DISEASE AND EMPLOYERS

LIABILITY INSURANCE

WORKING PARTY MEMBERS

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1. INTRODUCTION

- 1.1 Disease exposure in respect of Employer's Liability insurance is a key subject. Currently in excess of 50% of claims by number reported in Employer's Liability category is classified as a "disease", i.e. having a long potential exposure or development period. It is therefore vital for both pricing and reserving purposes that actuaries have a detailed understanding of these diseases, their causes, and the risk management process which will hopefully reduce the incidence of such claims.
- 1.2 Rather than give an overview of many diseases; industrial cancers and so on, it was thought appropriate to concentrate on three specific diseases. The three selected were Upper Limb Disorders, Deafness and Stress.

In addition rating and reserving issues will considered. These are vital for the sound financial management of an account writing business with a disease element.

1.3 In writing this paper we wish to thank the Loss Prevention Council for the use of the note on statistical analysis of deafness. This note was written by Orlando Machado and is based on work undertaken at Warwick University by Professor Copas, Bowater and Machado on data from the Medical Research Council collected by Dr Adrian Davis of the University of Nottingham.

2. OCCUPATIONAL ILL HEALTH

2.1 The Loss Prevention Council in its detailed resume "Occupational III Health in Britain" indicates the following statistics:-

In 1990 there were 2.5 million recorded health-impairing incidents in the workplace necessitating time off work. Seven hundred and fifty thousand of these related to occupational ill health, resulting in 13.5 million lost working days and costing employers nearly £600 million.

The estimated cost of Employer's Liability claims in 1991 was £589 million (excluding Lloyds). However, the total cost including lost productivity, replacement of plant and equipment, adverse publicity and so on has been estimated to be 5%-10% of profits, excluding public cost. All-in-all, it is estimated that the social and financial cost of Occupational III Health accounted for 2% of GNP.

- 2.2 Statistics are often misleading and it is extremely difficult to get an accurate assessment of the situation. These statistics are particularly influenced by misinterpretation, non-reporting and "flavour of the month". An example is the 20,000 cases of Carpel Tunnel Syndrome (Tenosynivitus) estimated for 1989. A number of these cases were not Tenosynivitus but other disorders. Deafness is the current largest source of EL disease claims, we estimate between 70,000-100.000 claims per year, whereas Occupational Deafness statistics indicate less than 500 new cases a year.
- 2.3 A paper on Occupational III Health could, therefore, be a compendium of 20 or more different diseases; cancers, asthma, vibration white finger and so on. Concentrating on three key diseases will enable actuaries to get a firmer feel for the extent of any problems and whether they are real or not. Similar understanding is needed for the other omitted diseases, however this would lead to a very long paper.
- 2.4 A definition is needed. In Employer's Liability a claim classified as an accident is made as a result of a specific event at a specific date. Conversely, a disease case has many years potential exposure. The current insured often deals with these disease claims, and apportions back the cost over the various exposure periods. Thus one claim can appear in the books of a number of insurers, leading to the multi counting of claim numbers.

Disease claims generally are based on apportionment, which is derived from market agreements. However, Tenosynivitus is not classified as a disease in

that the current insured is generally the responsible insurer and meets the claim in full. The exception is when a new insurer has taken over the risk, where a form of apportionment might take place in the first year.

2.5 Given that there is a need to concentrate on specific risks, three were selected. To a large degree they are "flavour of the month"; but this is the particular topical area where insurers should be concerned about the reserves and pricing issues. Accordingly, Upper Limb Disorders, Deafness and Stress were selected. In twelve months time this trio may be superseded by electromagnetic fields (EMF) or even the impact of polio vaccine on asbestosis claims.

After reviewing these risks, we turn to the rating and reserving issues and, in particular, the methods by which such risks might be funded.

3. UPPER LIMB DISORDERS - RSI

- The key work on this subject is Alan Tindall's excellent book "Tenosynivitus
 A Case of Mistaken Identify", published by Iron Trades. However, it would be useful to give a potted history.
- 3.2 Upper Limb Disorder is the term recommended by the Health and Safety Executive. The term Tenosynivitus ("Teno") is a particular condition of the wrist otherwise known as Carpel Tunnel Syndrome. Tenosynivitus is one of the few conditions that can be compensated under DSS Regulations, so there is a tendency for doctors to sign a complaint as "Tenosynivitus" for this reason. This has resulted in the high level of reported cases.
- 3.3 The alternative name used is repetitive strain injury (RSI). The term is about 12 years old but as a medical condition it has been known for centuries. Monks had it as "writers cramp". Other manifestations include "tennis elbow" and "housemaid's knee" to name but a few. The use of the term RSI has generated its own health panic and folk hazard. The normal cure for the majority of the conditions is to rest the limb.
- 3.4 RSI was first "discovered" in Australia and has spread like wild-fire. Most industrial diseases were focused on blue collar workers, but with this new phenomena the emphasis was shifted to white collar workers. The extent of the condition became an epidemic in the Australian Public Services and the concept was endorsed by trade unions, the medical profession and the press. With each press article the definition of "RSI" changed so there was no overall consistency. The problem is best illustrated with the following quote from the Australian Public Services in 1985.

"The difficulty on definition of RSI is due to the fact it is a generic term for a whole range of muscular-skeletal disorders. There is no common agreement on the lists of conditions in this range. Not all are repetitive, nor strain, nor injuries".

Littlejohn and Millar (I) attempted to clarify the issue by identifying three types:-

- *Type I* Clinical entities comprising inflammatory or degenerate soft tissue lesions or strains of the muscle-tendon unit.
- *Type II* Chronic pain syndrome in which there is no identifiable soft tissue inflammatory or degenerative change.

Type III A combination of I and II.

Type I includes Tenosynivitus.

All this confusion led to an eventual decline in the number of cases "Nowadays Australians wouldn't give a XXXX for RSI" (Pearce)

3.5 This type of history is not dissimilar to a typical "product cycle". Once the local market is saturated, the next step is to export - and indeed this is what happened. The disease was first identified in 1986 in the Spectator by Evelyn Waugh. The article was entitled "Introducing Kangaroo's Paw, a wonderful new disease from Australia".

"Briefly, RSI is the ache we feel when we do something too often or too long. It surfaces as tennis elbow, writer's cramp and in a thousand other discomforts. The normal treatment is to wait for it to go away. Since it was invented as a disease some six years ago, it has spread throughout the whole spectrum of employment". He concludes "I prophesy a tremendous future for this wxxxxx's disease in Britain, as soon as a few more people learn about it. It will go through the country like a dose of salts".

3.6 Having said all of this, there is clearly a danger of injury where repetitive manual work is involved. In Appendix 2 is set out a detailed analysis of a Tenosynivitus case for the period 1977-1982. No more complete up-to-date statistics exist. The new cases recognised for disablement benefit 1984-1991 indicates a range of 400-600 per annum.

In Appendix 1 is set out the industry where injury potential has been identified and the year. It can be seen that these all pre-date the RSI scheme.

- 3.7 In 1970 the University of Birmingham produced a report which indicated the type of industry where Upper Limb Complaint (RSI) had increased because of mechanisation. These industries are where emphasis is on:-
 - (1) Higher rates of repetition.
 - (2) Segmentation and specialisation.
 - (3) Working pace.
 - (4) Incentive schemes.
 - (5) Concentration on certain parts of the anatomy.
- 3.8 The broad conclusions of the above are:-

- (1) The disease has been recognised for some time.
- (2) We are going through a possible "flavour of the month" surge particularly based on the Australian experience.
- (3) The claims cost can be controlled by prudent underwriting and effective risk management of working practices as many of the issues have been known for many years.

4. INDUSTRIAL DEAFNESS

4.1 Approximately 40-50% of all Employer's Liability claims by number are due to Industrial Deafness. As such they currently form an integral part of the EL disease problem.

The problem is a complex one in that there are a number of key dates and regulations which at first recognise the issue and then seek to manage the risk. The basic problem is that industry has failed to recognise and manage the problem effectively, giving an opportunity for claims to be made which may not be valid.

- 4.2 In insurance, the aim is to compensate for injury and nothing else. Thus if a party which had a digit already missing has a second finger amputated, then compensation is made for the loss of one finger and not both. This is not necessary for deafness claims. Basically, an award for deafness is made by the case for comparison of the hearing loss at any time against a set norm. The basis of the calculation is given in the tables appearing in "Assessment of Hearing Disability" by Kings, Coles, Lutman and Robinson commonly known as the "Black Book". This issue will be returned to later.
- 4.3 The first key date is 1963 when a pamphlet entitled "Noise and the Worker" was produced. This gave the first indication of the problem, and exposure prior to this date is generally ignored. The second key date is 1974 with the Health and Safety at Work Act, together with guidance notes from the Health & Safety Executive Code of Practice for reducing the exposure of employed persons. In 1986 an EEC directive was published entitled "The protection of workers from risks related to exposure to noise at work" which was implemented in the UK under the Noise at Work Regulations 1989. This regulation gives three action levels. The first where an individual has a daily continuous noise exposure of 85dB(A); the second at 90dB(A) and the third where there is impulse noise with a level peak sound pressure exceeding 200 pascal. All this may sound complex to a beginner, so it is best to go back to basics.
- 4.4 The basic tool for measuring hearing is an audiogram. This measures the level of hearing in each ear at various frequencies, usually 0.25Khz, 0.5Khz, 2Khz, 3Khz, 4Khz, 5Khz, 6Khz, and 8Khz. Basically a sound is emitted at these frequencies and the level at which they fail to hear the sound gives the mark on the audiogram. This level is measured in decibels dB(A). The

hearing loss is then determined by taking the average of this figure over a specific range and comparing it with a figure from a standard table.

4.5 There are a couple of things to note from this approach. Firstly, that dB(A) is a relative and not absolute measure and is also on a log scale. Odb does not mean no sound. As it is a relative measure, the audiograms may not be consistent and are in need of regular calibration. A typical reading could be out as much as 5db from the "true" reading.

Secondly, the table that the risk group needs to be compared with is important. The social status of an individual is a factor which has been identified. White collar workers tend to have a 5db better hearing level than Blue Collar workers when all other factors are removed. Tables based on military personnel often have a bias towards the officer classes i.e. "too many chaps and not enough blokes".

Thirdly, the tables currently used have no feeling of "width" or deviation, being based on expected values with no reference to standard deviations. There is no measurement of "false positives", i.e. a possibility of hearing loss which may not be due to industrial noise.

- 4.6 When a claim is made, it is usual for one audiogram to be taken. This gives the current state of hearing. It is unusual for an initial audiogram to be taken on joining work and then up-dated regularly. Those industries that undertake regular audiometric readings have distinct advantages in defending claims in that they can identify the possible causes and put in preventative actions. The failure of an individual to wear hearing protectors when he has been officially warned is often evident of contributory negligence.
- 4.7 With these problems in mind, the University of Warwick team, under Professor John Copas, have been analysing data collected by the MRC by Dr Adrian Davis. This is an attempt to get a better understanding of the relationships between age, sex, social class, noise levels and hearing loss. A summary of the model is given in Appendix 4. This research has been sponsored by LPC and the Working Party is grateful for permission to publish this preliminary document. A full paper by Professor Copas et al entitled Hearing Impairment and the Log Normal Distribution has been submitted for publication in Applied Statistics (Series C of the Journal of the Royal Statistical Society).

This work indicates a possible approach but is not the final word on the topic. There are many complications still under discussion, for example the stratified nature of the MRC data. Until these are resolved caution is needed

in interpreting the model prediction. As a word of caution, the authors have indicated they would be unhappy if someone used the model in a mechanical or uncritical way without really understanding the nature of statistical model or being aware of the assumptions on which they are based.

4.8 The current method of assessing hearing loss is described in depth in the Black Book. This is based on H₁₂₃ being the average of Hearing Threshold Limit at 1, 2 and 3KHz. The level of disability is given by:-

 $D = U - 4.08173 \exp \left[0.11712 (4.08173 - U) \right]$ when $U = 100 \exp \left[-\exp(1.05594 - 0.0125309H_{122} - 0.000185186H^2_{122}) \right]$

An adjustment is made for the worst hearing:-

 $Heff = H_{123} + 10 - 33 \log (1 + 10^{\Delta/33}) \Delta$

Heff = effective hearing loss

 Δ = difference between ears

Basically what happens is the resulting disability is calculated and then deducted from the expected hearing loss for a particular age. For example if a claimant has Σ II = 150 over three ranges then the normalised hearing loss is 38%. From an alternative table for a male aged 60, the age related loss is 7%, giving an impairment of 31% for this individual.

The calculations assume a degree of uniformity independent of age. This is not found in practice.

- 4.9 Assessing the exposure to noise is difficult. Hearing loss research assumes the principle of equivalence of noise, ie a short time of very loud noise is equivalent to a long time of lower noise level. This may not be the case.
- 4.10 The "Warwick" model differs substantially from these approaches as it models statistically the distribution for each age, using a lognormal distribution in which both mean and variance depend on age, sex, social status and degree of noise exposure. The variance has an interesting feature in that it decreases after reaching a peak at or around 70.

When distributions of the same age and status, but different NIRO status are overlaid, the close proximity of the means and the shape of the distribution become apparent. With claims being based on 15db loss or higher based on one reading, the possibility of a "false positive" i.e. making a claim payment to someone with a non-noise induced hearing loss, is high.

- 4.11 The market practice is dominated by the Iron Trades agreement. Under this agreement any member of a specified Trade Union who suffers hearing loss based on a current audiometer reading is given compensation. The non-agreement market tends to follow the same features. What is really needed is audiograms on recruitment and at regular intervals to assess any actual hearing loss.
- 4.12 The Warwick model is "latitudinal" in that it tells the distribution of the hearing level for individuals. This is of help in the compensation calculation, but has limited help in assessing rating and reserving models. This can best be achieved by a longitudinal model which relates how individuals with certain degrees of hearing loss progress. Is there a sudden or gradual breakdown of hearing? Further studies are required on this issue.
- 4.13 Other issues which might be considered are as follows:-
 - (1) At the time an individual is employed, in the current economic environment, the level of hearing may be better than the average. This is because employers are naturally selective.
 - (2) Some hearing loss is not due to noise. Age is a major factor. Other examples include the possible impact of diet (i.e. lower class diets may result in adverse hearing) or due to hazards such as chemicals in the atmosphere (e.g. benzene). The assumption that industrial deafness is entirely noise related is invalid.
 - (3) The legal profession has not seen the Warwick model. Models based on actuarial or statistical analysis involving anything other than a "mean" are frequently misunderstood by judges. Anything different from the mean is exceptional.

5. STRESS

- 5.1 Stress is a factor in everyone's life arising from various sources, the two main of which are family and work. The difficulty is when stress becomes more than a motivation, but a disadvantage and an impairment to a happy and fulfilled life. Jobs are the number one source of stress for 36% of Americans, especially those with high incomes.
- 5.2 The World Labor Report of 1993 for the International Labor Organisation found that job related stress costs the US economy more than \$200 billion annually. This amount results from:
 - (1) reduced productivity
 - (2) increased workers compensation claims
 - (3) increased absenteeism
 - (4) increased health insurance costs, and
 - (5) increased direct medical expenses
- 5.3 Stress related claims accounted for only 5% of all US occupational disease claims in 1980 but increased to over 15% by 1989. Similarly, the State of California saw a seven-fold increase between 1979 and 1988 in job related stress claims. Comparable trends are apparent worldwide, even in Japan. Forty percent of all Japanese workers fear that they will literally work themselves to death (karoshi).
- 5.4 People are becoming more aware of the effects of stress. Stress related physical or mental conditions include:
 - (1) fatigue
 - (2) tight neck or shoulder muscles
 - (3) feelings of anger or anxiety
 - (4) insomnia
 - (5) headaches
 - (6) inability to relax after work
 - (7) difficulty with family members
 - (8) lost interest in friends, hobbies or other outside activities
- 5.5 These conditions lead to such stress related disabilities as:
 - (1) anxiety
 - (2) depression
 - (3) ulcers

- (4) colitis
- (5) hypertension
- (6) headaches and/or migraines
- 5.6 In addition, job related stress leads to job burnout, performance problems and serious physical and emotional complications.
- 5.7 Most stress claims are probably legitimate, however it is very difficult to determine how much of the stress, if any, is related to a person's employment and how much to other factors. In a recent study by St Paul Insurance Company, 25% of respondents reported 'significant personal life problems' caused by their jobs. Nearly 50% cited problem supervisors as the primary cause of stress. Job related stress is more detrimental to job performance than some of life's worst traumas, such as a death in the family.
- 5.8 The five major factors contributing to employees increasing stress levels are:
 - (1) too many constraints on how to do job
 - (2) substantial cuts in employee benefits
 - (3) merger, acquisition or change in ownership
 - (4) frequent, mandatory overtime
 - (5) layoffs or other reductions in the size of the workforce
- 5.9 The most important factor is lack of control over ones own job.
- 5.10 Interestingly enough, job related stress affects blue collar workers as much as white collar workers. In fact, manual workers such as assembly line and miners have the highest levels of stress which is attributed to the problem of working with pacing machines. Additionally, employees whose jobs have inherently stressful aspects (police officers, firemen and medical workers) say that more stress is connected with organisation and management of their work than the work itself. VDT operators whose jobs are electronically monitored by their supervisors also experience high stress levels.
- 5.11 Studies show that employees feel less stressed about their job if they have control over their work and support from their supervisor. Additionally, if jobs are stressful, anxiety and depression are high unless the quality of workers' relationships with their families is good. Companies can reduce their employees stress by instituting:
 - (1) supportive work and family policies
 - (2) flexible work schedules

- (3) improved communication between management and employees
- 5.12 Traditional stress related workers compensation claims in the US were caused by a physical blow or trauma from other workers causing a disabling mental or nervous disturbance, "traumatic neurosis." Sometimes these cases are called "physical-mental". Other traditional cases are ones in which the original injury or stimulation is a mental or nervous shock that causes a disabling physical reaction, often called "mental-physical."
- 5.13 The newer and more problematic cases are the "mental-mental" claims. These are ones where the mental disability is caused by a mental stimulus. It is very difficult to prove that these types of claims are job related since there is no physical corroboration for either the stress or the disability. Other factors such as personal relationships, personality disorders and financial considerations also play a part. Also, uncertainties inherent in psychiatry make it difficult to determine whether the employee was mentally ill before the accident. Finally, there is concern if a workers compensation claim is compensable if work-related stress aggravates a pre-existing condition.
- 5.14 In the first mental-mental claims, compensation was given if there was a sudden and horrifying experience. In more recent compensable mental-mental claims, no ascertainable horrific physical event is alleged. The individual states are only now beginning to set boundaries for such mental-mental cases. In the 1980's in California, stress claims were considered compensable under workers compensation if as little as 10% of the stress was job related. This has recently been changed to 40%.
- 5.15 The California Workers Compensation Insurance Rating Bureau investigated job related stress claims. They found that the average annual increase in the number of psychiatric claims from 1980 to 1989 was 22.1% while from 1989 to 1991 the increase was 42.6%. The average annual change in frequency (number of claims per 1,000 workers) from 1986 to 1989 was 25.5% while from 1989 to 1990 it was 41.6%.
- 5.16 The following table shows that while the average amount of a stress claim may have decreased slightly in California, the number of claims is still increasing:

Type of Claim	1989	1990	Change
Pure Mental-Mental			
Frequency per mille	0.6	0.8	33.3%
Average Cost \$	15,318	19,830	29.5%
Mental-Physical			
Frequency per mille	1.1	2.0	81.8%
Average Cost \$	20,249	18,347	-9.4%
Physical-Mental			
Frequency per mille	2.5	3.4	36.0%
Average Cost \$	35,469	29,640	-16.4%
Total Claims			
Frequency per mille	4.2	6.2	47.6%
Average Cost \$	28.742	24.808	-13 7%

California WCIRB Study

- 5.17 Suggestions for cost cutting measures for both insurers and employers include:
 - Requiring a panel of experts (two psychiatrists) to objectively determine causation and degree of disability and to concur on diagnosis.
 - (2) Periodically re-evaluate claims for both extent of impairment and causation.
 - (3) Require two years from time of original diagnosis until the disability
 - is considered permanent.
- 5.18 Suggestions to employers for preventing job related stress in the first place include:
 - (1) formulate a preventative strategy
 - (2) develop a stress diagnostic system
 - (3) involve top management in setting priorities and development programs for stress reduction
 - (4) monitor effectiveness of these programs
 - (5) document all efforts

- 5.19 Once an occupational stress claim is filed, suggestions for claims management include:
 - (1) making sure that the mental malady is not a pre-existing condition
 - asking other workers about the incident supposedly resulting in disability
 - (3) obtaining information about the claimant's background
- 5.20 The best strategy overall, however, is to teach workers how to handle job pressures and reduce the level of workplace stress.
- 5.21 Anyone wishing to review further the causes and control of stress is recommended to read the book "Why Zebras don't get Ulcers" by Robert M Sapolsky.

6. RESERVING, RATING AND ACCOUNTING

- 6.1 It is impossible to establish precise reserving procedures. However, disease reserving models will tend to have the following features:-
 - (1) They can be expressed simply as a multiple of current annual paid losses.

The level of this multiple gives an indication of where the reserver views the losses in the current cycle.

- (2) The reporting/payment pattern generally starts slowly, reaches a peak and then dies down; often rapidly. It is akin to a product cycle. Underlying this may be a constant flow of regular claims. The "product cycle" approach recognises that when there is a problem and everyone jumps on the band wagon. When a company undertakes appropriate risk management, the problem tends to be mitigated and eventually disappear over time.
- (3) The extent of the cycle is proportional to the extent of any redundancies, or lay offs in the workplace. Redundant workers tend to try and obtain as much as possible as there is little downside in indicating that they are hard of hearing. They may feel that a claim while in full-time employment may prejudice their future with their employees. Redundant workers are also more susceptible to trawling lawyers.
- (4) The extent of lawyers trawling and advertising for claims.
- 6.2 The Actuary also should be aware that in this modelling, some of the future claims are not true IBNR's but relate to further exposures. The insurer may not be the carrier of the risk at the time a claim is made and may only be "proportionally" responsible.

Once the pattern has been established then the number of expected claims in a period is multiplied by an expected average cost to give a reserve.

6.3 Having viewed the disease reserve line by line the Actuary then needs to review the aggregate extent of any such reserve. Does the sum of the parts contribute to the whole, or is there likely to be additional reserves needed for unknown claims? Should a claim equalisation (catastrophe) reserve be incorporated?

6.4 There are one or two issues linked with the approach. Most disease claims have lawyers involved and there is thus a finite limit to how may claims they can handle. However, as soon as one series of claims declines or is eventually managed by the insurers limiting the lawyers involvement then they will search for a new type of claim.

One could argue there is thus a continuous potential for disease claims to arise in one form or another and that all Employer's Liability accounts are open to new disease claims, some of which may be of current little concern. It should be noted, however, that deafness and asbestosis were considered to be of limited consequence and restricted to a few specific industries only to later explode into the problems we have today.

- 6.5 To summarise:-
 - (1) Reserving for disease claims should take account of the likely profile of claim notifications; including the level norm. In principle the claim numbers need to be split into regular and "surge" claims. This could be done on a policy industrial classification basis, because different industries are in different parts of the cycle. It also involves old policies, so an accurate record of these must still be maintained.
 - (2) Exposure analysis is also part of the reserving process.
 - (3) Consideration could be made for unknown diseases through an equalisation reserve. This will be considered later.
- 6.6 The basic issues in pricing may be summarised as follows:-
 - (1) How much should be allowed for future exposure to known diseases.
 - (2) How much should be allowed for future exposure to unknown diseases.

These questions are answered by getting the balance "right", i.e. what the market believes should be charged. The competitive nature of the business stops overpricing but not underpricing!

6.7 There is a natural relationship between pricing and reserving. Historically, because of the absence of any specific reserve for latent claims, this part of the premium has transferred through directly to the Profit and Loss account and then transferred out to shareholders in the form of dividends. When the claims arise a shortfall is encountered and shareholders and management

speculate why such a profitable account should suddenly turn bad, and look around for the villains. The need for some form of equalisation reserve becomes apparent and is justified by historic trends. However, caution is needed.

6.8 Claims Equalisation Reserves ("CER") are currently under discussion by a Joint Working Party consisting of the Association of British Insurers, the Government Actuary's Department, the Department of Trade and Industry and the Inland Revenue. It appears that current thinking is that CER will be built up by the transfer of defined percentages of annual net premium income for specific classes of business up to a statute defined limit for those classes. Transfers out of the equalisation reserve will then be made by a company satisfying a loss ratio or loss event criteria (again enshrined by statute by class of business).

The exact workings and details of CER are currently under discussion at the time of writing this document. However, it would appear that the operation of such a statute based system could ensure that equalisation reserves are created on a level playing field for insurers. As such, it should assist in the rate setting process by enforcing utilising a proportion of net premium income to build up a CER, which could then be utilised to mitigate adverse loss development for latency/unknown claims, which one might regard (or be able to be regarded) as a catastrophic event. A word of caution is required here, as the "current thinking" has not included liability in the permitted classes for the setting up of a CER, the current emphasis being directed towards short-tail property, and Marine and Aviation risks.

- 6.9 A level playing field does not mean the reserving basis is similar. A company with only 5% of its portfolio in a class has a different consideration of materiality to one that has 40% of its business in the same class. A 100% error is a nuisance to one operation but will certainly make the other insolvent!
- 6.10 Equalisation reserves are the answer only if all companies agree and a specific formula for transfer is established. It needs the influence of the industry and Government to solve the problem, and a degree of compulsion, as recognised in catastrophe reserves, is needed. The current debate on catastrophe equalisation reserves indicates the need for a compulsory mechanism. Once this is established, there is a cascading impact on pricing, profitability and other reserving issues.

7. RISK MANAGEMENT AND OTHER ISSUES

- 7.1 Employers Liability insurance premiums are just one element of the cost to industry of Occupational III Health. Accordingly it is in the interest of both employers and insurers to maintain a good health standard at work. The absence of good risk management can only lead to the eventual downfall of the company.
- 7.2 As the cost of Occupational III Health is substantial, it is vital for an industrial concern to have a strategy, led and formulated by top management. This is similar to the suggestion in 5.18(3). Once a strategy is formulated, its progress needs to be monitored.
- 7.3 One of the difficulties of developing such a strategy is the apparent cost/benefit. The Company's risk management strategy will not have immediate impact. An employee subject to high levels of noise still requires several years exposure before deafness is diagnosed. The issue is similar to insurance companies where policies issued by one underwriter may not give rise to claims until after he has retired. The sins of one generation are passed down to another.

It is therefore difficult, on current rating methodology, to allow for the full potential of any preventative measures by a reduction in premium. One solution may be joint ventures between insurers and insureds where the former offer a consultancy service on the risk management aspects for a potential saving, in much the same way as Environmental Impairment Liability insurance is placed. This will ensure a satisfactory standard is in place.

- 7.4 Another issue is the control placed by management on safety issues. Does a worker without earnuffs in a noisy environment get an official warning if found out? Does the 'trade union support such initiatives? Making cost centre managers pay for its own claims, and rewarding accordingly for good claims experience is a wonderful incentive.
- 7.5 Once a claim is made, how do insurers control the claim process? Most claims are made through legal representatives; usually union lawyers. Lawyers have been known to trawl for claimants by waiting at factory gates, mail shots, and even with the support of a Local Authority! The reaction of the insurers to a flood of claims, and the management of the claims process is vital. Savings in legal costs have been made by the establishment of settlement and quantum with individuals seeking compensation through Trade Unions. Certainty of quantum is guaranteed against the uncertainty of

8. AND FINALLY

8.1 The understanding of industrial diseases and the consenquences from the Insurance Business is an essential part of any General Insurance Actuary's education. The number of contingencies and possibilities outweigh those in other parts of the business.

The Casualty Actuarial Society was created in United States to study and advise on Workers Compensation Schemes. Even in the U.S. there is still not a great depth of knowledge or expertise of industrial diseases.

- 8.2 We believe this paper lays the foundation for further indepth research into the problems, and the financial management of the issues, be they by insurance, social welfare, or risk management techniques. The research work on diseases started by the LPC initiative will continue and assist in this process. Actuaries need to be aware and be part of such initiatives.
- 8.3 The management of the issues relating to industrial diseases has common theme namely that of risk management as opposed to insurers pricing out or excluding the problem. The uncertainty is more difficult to handle than many other risks. As management of such uncertainty is a key role of actuaries, an understanding of these issues is needed.
- 8.4 This is not the end, but the beginning of further actuarial involvement into the issues surrounding Industrial Occupational Diseases.

m worddata/giro/disease

an expensive legal system. Such agreements also became the standard for settlement outside such arrangements.

REFERENCES

GENERAL

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RSI

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APS Australian	Repetitive Strain Injury in the Public Service <i>A Task Force Report (1985)</i>
Waugh wonderful	Introducing Kangaroos Paw, a new discase from Australia Spectator 15 November 1986
Littlejohn & Miller	Repetitive Strain Injury; divide and conquer Australian Family Physician - Vol. 5 No. 4 pages 409-413

Other Reading

HSE (1990)

Work related Upper Limb Disorders HMSO

Other Reading

HSE (1990)	Work related HMSO	Work related Upper Limb Disorders HMSO			
BAC (1992)	Work related Upper Limb Disorders (HMSO)				
	DEAFNESS				
King, Coles, Lutman & Robinson	l	Assessment of Hearing			
Disability		Whurr Publishers 1992			
The Effects of Occupational Nois Re Development	e on Hearing:	Loss Prevention Council 1991			
The Noise at Work Regulations 1 and their Insurance Regul	989 ations	Loss Prevention Council 1991			
Bowater, Copas, Machodoz Davi	s	Hearing Impairment and the Log-Normal Distribution (to appear)			

STRESS

Sapolsky (Robert) Why Zebras don't Get Ulcers W H Freeman & Company New York 1994;

<u>Tenosynivitus</u> <u>Recognised Traders</u>

(from Tindall)

	Tobacco and Tea Packers	(1931)
	Agricultural Works	(1942)
	Fitting and assembly work in car industry	(1951)
	Braiders in Ropemaking	(1951)
	Hop Pickers	(1955)
	Carpenters, Upholsters and Linoleum Fitters	
	hammering nails	(1955)
	Core Making and Ramming	(1954)
1965	HM Inspector of Factories Report	
	Packaging of Food	
	Typing	
	Comptometer Operating	
	Sewing Machinery	
	Chicken Preparing	
	Metal and Woodworking	
	Gardening	
	Hop Picking	
	Upholstery	
	Net and Grommet Making	
1970	University of Birmingham Report	
	Bricks - hand making, handling, laying	
	Chicken - eviscerating, trussing, packing	
	Engineering - press operating, HGV assembly	
	Food preparation for canning	
	Boot and Shoe industry	
	Furniture manufacturing	

<u>Tenosynivitus</u> <u>Total Number of Spells of Tenosynivitus 1977-1982</u>

	Industry Classification	Number			
I	Agriculture, Forestry and Fisheries	629			
II	Coal Mining	414			
	Other Mining and Quarrying	109			
III	Food, Drink and Tobacco	2,301			
IV	Coal and Petroleum Products	25			
v	Chemicals and Allied Industries	416			
VI	Metal Manufacture	598			
VII	Mechanical Engineering	910			
VIII	Instrument Engineering	153			
IX	Electrical Engineering				
Х	Shipbuilding and Marine Engineering	90			
XI	Vehicles	622			
XII	Metal Goods not otherwise specified				
XIII	Textiles	705			
XIV	Leather, Leather Goods				
XV	Clothes and Footwear	677			
XVI	Bricks, Pottery, Glass, Cement etc.	948			
XVII	Timber, Furniture etc.	468			
XVIII	Paper, Printing and Publicity				
XIX	Other Manufacturing Industry	846			
III-XIX	All Manufacturers	11,509			
XX	Construction	1,361			
XXI	Gas, Electricity and Water	233			
XXII	Transport and Communication	328			
XXIII	Distribution Trades	1,155			
XXIV	Insurance, Banking, Finance etc.	146			
XXV	Professional and Scientific				
XXVI	Miscellaneous Services	544			
XXVII	Public Administration, Defence	477			
	Industry not known	417			
	All Industries	17,804			

Source - HSE Health & Safety Statistics 1988

Black Book Hearing Model

Age	M	%	F	%	Age	M	%	F	%
18	0	2	0	2	46	20	4	15	4
19	0	2	0	2	47	20	4	15	4
20	0	2	0	2	48	20	4	15	4
21	0	2	0	2	49	20	4	15	4
22	0	2	0	2	50	25	5	20	4
23	0	2	0	2	51	25	5	20	4
24	0	2	0	2	52	25	5	20	4
25	0	2	0	2	53	30	6	20	4
26	0	2	0	2	54	30	6	25	5
27	0	2	0	2	55	30	6	25	5
28	0	2	0	2	56	30	6	25	5
29	5	3	0	2	57	35	7	25	5
30	5	3	0	3	58	35	7	30	6
31	5	3	5	3	59	35	7	30	6
32	5	· 3	5	3	60	40	7	30	6
33	5	3	5	3	61	40	7	30	6
34	5	3	5	3	62	45	8	35	7
35	5	3	5	3	63	45	8	35	7
36	5	3	5	3	64	50	9	35	7
37	10	3	5	3	65	50	9	40	7
38	10	3	5	3	66	50	9	40	7
39	10	3	10	3	67	55	10	40	7
40	10	3	10	3	68	55	10	45	8
41	10	3	10	3	69	60	11	45	8
42	15	4	10	3	70	60	11	45	8
43	15	4	10	3	71	65	12	50	9
44	15	4	10	3	72	65	12	50	9
45	15	4	15	4	73	70	13	55	10

Warwick Study

Department of Statistics

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Statistical Analysis of Hearing Loss Data: A summary of the models developed at the University of Warwick

1 Introduction

Analysis of the Nottingham MRC hearing loss data was carried out with the aim of relating the probability distribution of an individual's hearing threshold level (HTL) to a series of measurable quantities. Ideally, we would wish to be able to determine the probability of a person's HTL lying within any specified range of values, once a set of characteristics about that person were known.

The two principal questions asked were:

- What particular information appears to be most predictive of the distribution of HTL?
- 2. How, in mathematical terms, can we link this information, for any particular individual, to his HTL?

As discussed previously, the research centered around using the information (explanatory variables) to construct a lognormal distribution to model the variation in HTL: each of the three parameters of this distribution was related to the values of the explanatory variables via a mathematical function.

Figure 1 illustrates that, despite the fact that different samples of individuals show hugely different values of HTL, each distribution appears to be well described by a lognormal distribution (shown by the solid line).

2 The Models

Four different statistical models have been developed:

- Model 1 A model for the distribution of the average of the HTLs measured at 1, 2 and 3 kHz, for the better ear.
- Model 2 A model for the distribution of the HTL for the better ear, taken at 4kHz.

Model 3 As 1, but more specifically suited to individuals over the age of 50.

Model 4 As 2, but more specifically suited to individuals over the age of 50.

Models 1 and 2, covering all ages, give an acceptable fit to the observed data. However, the lognormal distributions seemed to fit particularly well for the older subjects (those over 50), so models 3 and 4 were developed separately.

The explanatory variables used for each model are as follows:

1. Age.

- 2. Sex. Taken to be 1 if the individual is female, and 2 if male.
- Socio-economic grouping. Taken to be 1 for non-manual workers, 2 for manual workers.
- 4. NIRO level.
- 5. Answer to the question: "Have you had to raise your voice to be heard at work in the last six months?" Taken to be 0 if "no." 1 if "yes."

The choice of explanatory variables was, in each case, a purely statistical one, based upon the evidence of the MRC survey data. Other variables may, of course, be related to HTL, but their effect on HTL is adequately subsumed in the basic variables given. Once these variables are specified, no other factor measured in the survey appears to have any additional "statistically significant" role in explaining the observed variation in HTL.

Model 4 is notable for the *absence* of the Noise Question from its list of explanatory variables. This might simply be due to the fact that the model was developed with a greatly reduced sample size (those over 50 years of age only).

The value of each variable directly affects the form of the predicted probability distribution. Furthermore, variables do not necessarily act "additively"; the value of one can affect the role of another. The models automatically allow for such interactions between variables.

3 How do the variables affect predicted distributions?

Figures 2 and 3 attempt to show the effect of some explanatory variables upon the distribution of HTL, as predicted by the models. They are only examples of the models' capabilities, many others might have been chosen.

Figure 2 describes the effect of noise on the predicted HTL distribution (at 4 kHZ) for a 50 year old male manual worker. The graph displays Model 4's prediction of the cumulative probability distribution function, that is to say the probability that his HTL lies *below* a specified level. For example, it is seen from the graph that, at NIRO level 0, the probability that a 50 year old male manual worker's HTL at 4 kHz is less than 20 dB is roughly 0.3, or 30%. As NIRO increases, the function is shifted further and further to the right. This shows that the probability that his HTL lies below a particular level *decreases* with increased noise exposure. Note that percentiles can be read from such a graph, where u is the $100p^{th}$ percentile if the probability that the HTL lies below u is p. This is done by fixing p on the y-axis, and reading off the corresponding *x*-axis value

Figure 3 illustrates the way in which NIRO level alters the predicted HTL probability distributions for male manual workers of different ages. The median, or 50th percentile, is shown—this can be thought of as a measure of the "midpoint" of the distribution. The graph shows that increasing NIRO and increasing age both have the effect of raising the median non-linearly (the age effect markedly so). The Noise Question is also seen to change the medians for the lower ages (which were calculated with Model 2)—an answer of "yes" leads to a higher predicted median than an answer of "no." The medians for the older ages were calculated using Model 4.

4 A comparison of the model to empirical data

Figure 4 shows a comparison between percentiles of HTL predicted using Model 2, and those estimated directly from the MRC data. The dotted lines represent modelled values, whereas the points are empirical values. The graph demonstrates the pleasing correspondance between the two, especially for those percentiles towards the middle of the distribution, for example the median.

When inspecting such a diagram, it must be borne in mind that any percentile estimated from data is highly susceptible to sampling variation, which increases as we try to draw inference about the tails of the distribution (the 5th and 95th percentile). Furthermore, the estimates have less precision as the sample size decreases, as is the case with older ages.

5 Applications of the model

The Appendix gives the formulae which link a person's explanatory variables to the parameters of his predicted HTL distribution. Given this information, we can derive informative characteristics about this distribution.

This can be illustrated with some examples:

Example 1 Mr. Brown is a 40 year old male manual worker. His NIRO level has been assessed as 2, and he has answered "yes" to the noise question. Substituting this information into the equations for Model 1 yields parameter values $\alpha = -10.6$, $\mu = 3.13$ and $\log \sigma^2 = -1.63$, so $\sigma = 0.442$. Thus we can calculate the mean of the distribution of the average HTL over 1, 2 and 3 kHz to be

Mean =
$$-10.6 + e^{3.13 + \frac{1}{2} \times 0.442^2}$$

= 14.6dB

Example 2 Mrs. White is a 35 year old female non-manual worker, with NIRO level 0, and has answered "no" to the noise question. Using the equations for Model 2, we calculate $\alpha = -20.5$, $\mu = 3.29$ and $\log \sigma^2 = -2.18$. thus $\sigma = 0.336$. We now derive the median. Note that in the percentile formula, the $\sigma \Phi^{-1}(p)$ term disappears, since for the median, p = 0.5, and $\Phi^{-1}(0.5) = 0$. Therefore,

Median =
$$-20.5 + e^{3.25}$$

= 6.34 dB

Hence there is a 50% chance that her HTL at 4 kHz is less than 6.34 dB. Example 3 Mr. Orange, aged 55, is a non-manual worker. His NIRO level is 1, and his answer to the noise question is "no." Model 3's equations lead to parameter values $\alpha = -9.44$, $\mu = 3.15$ and $\log \sigma^2 = -1.66$, giving $\sigma = 0.436$. The 75th percentile is

75th percentile =
$$-9.44 + e^{0.436\Phi^{-1}(0.75)+3.15}$$

= 21.9dB

So there is a 75% chance that the average of his 1. 2 and 3 kHz HTLs will lie below 21.9 dB.

Example 4 60 year old Miss Pink is a manual worker with NIRO level 3. She answered "yes" to the noise question. The formulae for Model 4 tell us that $\alpha = -11.7$, $\mu = 3.78$ and $\log \sigma^2 = -1.77$, thus $\sigma = 0.414$. We now work out the percentage exceedance at 25 dB:

Exceedance =
$$100 \times (1 - \Phi(\frac{\log(25 + 11.7) - 3.78}{0.414}))$$

= 67%

which is the probability that her HTL at 4 kHz is greater than 25 dB.

6 Limitations of the model

Analyses of the models' fit to the MRC data have demonstrated that they provide acceptable predictions of the central portion of a probability distribution.

When used for this purpose, the models can be a powerful tool, as they provide means for calculating, amongst other things, quantities such as percentiles and exceedances (see above).

It has, however, been asserted that predictions made about the form of the extreme tail ends of a distribution are made with rather less confidence. and are to be used with caution.

For a technical appraisal of the model checking techniques, see Russell Bowater's report.

7 New developments

A characteristic of the lognormal distribution is that a random variable with this distribution cannot take any value below a "threshold" parameter. The statistical modelling procedure involves estimating this parameter from data, a process which has always been very sensitive to the low values in the data set. In particular. *just one* unexpectedly low data point could drastically alter the form of the fitted distribution—a trait which is undesirable when, for example, the low extremity might simply be the result of experimental error.

Current research involves modifying the distributional assumptions in order to increase "robustness" of the modelling technique to outliers in the data set, whilst retaining the descriptive power of the lognormal distribution.

8 · Appendix

The modelling assumption is that, if X is the random variable defined by a person's hearing threshold level, then X has probability density function

$$f(x|\alpha,\mu,\sigma) = \frac{1}{\sqrt{2\pi}\sigma\log(x-\alpha)}\exp(-\frac{(\log(x-\alpha)-\mu)^2}{2\sigma^2})$$

where α , μ and σ are fuctions of explanatory variables.

Once α , μ and σ are known, they can be used to calculate useful quantities associated with the probability distribution:

• The mean of the distribution is

$$Mean = \alpha + e^{\mu + \frac{1}{2}\sigma^2}$$

• The variance of the distribution is

$$Variance = e^{2\mu + \sigma^2} (e^{\sigma^2} - 1)$$

• The (100p)th percentile of the distribution is

$$(100p)^{th} percentile = \alpha + e^{\sigma \Phi^{-1}(p) + \mu}$$

where Φ represents the cumulative distribution function of a standard Normal N(0, 1) random variable.

• The percentage exceedance at x dB is

$$Exceedance = 100 \times (1 - \Phi(\frac{\log(x - \alpha) - \mu}{\sigma}))$$

8.1 Evaluating the parameters from the explanatory variables

In order to calculate the values of α , μ and σ for a particular individual, it is first necessary to determine which of the four models seems most appropriate (see main body of text).

The parameters are then evaluated using the formulae below, where

- S is the individual's sex, coded as 1 for female and 2 for male.
- A is his age.
- M is his job category, coded as 1 for a non-manual worker and 2 for a manual worker.
- Ni is his NIRO noise category.
- Nq is his answer to the noise question mentioned earlier, coded as 0 for a "no" and 1 for a "yes."

Note that formulae for $\log \sigma^2$ rather than σ itself are given— σ can be determined directly from these.

Model 1

 $\alpha = -14.60 + 0.1004 \times A$ $\mu = 3.594 - 0.6483 \times S + 0.07260 \times M - 0.05183 \times A +$ $0.0006857 \times A^{2} + 0.06817 \times Ni + 0.02718 \times A \times S -$

$$0.0002591 \times A^2 \times S + 0.09237 \times (S-1) \times (M-1) +$$

 $0.09173 \times Nq$

$\log \sigma^2 =$

$$\begin{aligned} &-1.895 \pm 0.4294 \times S \pm 0.6878 \times M - 0.09936 \times A \pm \\ &0.003415 \times A^2 - 0.00002587 \times A^3 - 0.3390 \times Ni \pm \\ &0.1208 \times Ni^2 - 0.009528 \times A \times S - 0.01061 \times A \times M \end{aligned}$$

Model 2

$$\begin{aligned} \alpha &= -12.82 - 7.650 \times S \\ \mu &= 2.342 + 0.6132 \times S + 0.04586 \times M + 0.04193 \times A - \\ &= 0.001027 \times A^2 + 0.00001007 \times A^3 + 0.05743 \times Ni - \\ &= 0.03477 \times A \times S + 0.0009924 \times A^2 \times S - \\ &= 0.000008178 \times A^3 \times S + 0.08019 \times (S - 1) \times (M - 1) + \\ &= 0.05434 \times Nq \end{aligned}$$

 $\log \sigma^2 =$

$$\begin{aligned} -2.283 &= 0.3547 \times S + 0.9021 \times M = 0.05231 \times A + \\ 0.002278 \times A^2 &= 0.00001937 \times A^3 = 0.1116 \times Ni = \\ 0.01647 \times A \times M \end{aligned}$$

Model 3

 $\alpha = -9.440$

$$\mu = 7.242 - 2.905 \times S + 0.01516 \times M - 0.1681 \times A + 0.001639 \times A^2 + 0.09210 \times Ni + 0.1001 \times A \times S - 0.0008455 \times A^2 \times S + 0.1531 \times (S - 1) \times (M - 1) + 0.06753 \times Nq$$

$$\log \sigma^2 = -7.310 - 0.1753 \times S + 0.2116 \times A - 0.001796 \times A^2 - 0.0008455 \times A^2 - 0.000855 \times A^2 - 0.00$$

 $0.3227 \times Ni \pm 0.1196 \times Ni^2$

Model 4

$$\begin{aligned} \alpha &= 19.732 - 31.40 \times S \\ \mu &= 4.464 - 1.002 \times S + 0.0434 \times M - 0.09745 \times A + \\ 0.001143 \times A^2 + 0.3569 \times Ni + 0.07006 \times A \times S + \\ 0.1053 \times (S - 1) \times (M - 1) - 0.0006772 \times A^2 \times S - \\ 0.002566 \times A \times Ni - 0.06916 \times Ni \times M \\ \log \sigma^2 = \end{aligned}$$

 $-10.18 - 1.296 \times S + 0.3377 \times A - 0.002820 \times A^2 - 0.1330 \times Ni$





The effect of noise on 50 year old male manual workers

Cumulative Probability Distribution Function



dB Hearing Threshold Level at 4 kHz



Observed and modelled percentiles

dB Hearing Threshold Level at 4 kHz