to be 1% of the total costs (Crocker 1971).

Wet weather can interfere with many different construction processes. Indeed, it is thought that in Britain more delay is caused by rain than by any other climatic element (Lacy 1977). Many outdoor jobs may be stopped when it is raining, merely because it is too unpleasant to continue working, whether or not there is any actual physical interference with the particular process. It is not possible to specify an exact rate of rainfall at which workers will stop working. The rate may depend on the kind of work being done, or on the state of the ground at the site, but could also vary with other weather variables (Lacy 1977).

In South Africa the rainfall normally peaks during the summer months, the Western Province being the only winter rainfall region. During these months windy conditions, high temperatures and humidities may also occur, and these could increase the sensitivity of the worker to the environment, and affect his productivity.

Wind Effects

According to British standards, cranes are designed to be usable as long as the wind pressure on the crane does not exceed 240 N/m^2. This corresponds to a wind speed of 17 ms^{-1}, including gusts. A crane is responsive to gusts of quite short duration, possibly ten seconds or less (Lacy 1977). Depending on the roughness of the terrain, gusts may be from 30% to 100% higher than the mean wind speed, whilst the speed of gusts also increases with height above the ground. With some kinds of loads the crane or load may well become unmanageable at lower speeds, probably 12 ms^{-1}. The erecting and handling of panels and shutters is also adversely affected by windy conditions. Melbourne and Joubert (1971) found that wind gusts of 20 ms^{-1} will unbalance and seriously inconvenience a number of people, whilst gusts of 23ms^{-1} could cause people to be blown over. Reliable statistics of time lost because of wind are hard to obtain, but it has been reported that at one site in Liverpool, lost time amounted to 33% during one winter (Lacy 1977).

The cooling or heating effects of the wind can be as unpleasant as its mechanical effects, with a detrimental influence on human comfort and productivity.

Temperature and humidity

The effects of heat and cold stress on human efficiency and task performance have been well documented by, for example, Teichner and Wehrhamp 1954; Pepler 1958; Wyndham et al 1964; Pepler and Warner 1968; Wyon 1974; Mather 1974; Wyon 1976; Meese et al 1981; Kok et al 1982; Meese et al 1982.

This literature has dealt mainly with physiological thermoregulation and reflexes (e.g. sweating and shivering), self-reports of comfort, and non-motivational effects of heat and cold on performance. Results indicate that, although the body has a remarkable capacity to adjust and acclimatize to thermal stress, extreme conditions rapidly produce a decrease in performance and ability (Mather 1974).

The results of Meese et al (1982) show that a wide range of manual skills are adversely affected by the low temperatures ($<18°C$) commonly encountered in factories in South Africa in winter. It is suggested that simple improvements to factory building construction, could pay for themselves in improved productivity. Kok et al (1982) report a decline in performance at 38°C in spite of a very low humidity (vapour pressure 1,0kPa). At higher humidities this temperature threshold would be substantially lower as thermal heat stress can be linked directly to the moisture conditions of the environment. The evaporation of perspiration is a major way in which the body exchanges heat with its surroundings. This process is dependent amongst others on the temperature of the evaporating surface, the relative humidity of the air in contact with the skin and the rate of air movements (Mather 1974). From this it follows that an average environment temperature and a high relative humidity will also adversely affect the heat exchange process between man and environment, and this could have a negative effect on productivity.

Behavioural thermoregulation has largely been neglected in the literature, although Hardy (1961) and Chatonnet and Cabanac (1965) make reference to it and Nicol and Humphreys (1973) and Parsons (1979) give it explicit emphasis. During behavioural thermoregulation a task is performed in such a way that excessive heat or cold is avoided as the following example illustrates. A man is paid to shovel gravel in a warm ambient temperature. The harder he works, the hotter he gets whether by tossing more shovel-fulls per minute (rate) or by putting more gravel in the shovel for each toss (force). Along with fatigue, the increased heat will tend to decrease the rate or load (or both). He tries to avoid the consequences of increased heat by either not raising the rate of shoveling or not increasing the load. He may also simply stop shoveling and rest (incompatible behaviour), thereby reducing or postponing the additional heat caused by shoveling. What he does, will also be influenced in part by how much and how he is paid, for example, for the amount shoveled or by time on the job (Parsons 1979).

Clothing can play an important role in maintaining the bodily heat balance in cold conditions, but it can also upset the balance under warm conditions. Wet clothes have a lower insulation value than dry clothes, since water is a better heat conductor than air (Mather 1974).

From the above discussion it is suggested that activities on a construction sites in South Africa are effected by a large variety of meteorological and climatic variables, which could have an influence on productivity and profits. The methods and results of the research will be discussed with specific reference to this historic perspective.

AIMS OF THE STUDY

1. To determine the status of the weather and the climate in the South African building and construction industry.

2. To determine the effects of the weather and the climate on the operational activities in the South African building and construction industry.

3. To identify and evaluate climatic conditions and weather variables which influence production.

4. To determine the loss in production which results from weather and climate changes.

5. To make recommendations that could effect productivity in the building industry.

STUDY AREAS

Six regions were selected as study areas on the basis of (i) intense building and construction activities in the region and (ii) weather and climate characteristics which make the region unique. The following six regions were identified:

1. The Natal Coastal Region
2. The Cape Peninsula
3. The Witwatersrand Region
4. The Pretoria Region
5. The Port Elizabeth/Uitenhage Region
6. The Orange Free State*

* The following abbreviations are used for the regions in the tables throughout the text : DBN, CT, JHB, PTA, PE, BFN.

METHOD OF RESEARCH

A comprehensive questionnaire was sent to all building and construction companies which were members of the Master Builders and Allied Trades Association in 1983, as well as to other building firms which were traced through telephone directories.

Each questionnaire consisted of three parts, and questions dealt, inter alia, with the influence of the climate and the weather on activities in the building and construction industry. In the first part questions were asked which identified the company, its main activities, number of employee's and annual turnover. The second part dealt with the climatological impact. Respondents amongst others, had to identify the season with the highest production potential, and they had to rank winter and summer related productivity problems. They were also required to indicate whether they used any special techniques or methods in any given season, and had to give an indication of facilities which they provide to comfort outdoor workers. The third part of the questionnaire dealt with the weather impact, and more specifically with the influence of weather changes and weather forecasts. In this part respondents also had to estimate their production losses due to weather and climate conditions.

INTERVIEWS

Interviews, which allowed for valuable in depth discussions, were conducted with 32 experts associated with the construction industry. In South Africa interviewees were associated with the C.S.I.R. (N.B.R.I.); S.A. Universities (U.P., Wits., U.O.F.S., R.A.U,); professional firms and the construction industry and its controlling bodies. A questionnaire was also completed by each of the interviewees.

Interviews were also conducted in the U.S.A. with persons associated with Colorado State University; the National Climatic Centre, Denver; the University of Maryland and construction firms. The Watford Building Research establishment in Watford, close to London was also visited.

The outcome of these interviews is not treated separately, but as a unit with the main research.

CASE STUDY

A case study was carried out to determine the effects of one rainfall incident on construction activities (Appendix 1). This study applied to two rain days, the 8th and 9th of April 1984, during which heavy showers occurred along the Natal coast. The rain disrupted construction activities, more so, because it was largely unexpected as forecasts had not given any indications of rain.

NUMBER OF COMPANIES INVOLVED IN THE SURVEY

Table 1 gives a general picture of the number of firms involved in the survey, and number and percentage of questionnaires returned. From the table it is clear that the response was satisfactory. In five regions at least 60% and as many as 83% of the questionnaires were returned. However less than 50% of the questionnaires were returned in the Pretoria region. In this region approximately 30% of the questionnaires were sent to small firms with turnovers of less than R2 million per year, and only three of these (15%) responded. The fact that the questionnaire was in English could also have possibly affected returns in the Pretoria region. In the other regions less than 10% of the firms sampled could be categorised as small firms.

Table 1. Analysis of response of companies to which questionnaires were sent.

Region	No. of companies to which questionnaires were sent	No. of companies that returned questionnaires	% Companies that returned questionnaires
DBN	53	44	83,0%
CT	24	15	62,5%
JHB	37	23	62,2%
PTA	64	26	40,6%
PE	20	15	75,0%
BFN	15	9	60,0%
	213	132	61,9%

Firms that had not responded were again contacted during the second part of 1984, whilst a few additional companies were also approached at that stage.

During the editing of the questionnaires it was established that six of the questionnaires (4.5%) had been filled in so incompletely or incorrectly that the information contained could not be used. The data provided by 126 respondents were therefore eventually included in the analysis.

HOW REPRESENTATIVE IS THE TEST GROUP

Questionnaires were sent to all companies which were members of the Masters Builders Association 1983. According to M.B.A. officials more than 80% of the construction work is handled by these firms, which in most cases have turnovers of more than R10 million per annum. In several cases single companies completed more than one questionnaire. This was the result of questionnaires having been sent to the branch offices or construction sites, and not necessarily to head offices. It however, had a broadening effect on the sample. With the aforementioned in mind, the test group can be regarded as representative of the all construction companies and the views and information obtained as a reliable picture of the universe.

RESULTS AND DISCUSSIONS

ASSESSMENT OF CLIMATE IMPACT

Determining the climatological season with the highest production potential

Previous research (Cekal 1971; Lacy 1977) has indicated that productivity in the building and construction industry varies in different climate seasons, with the winter period often having the lowest productivity. Respondents were therefore asked to rank the four climatological seasons, allotting a one to the season with the highest production potential, and a four to the season with the lowest production potential. Low productivity resulting from holiday periods had to be ignored in the assessment. The results are shown in Table 2.

Table 2. Seasonal Production Potential

	DBN		CT		JHB		PTA		PE		BFN	
Winter	1	(1)	4	(4)	3	(4)	4	(3)	4	(4)	4	(4)
Summer	4	(4)	3	(1)	4	(3)	3	(4)	1	(1)	3	(1)
Spring	3	(2)	1	(3)	1	(1)	2	(2)	3	(2)	1	(2)
Autumn	2	(3)	2	(2)	2	(2)	1	(1)	2	(3)	2	(3)

The values in brackets represent the second choice for the specific region. Although other preferences existed in each region, the arrangements in Table 2 were selected by more than 50% of the respondents. From the table it is clear that the winter months are seen as the period with the lowest production potential. The only exception is the Durban region in which the winter months are rated as the period with the best production potential. In four of the six regions viz. Cape Town, Johannesburg, Pretoria and Bloemfontein spring and autumn are rated the best production periods.

Winter productivity problems

Certain climate variables seem to be more disruptive than others. In Britain, for example, more delay is caused by rain, than by any other climate element (Lacy 1977), whilst low temperatures are more important in Canada (Crocket 1971). Companies were therefore asked to rank the variables impeding their winter productivity on a scale from one to six. A list containing six possible conditions was supplied. The results are shown in Table 3.

Table 3. Variables impeding winter productivity

VARIABLES	DBN(%)	CT(%)	JHB(%)	PTA(%)	PE(%)	BFN(%)
Lower production because of shorter day light hours.	14,3	7,1	30,4	25,0	6,7	25,0
Lower production because of low temperatures.		28,6	39,1	41,7	40,0	50,0
Lower production because of rain	4,8	42,9			26,6	
Lower production because of wind	9,5	14,3	17,4		20,0	12,5
A combination of these factors		7,1	13,1		6,7	12,5
Other						
No problems	71,4	0,0	0,0	33,3	0,0	0,0
Total	100,0	100,0	100,0	100,0	100,0	100,0
n	42	14	23	24	15	8

The ratings which the companies accorded to each of the variables, is expressed as a percentage of the number of companies who answered the question. From the table it is interesting to note that 71,4% of the firms in the Natal Coastal Region do not experience winter associated productivity problems. The biggest problem in this region is the shorter day light hours which was mentioned by 14,3% of the companies. Pretoria is the only other region in which winter has a relatively small influence on productivity, with 33,3% of the firms in that region indicating that winter conditions do not influence their productivity. Construction companies in Cape Town and Port Elizabeth on the other hand apparently experience fairly serious winter time productivity problems with rain and low temperatures rated the largest negative influences. Johannesburg and Bloemfontein's problem ratings are exactly the same, with low temperatures and shorter days rated as the most important.

From the above it follows that winter has a influence on building and construction activities in all the regions. Unfortunately it is not possible to express the actual economic sensitivity in monetary terms. The need for research on the methodology of climate impact assessment is however quite clear.

Summer productivity problems

All the study areas could be classified as summer rainfall regions, with the exception of the Cape Peninsula which receives winter rainfall. This condition, together with summer day-time temperatures which regularly exceed 30°C, amongst others, has the potential of hampering productivity. Companies were therefore asked to rank the variables impeding their summer productivity on a scale from one to eight.

Table 4. Variables impeding summer productivity

VARIABLES	DBN(%)	CT(%)	JHB(%)	PTA(%)	PE(%)	BFN(%)
Lower production in summer because of rain	26,2		43,5	25,0	6,7	50,0
Lower production because of thunderstorms	9,6		26,1	12,5		12,5
Lower production in summer because of high temperatures	19,0	21,4	21,8	41,7	26,7	25,0
Lower production in summer because of high humidities	21,4	21,4			13,3	
Lower production because of wind	4,8	42,9			20,0	
Lower production in summer because of dust storms			8,6			12,5
A combination of these factors e.g. high temperatures and humidities causing heat stress	19,0	14,3		20,8	13,3	
Other						
No problems	0,0	0,0	0,0	0,0	20,0	0,0
Total	100,0	100,0	100,0	100,0	100,0	100,0
n	42	14	23	24	15	8

A list containing eight possible conditions was supplied. The ratings which the companies accorded to each of the variables was expressed as a percentage of the number of companies who answered the question. Table 4 contains the results which indicates that high temperatures and/or high humidities and/or rain are seen as the climatic variables that influence productivity in most regions. In four of the regions viz. Durban, Cape Town, Pretoria and Port Elizabeth heat stress is also seen as an important factor. It is striking that heat stress has a lower rank order than high humidity and high temperatures in these regions, which suggests that the negative effect of this variable is not understood by the construction industry. This also applies to Johannesburg and Bloemfontein where high temperatures are seen to influence productivity, but not heat stress.

In five of the regions all the respondents indicated that summer conditions negatively affect productivity. The Port Elizabeth area was the only exception, where 20% of the respondents felt that summer conditions had no effect on their activities.

The seasonal use of special techniques and methods*

The seasonal use of special techniques to improve productivity and working conditions can be seen as an indication of the level of sophistication of the individual firm. Earthworks, concreting, drain laying, brickwork, and all outside work can, for example, be continued successfully after dusk by the provision of suitable floodlighting, whilst inflated or scaffolding enclosures enable building work to continue without interruption. In this question companies were therefore asked to mark the methods they used in a list which contained seven possible

* The terms "techniques" and "methods" were seen as synonyms for the purpose of this question.

techniques. A space was left blank for other suggestions. The results are shown in Table 5. The table also gives an indication (in % per region) of the firms that do not use any special methods.

Table 5. The seasonal use of special methods

Techniques or methods	DBN	CT	JHB	PTA	PE	BFN
Special plaster mixtures						
Special techniques when working with concrete, e.g. straw covers, insulating quilts, etc.	X		X			X
Protecting completed brickwork against low temperatures						X
Site lighting to reduce hazards and lengthen the work day.		X	X	X	X	
Use of heaters.						
Provision of temporary protection for work under construction	X	X	X	X	X	
Provision of temporary protection to improve operative conditions e.g. scaffolding covered with plastic sheeting		X				
Other						
No special seasonal techniques or methods (%)	66,7	28,6	17,4	41,6	60,0	0,0
n	42	14	23	24	15	8

In three of the regions, viz. the Natal Coastal Region, the Pretoria Region and the Port Elizabeth Region a relatively large percentage of the firms do not use any special method in their building operations which could affect their productivity. The figure (66,7%) for the Natal Coastal Region is striking, but the mild winters might to a certain extent explain the absence of some of the methods. It is however strange to note that no site lighting is used in this region. In the other three regions, a relatively high percentage of the firms use special techniques. The provision of temporary protection to improve operative conditions in the Cape Peninsula is encouraging, but only 28,6% of the firms indicated that they used this method. It should also be noted that the techniques used in the Free State region are relatively unsophisticated.

Table 5 shows that floodlighting is used by firms in four regions. This method was however not used by more than 50% of the respondents in any of the regions.

In the category "other methods" the following were mentioned :

(i) An increase in working hours.

(ii) A change in working hours to adapt to seasonal conditions.

(iii) Special methods during crane operations to obviate problems with high wind.

(iv) Air conditioning for top project managers.

Of the above mentioned methods, the second, viz. a change in working hours to adapt to seasonal conditions has merit, but it is used by a limited number of companies.

From the above discussion it can be concluded that the South African Building and Construction Industry has not yet developed a sophisticated response to varying climatological conditions. This means that climate changes can severely affect productivity by producing poor working conditions and by inhibiting certain building activities.

The seasonal provision of special facilities

The provision of protective clothing* is an important factor in enabling work to continue in inclement weather, and facilities like fires and showers can be seen as the first essential steps for maintaining a high morale (and productivity) on the building site. In this question companies were therefore asked to mark the facilities they provide for workers in a list which contained winter and summer facilities. The results are shown in Table 6. The table also gives an indication (in % per region) of firms that do not provide any special facilities.

* Clothing is treated as a facility for the purpose of this question.

Table 6. The seasonal provision of special facilities

Facilities	DBN	CT	JHB	PTA	PE	BFN
Winter						
Other (warmer) overalls		X	X	X	X	
Coats	X		X			
Heaters					X	
Fires		X	X	X	X	X
Raincoats		X				
Other facilities						
Summer						
Cooling facilities					X	
Showers	X		X		X	
Rain coats	X		X			
Other facilities						
% firms that provide no special facilities	61,9	50,0	30,4	58,3	59,9	50,0

In three of the regions, viz. the Natal Coastal Region, the Pretoria Region and the Port Elizabeth Region about 60% of the firms do not provide any special facilities. The mild winters in these regions, to a certain extent, explain the non-provision of some facilities. It is however striking that no summer facilities are provided in the Pretoria region. In the other three regions, a relatively high percentage of the firms provide special facilities, with the winters quite adequately provided for in the Witwatersrand and Cape Peninsula. It should however be noted that only fires are available in the Free State Region. In the category "other facilities" gum boots were mentioned by companies in the Witwatersrand.

The provision of facilities for the comfort of the outdoor worker can in conclusion be seen as concern on the part of management for the plight of its workers, which at times, can be relatively harsh in most of the regions. The cost of providing such facilities would in most cases be balanced out by the higher productivity of a happier workers corps.

The use of climatological data in long term construction planning

Climate plays as significant a role in many aspects of commerce and industry, as it does in health, clothing and housing. It's influence in these latter fields may be easily identified. The effect of climate on many industrial or engineering operations is however, often not recognized or considered. Management may be so concerned with material and transportation problems, that they fail to see the role that climate can and does play in their activities. The use of climatological data in planning their long term programmes, is thus a good indicator of their awareness of climatic influences. A list containing thirteen climatological variables, all of which could have an influence on construction activities, were supplied. Respondents were asked to mark the variables that they use. The results are shown in Table 7. The table also gives an indication (in % per region) of the firms that do not use climate data in the planning of long term programmes. From the table it is clear that little consideration is given to climatic data in long term planning, as it is not considered by more than 50% of the companies in five of the regions. A further disappointment is that data of only one climatological variable is used in the Pretoria and Free State regions. It is nonetheless encouraging to note that information of a number of climatic variables are used in four of the regions.

Table 7. Climatological data used in long term construction planning.

Climate variables	DBN	CT	JHB	PTA	PE	BFN
Mean monthly temperatures						
Average maximum daily temperatures			X		X	
Average minimum daily temperatures					X	
Average number of days with frost			X			
Average annual rainfall	X	X	X		X	
Average number of rain days per year	X	X	X	X	X	X
Wind direction		X				
Wind frequency	X	X			X	
Wind speed		X			X	
Average daily duration of sunshine		X				
Relative humidity	X					
Vapour pressure						
Radiation						
Other						
% firms that do not use climate data in long term planning	47,6	57,1	56,5	75,0	66,6	62,5

One of the most important reasons for this laisser-faire attitude is undoubtedly an "inclement weather clause" which forms part of most building contracts. Although there is a variation in wording, the general intent and effect of this clause is that the builder is permitted an extension of the agreed contract period if he is unable to continue work because of unfavourable conditions. In other parts of the world the view has been expressed that this clause enables contractors to obtain extensions of contract periods too readily and that its removal or amendment would encourage productivity (Winter Building 1971).

The response of management and workers to any climatic challenge will, in conclusion, be important in determining the limiting nature of such an impact. The use of climatological data in long term planning is an important prerequisite for an efficient response.

What other climatological data would be of value to you?

In other parts of the world climatological data are published which relate directly to the building industry in those regions. This question was therefore used to identify the need for such data in South Africa. One suggestion was made to the respondents viz. average number of hours in the period 07h00 to 17h00 with rainfall. A space was left blank for the respondents to identify any other climatic data which they need. Almost all the respondents indicated that the suggested daytime rainfall data would be of value. In the "own suggestions" part requests were made for data like wind speed and average temperatures which are readily available from the South African Weather Bureau. The fact that it was requested however suggests either ignorance on the part of the respondents or poor marketing from the Weather Bureau or both.

ASSESSMENT OF WEATHER IMPACT

Reaction to quick unexpected weather changes

There seems to be general agreement that bad weather can cause great delays in construction work. As might be expected, the losses depend not only on the weather, but also on the responses of management to the weather conditions, as well as on the type and stage of the contract (Lacy, 1977). The first question of this part of the questionnaire therefore dealt with unexpected weather changes and the respondents reaction to this. The four options below were cited and firms had to mark those they use most.

1. The specific work planned for that day must go on, regardless of the weather.

2. If the weather necessitates it, the work programme is changed.

3. If bad weather makes work impossible, the workers get time off.

4. Certain tasks are held in reserve and are only executed during bad weather when the normal programme cannot be followed.

In the Durban region 82% of the respondents used options two and three during unexpected weather changes. It is encouraging to note that 68% of these respondents also held certain tasks in reserve (option 4) and only executed them in bad weather when the normal programme cannot be followed. Only 18% of the respondents followed the first option ... work must go on regardless of the weather. In Cape Town, Port Elizabeth and Johannesburg the pattern was much the same as in the Durban region. In the O.F.S. options two and three were also followed most viz. by 75% of the respondents and option four by 40% of these respondents. Only 25% of the respondents used the first approach. In the Pretoria region builders however reacted differently to unexpected weather changes, 40% of the respondents indicated that work must go on regardless of the weather, whilst 60% selected the other possibilities.

These results indicate that the majority of the construction companies in South Africa are aware of the impact of weather changes on their activities and their responses to these changes could be described as fairly sophisticated.

Weather forecasts

The Weather Bureau's forecasts for 24 to 48 hours ahead are based on the analysis, on a real-time basis, of actual weather reports received from the whole Southern Hemisphere. These reports are received at four internationally fixed times daily and are analysed by a powerful mainframe computer (van den Bergh, 1985). A considerable effort is therefore an essential part of every forecast, and the results are often good, but certainly not perfect. It is however important that the benefits that can be derived from weather forecasts be fully utilized. Respondents were therefore asked to indicate whether they listened to forecasts and used them in the planning of their daily activities. Reasons had to be given for not utilizing weather forecasts in the planning of daily activities. The responses from the different regions showed little variation and they are therefore treated together.

Weather forecasts are regularly listened to or studied and then considered in daily activities by nearly 80% of the respondents. It however appears that the decision to change the previously planned programme is postponed till the last moment. The reason being that forecasts are not seen as reliable enough for longer term decision taking.

Sixteen percent of the respondents do not pay any attention to weather forecasts at all because they consider them too inaccurate for planning, whilst 5% of the respondents do not consider the forecasts for other reasons like lack of time or a trust in their own feelings.

The effect of certain weather variables on building and construction activities.

Previous research has indicated that certain weather variables have a significant influence on building and construction activities (Lacy 1977).

In this question the companies therefore had to indicate to what degree their activities are influenced by certain weather variables. A list containing seven possible conditions was provided and the firms had to indicate whether any specific variable had an insignificant, a significant or a very significant influence on their activities. The responses are shown in Table 8 which depicts the four variables with the largest impact (in ranked order) as well as the percentage of respondents which regarded those variables as very significant and insignificant in the respective regions. From the table it follows that the companies regard rain as one of the most important negative influences in the construction industry. Only in the Port Elizabeth region are windy conditions seen as more important than rain, whilst low temperatures are ranked first in the Orange Free State. It is difficult to explain why a relatively high percentage of the respondents in the Durban region see rain, windy conditions and a combination of high temperatures and humidity as having an insignificant influence. If the climate of the region is considered, these variables should have a pronounced effect on building and construction activities and therefore on productivity.

Table 8. The influence of certain weather variables on building and construction activities.

Regions	Variables	% respondents regarding influence as very significant	% respondents regarding influence as insignificant
Durban	Rain	50,0	11,9
	Combinations of high temp. and humidity	42,9	14,3
	High temp.	19,0	9,6
	High wind speed	0,0	26,2
Cape Town	Rain	57,1	0,0
	High wind speed	42,8	0,0
	Gusts	14,3	14,3
	High temperatures	0,0	50,0
Johannes-burg	Rain	34,8	8,7
	Low temperatures	26,1	13,0
	Gusts	13,0	34,7
	High temperatures	0,0	47,8
Pretoria	Rain	58,3	0,0
	High temperatures	37,5	0,0
	Low temperatures	0,0	0,0
Port Elizabeth	High wind speed	40,0	0,0
	Gusts	33,3	0,0
	Rain	26,7	0,0
	High temperatures	0,0	33,3
Orange Free State	Low temperatures	50,0	0,0
	Rain	37,5	25,0
	High wind speed	25,0	0,0
	Gusts	12,5	0,0

Estimating the effect of adverse weather and climate conditions on total production

It has been shown that the construction phase of the building industry in many parts of the world has a high dependency on the weather and climate and that large amounts of money are lost annually because of adverse weather conditions.

Data collected in this survey indicate that to some extent this also applies to the South African construction industry. In this question respondents were therefore asked to estimate the effects of adverse weather and climate conditions on their production. As the methodology for accurate climate impact assessments is not readily available, the estimates submitted by the respondents can at best be regarded as calculated guesses. The large variation in estimates (Table 9) within regions validates this point. Although without scientific support, the average figure of 7,2% loss in production seems to be fairly reasonable if it is compared with other values. In Britain, for example, the production of the average builder who does not take precautions against inclement weather drops by about 10% during the winter months (Winter Building 1971). Model studies in the same country show 4,5% and 4,0% increases in production time as a result of wind effects and rainfall respectively (Harris and McCaffer, 1975).

Table 9. The effects of adverse weather and climate on annual total production.

Region	Average annual loss of production (%)	Highest loss (%)	Lowest loss (%)	% respondents indicating that they did not know
Durban	10,4	27,0	1,5	11,9
Cape Town	5,9	12,0	2,5	42,8
Johannesburg	3,5	10,0	1,0	43,3
Pretoria	1,9	3,0	1,0	50,0
Port Elizabeth	3,8	8,0	0,5	40,0
O.F.S.	13,6	30,0	0,5	25,0
Average	7,2	17,8	1,3	32,5

CONCLUSION AND RECOMMENDATIONS

It has been shown that labour productivity in the South African construction industry has had an average negative growth rate of 0,59% during the period 1970 to 1982 (Louw 1984). The reversal of such a negative process could be initiated with a study on the measurement of productivity and the setting of productivity objections. Construction site management, amongst others, should measure the m^3 of concrete placed, m^2 of shuttering erected or stripped, kg of steel fixed, number of bricks laid and should have, as criterion, production standards which could be applied under varying conditions (Louw, 1984). A study of productivity and setting of productivity objectives would however have limited value without knowledge of the impact of climate and weather on productivity and empirical standards. This implies firstly that construction site management should have a sound knowledge of the climatology of the region. A "feeling for the climate" is not acceptable. Climatology gives an indication of average variations in weather, as distinct from the actual weather at a specified time, and it can help the builder:

(a) Decide if a building practice used in one area, is likely to be successful elsewhere. Wind and gust frequency and wind speed are, for example, much higher in Port Elizabeth than in Pretoria.

(b) Assess how outdoor work may be interrupted or affected by frost, heavy rain, strong winds and gusts and heat stress conditions.

(c) Plan excavation works. Data on the frequency of heavy rains and probably rates of evaporation, together with the details of the ground, can indicate the working conditions to be expected (Lacy 1977).

It would appear (see Table 7) that the consideration and use of climatological data in the South African construction industry leaves much to be desired. Planning of building and construction activities can therefore hardly be seen as being scientific. Climatological data are fairly readily available from the South African Weather Bureau in Pretoria and its regional offices. The format of the data should however be such that easy interpretation is possible. This is not always the case with existing publications. A continuous updating of publications and printing of new data is essential. Above all, the South African Weather Bureau should communicate the availability of such material to the user.

From the above discussion it follows that the Building and Construction Industry has not yet developed a sophisticated response to varying climatological conditions. This means that climate and weather changes can severely affect construction activities and therefore productivity.

At the beginning of a contract the cost of ensuring reasonable means of protection for men, vulnerable work and plant must be weighed against the cost of delays and possible damage to new work. Methods of protection should be studied with a view to utilization, and the necessary protection materials should be allocated at the outset of the job. Other sophisticated methods like site lighting should be considered in the planning stages and implemented when necessary. Simple meteorological instruments like thermometers and rain gauges should be standard equipment on every building site.

This study has shown that most companies are aware of the weather impact on their activities, but do not really plan ahead because of doubts in the accuracy of weather forecasts. Forecast accuracy will undoubtedly improve with technological developments, but an extension of the reports are important. Directed early warnings of heavy rainfall, frost, and gusts would be of great value not only to the building industry, but also to agriculture, hydrology, sports administrators etc. Reference to possible heat and cold stress conditions in forecasts has furthermore been identified as an important need. This should include reference to the effects of wind on human comfort.

Care of personnel is, in conclusion, an important factor in enabling work to continue in bad weather. In this respect too the South African construction industry leaves much to be desired (see Table 6). Protective clothing should form an important part of such an action. Differentiation between summer and winter clothing, and dry and wet weather clothing, is essential. The effects of clothing in promoting heat stress and low productivity should always be considered. From this it follows that the type, weave and colour of the material are important. Natural fibres are obviously more suitable for clothing than artificial fibres. Adequate site facilities for the welfare of workers are furthermore necessary throughout the year.

A mess with lockers, heaters, showers etc. seems to be an important starting point. A healthy, productive worker needs a balanced diet. It is therefore desirable that workers should have good canteen facilities on site with the opportunity to buy cheap, well cooked meals. The South African mining industry is a good example of an investment in personnel facilities that pays sound dividends in productivity.

Appendix 1 : Case Study : Natal Coastal Region

This case study concerns two rain days, Monday and Tuesday the 9th and 10th of April 1984. On these days between 50 mm and 100 mm of rain fell on the first day, followed by a further 25 mm to 50 mm on the second day. These relatively heavy falls caused serious disruptions and damage in the building industry in the Natal Coastal Region. The disruption was aggravated by the following:

1. The rain fell at the end of the rain season when falls of that nature are unusual.
2. It came in the wake of two tropical cyclones, Imboa and Demoina which caused flood damage amounting to millions of rand. Transport and other communication links were seriously affected by the cyclones and still under repair in april. The soil moisture content was high after the cyclones. Rain therefore easily resulted in muddy conditions on building sites.
3. The rain was largely unexpected because weather forecasts during the week prior to the two rain days gave a little indication of rain. The forecast screened on television on Saturday the 7th of April in fact gave the Natal Coastal region a 20% probability of rain.

To assess the effects of this rain 18 construction companies in the Natal Coastal Region were telephoned on the 11th and 12th of April and the following questions were put to them:

1. Did you listen to the weather forecasts during the weekend?
2. Was there anything special in it for you?
3. What was your reaction to the weather forecasts? Anxiety, preparation, etc.
4. Did you expect the heavy rainfall of Monday and Tuesday?
5. Estimated damage?

6. Will accurate, directed forecasts be of any help?
7. Can preventative action be taken?

Sixteen of the eighteen respondents indicated that they had listened to the weather forecasts during the weekend prior to the rain, but that there was nothing special (a warning) for them in the forecasts. From this it follows that no preparations were made to minimise the disruptions and damages.

Three of the respondents indicated that they felt "uneasy" on the Sunday before the rainfall events when they observed the changes in the weather. The other thirteen respondents however had no anxiety or fear. Not one of the respondents expected the heavy rainfall of Monday and Tuesday. The weather expectations of the three respondents that felt uneasy varied between light showers, rain and a good down pour.

The respondents were asked to estimate their losses (question 5). The results are given in Table 1.

Table 1 : Estimated damage experienced by eighteen construction companies in the Natal Coastal Region on two rain days.

Total estimated damage for two rain days	Number of companies
Less than R5000	5
Between R5000 and R10 000	4
Between R10 000 and R15 000	2
Between R15 000 and R20 000	2
More than R20 000	5

The respondents in the first category attributed their low losses mainly to luck, in the sense that they were at stages in their operations where the rain had a limited effect. Respondents in the last category, alternatively, felt the full impact of the weather because they were at vulnerable stages in their operations. In one particular case this meant the destruction of a causeway, which was the only access to the site, and the filling up of excavations. In the "more than R20 000 category" the estimated damage varied between R25 000 and R100 000 with an average of R58 000 for the five companies. The average estimated loss for the eighteen companies in the survey was calculated at just more than R10 000.

In conclusion, thirteen of the eighteen respondents felt that preventative measures were possible and that directed accurate forecasts would have a meaningful effect on losses in the building industry.

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