

AN INVESTIGATION INTO A 'WEEKEND (OR BANK HOLIDAY) EFFECT' ON MAJOR ACCIDENTS

Nicola C. Healey[1] and Andrew G. Rushton[2]
[1]Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire, SK17 9JN
[2]Hazardous Installations Directorate, Health and Safety Executive, Redgrave Court, Bootle, L20 7HS

A number of recent and high profile accidents in the process industries have occurred on bank holidays or at weekends. This has led to the suggestion that there was a potential for higher numbers of accidents, particularly those classed as major accidents, to occur on a bank holiday or a weekend.

If this perception should represent an actual effect, there could be serious implications for the work of the safety regulators of major hazard industries and the industries themselves.

The Health and Safety Laboratory (HSL), was commissioned by the Health and Safety Executive (HSE) to analyse a selection of data on major accidents. The aim of the analysis was to identify whether there was evidence of a weekend or bank holiday increase in the numbers of major accidents.

Attempts were made to normalise the data to account for the reduced operations and staffing levels sometimes present at process industry sites on weekends or bank holidays. Unfortunately, sufficient data could not be found to normalise the accident data in these respects.

Main findings are:

- Analysis of the aggregated data and sub-sets consistently failed to provide evidence for either a weekend or bank holiday increase in the number of major accidents.
- Fairly consistent evidence was seen of a mid-week peak and a weekend dip in the number of accidents reported.
- Chi-Square tests consistently showed either 'no significant difference', or 'significantly more accidents occurring on a weekday' in comparison with accidents occurring on a Saturday, Sunday or bank holiday.

In essence, the results show either no evidence of an effect, or that the effect is too weak to stand out over other factors within the data available.

INTRODUCTION

Unfortunately, major accidents involving dangerous substances in the process industries have occurred and continue to occur despite continued efforts aimed at their prevention, control and mitigation. The control and regulation of process industry major hazards is informed by analysis of those accidents (as well as by first principles approaches to hazard management).

Several high profile incidents have occurred at weekends. Examples include those at Flixborough, Seveso, Milford Haven and Buncefield (Parker, 1975, Orsini 1977, HSE 1997, Newton 2006). The publication, in 2005, of a report into a bank holiday incident at the Humber Refinery in the UK (HSE 2005) was the prompt for the present work.

Speculation based on anecdotal evidence, has led to the suggestion that there is a potential for higher than proportionate numbers of accidents, particularly those classed as 'major' accidents, to occur on a bank holiday or a weekend (Saturday or Sunday). Here, this postulated increase of accident incidence on a weekend day or bank holiday is termed a "weekend (or bank holiday) effect". The term bank holiday is not used in the strict sense, but is used loosely to refer to the kinds of 'national holiday' days when roles that are normally filled on week days will not be filled.

If this perception should represent an actual effect, there could be serious implications for the work of the regulators regarding major hazard activities and industries. The confirmation of any clear weekend (or bank holiday) effect might justify further research clarifying the causes of the effect and the targeting of resources on reduction of those causes or the introduction of additional barriers tailored to the identified effect paths.

This paper reports the findings of research carried out by the Health and Safety Laboratory, commissioned by the Health and Safety Executive. An analysis of data from a selection of major accident lists and databases was performed, to search for significant differences in the numbers of major accidents occurring on weekdays when compared with weekend days and bank holidays. Significant differences might provide evidence in support of a weekend or bank holiday effect on the occurrence of major accidents.

More specifically, the objectives of the exercise were:

- To review five collections (lists or databases) of major accident information (data sources);
- Identify whether these accidents occurred on a weekday, weekend or bank holiday;
- Analyse the data to determine significant (or non-significant) differences in accidents occurring on a weekend or bank holiday in comparison to non bank holiday weekdays.

Throughout this paper the term 'accident' is used to refer to accidents and incidents recorded across the five sources of data.

Full details of the analysis are reported by Healey 2007. This paper provides a summary of the work and some discussion of the context and implications.

PREVIOUS WORK

A literature search found no previous work specifically investigating the presence of a weekend or bank holiday effect on the occurrence of major accidents.

A study of fatal accidents at work associated with maintenance (HSE, 1985) found that accidents occurred throughout the working week with a peak observed mid-week. "Surprisingly, only 13% happened during weekend maintenance work, but this may be affected by the recession or reduced production pressures". If accidents were proportionately

spread over the entire week (that is, if there were no reduction in activity or numbers of people at risk and accidents were evenly distributed) then of course about 30% of accidents would occur at weekends (2/7 ~0.3).

DATA SOURCES AND ANALYSIS

A selection of five data sources, with appropriate inclusion criteria, were identified and utilised throughout this work. Appendix A gives an outline description of the sources, an indication of the criteria for inclusion of data in each source and, where appropriate, additional criteria applied in the data selected for this study.

The data sources covered a varying range of the process industries, and varied in their inclusion criteria.

Each of the five data sources was interrogated and information extracted. Journal articles and websites (see references) were used to supplement the 'date' and 'country' information from the accident data sources to identify the day of the week an accident occurred on. Using this information most accidents could be tagged according to whether they occurred on weekdays, weekends or bank holidays.

There was apparent replication of some accident reports both within and between the various data sources. In some cases the replication was clear, whilst in other cases it was not so clear. Where possible, replicated accident reports were removed to reduce the likelihood of duplication in the analyses. HSL relied on its subjective judgement to remove this replicated information.

ATTEMPTED NORMALISATION OF THE DATA

There are potentially numerous and varied factors which might influence the occurrence of accidents on weekdays, weekends or bank holidays. One obvious factor is the extent to which operations may (or may not) differ: some sites will operate in similar mode regardless of the day of the week, others may operate very differently (perhaps not at all) on a bank holiday. Another factor is the presence of population (both on and around the major hazard site). The effects of these factors may be simple (e.g. fewer operations leading to fewer opportunities for accidents) or complex (e.g. fewer people on site may result in fewer casualties in the event of an accident, or, a greater number of people on site, by virtue of their appropriate actions, may inhibit the escalation from an initiating event to a reportable accident).

A fair comparison of the incidence of accidents (and their consequences) would take account of other factors which raise or lower the potential for such accidents at weekends or bank holidays. To some extent the occurrence of accidents may be inhibited at weekends or bank holidays if operations are reduced or consequences may be inhibited if fewer people are present. So, for example, a fair comparison would take account of reduced operations (or exposure to consequences) outside weekdays.

In the discussion above, a simple definition of "weekend" (i.e. a Saturday and Sunday) has been used. However if there is a "weekend effect" it may not be relevant to

distinguish between midnight on Sunday and resumption of normal "office hours" on Monday. A weekend effect may also be somehow related to (or, at best, confounded with) diurnal effects (which have been studied separately, Fortson 2004).

It was, therefore, desirable to explore whether the analysis was sensitive to scaling of the data to factors such as 'degree of weekend working' and 'population present'. So it was envisaged that alternative analyses would be undertaken with the data "normalised" in respect of these factors.

Literature and abstract searches were carried out in order to identify a method (i.e. a relevant data source) for normalising the major accident data, in line with differences in the productivity levels and work patterns typically observed in the different industries reporting accidents. An appropriate source for this information was not identified.

Furthermore, the accident information held in the data sources was not detailed enough to identify information such as staff shift patterns or patterns in productivity levels, and normalisation of the accident data was not possible (neither for these factors nor for other factors).

ANALYSIS

Analysis was performed on the aggregated data from all sources, on data from each source separately (or a selection of that single-source data) and on subdivisions of the aggregated data (for example, the aggregated set of accidents with reported consequences including ten or more fatalities).

The Chi-square test was applied to the accident information collected from the five data sources to assess the significance (or non-significance) of differences between the proportions of major accidents occurring on weekdays, weekends and bank holidays.

A variety of t-test was used to determine the statistical significance of differences in the relative proportions of 'weekend' to 'weekday' accidents in subsets of the data, when compared with the same proportions in the overall aggregated data.

RESULTS

An 'overview analysis' was performed on the aggregated data from all sources. The raw aggregated dataset consisted of information relating to 4333 accidents, collected across the five data sources. Replicated accident reports (numbering 487) were removed from the dataset before the overview analysis.

The remaining sample of 3846 accidents were classified according to the day of the week on which they occurred.

Figure 1 shows the breakdown of the accidents, by day of the week. Information was 'not available' (N/A) for some accidents. The chart shows a mid-week peak and a decrease in accidents reported as occurring at the weekend (Saturday and Sunday).

Table 1 shows the breakdown of the sample, by bank holiday accidents. To determine a bank holiday both the country, and exact date were required. This additional data was not always available leading to a higher number of accidents classed as 'N/A'.

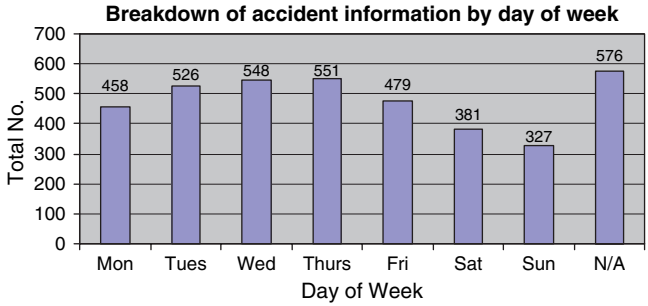

Figure 1. Breakdown of accident information by day of week (n = 3846)

Results of Chi-square calculations showed there were significantly more accidents on a weekday (Monday–Friday) than on a Saturday, Sunday, weekend (Saturday and Sunday) or bank holiday in this overall sample. A little over 20% of accidents occurred on a weekend (compared with ~30% for a flat distribution). Significantly more accidents occurred on a Saturday, in comparison to a Sunday.

ANALYSIS: BY DATA SOURCE AND BY CONSEQUENCE (NUMBERS OF FATALITIES)

Further analyses of the accident data were also performed to explore the sensitivity of features in the data to the data source and to a measure of accident consequence (number of fatalities).

The data from each data source in isolation was analysed. The results for each data source, comparable with Figure 1 for the aggregated data, are presented in Appendix A.

The aggregated data was subdivided by ranges of numbers of fatalities (a crude indication of accident severity). The results are detailed in Healey 2007.

In most cases, for either individual data sources or for subsets of the aggregated data based on bands of consequence (ranges of numbers of fatalities), the features of the "overview analysis" were confirmed.

Table 1. Breakdown of bank holiday accident information (n = 3846)

Bank holiday	Total no. accidents
Yes	46
No	2308
N/A	1492
Total	3846

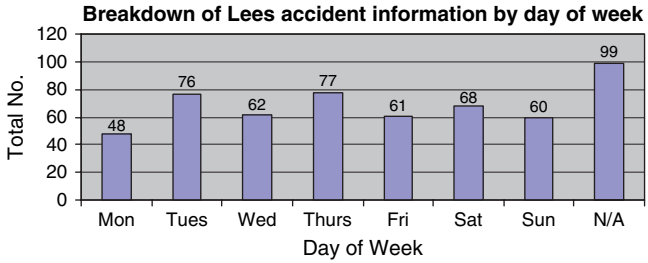

Figure 2. Breakdown of Lees accident information by day of week (n = 551)

There were some apparent distinctions between features of the "overview analysis" and the analysis of individual data sources or sub-sets of the aggregated data. For example, a relatively high proportion of 'weekend' to 'weekday' accidents was seen in both the Lees data (Figure 2, Appendix A) and a 'ten or more fatality accidents' subset of the aggregated data, when compared to the overall aggregated data. A Chi-square test showed 'no significant difference' between accidents on weekdays and weekends for these two cases, where the overall, aggregated data had shown significantly more accidents on weekdays.

Further statistical analysis was necessary to establish whether this change was significant or merely a consequence of the smaller amount of data in a single source or sub-set of the aggregated data.

A form of t-test was used to determine the statistical significance of differences in the relative proportions of 'weekend' to 'weekday' accidents in individual data sources or sub-sets of the aggregated data, in comparison with the overall, aggregated sample. A statistically significant higher proportion of 'weekend' to 'weekday' accidents was observed in both the Lees data and a 'ten or more fatality accidents' subset of the aggregated data, when compared to the overall aggregated data.

Therefore, the dip in weekend accidents noted earlier (HSE 1985) and here in the "overview analysis" is significantly less pronounced in some subsets of the data.

Although these findings do not show evidence in support of a weekend or bank holiday effect, the results of the t-test suggest that some subsets of the data (in particular the Lees data, and a 'ten or more fatality accidents' subset of the aggregated data) are different in nature to the overall, aggregated data. It is possible this is evidence of a weak, relative association of larger/more severe accidents with weekends.

In no case was there evidence of an excess in the incidence of accidents on weekends (or bank holidays). The full results are reported by Healey 2007.

DISCUSSION

The aggregated data studied here is principally distinguished from the data reviewed earlier by HSE (HSE 1985) by its focus on the process industries (i.e. excluding construction etc).

The aggregated data (particularly because it includes the large IChemE dataset) includes a wide range of consequences, including but not limited to 'major' accidents.

From the distribution of accidents by day of the week (Figure 1) and statistical analysis, it is clear that there is no absolute and disproportionate increase in the incidence of accidents on weekends (or bank holidays). In no case were accidents occurring on weekends or on bank holidays in excess of those expected in a flat distribution (where accident frequency is statistically independent of the day).

In the aggregated data, there is a relative increase in weekend accidents when compared to the broader-based study (from ~13% in HSE 1985 to ~20 % in the aggregated data here).

There were significantly more accidents on a weekday (Monday – Friday) than on a Saturday, Sunday, weekend (Saturday and Sunday) or bank holiday in this overall sample. A little over 20% of accidents occurred on a weekend (compared with ~30% for a flat distribution). Significantly more accidents occurred on a Saturday, in comparison to a Sunday.

Analysis of the individual data sources which are more clearly restricted to "major" accidents (for example Lees), or subsets of the data more restricted to large scale consequences (for example accidents associated with ten or more fatalities) showed a weak relative increase in the incidence of accidents on weekends. But these increases were of little or no statistical significance, or else were confounded by the reduced amount of data.

These analyses produced no general evidence of a disproportionate increase in accident numbers on weekends or bank holidays and no conclusive evidence that more consequential, influential or spectacular accidents correlate positively with weekends or bank holidays. There were some indications that more consequential, influential or spectacular accidents are relatively (but not absolutely) more likely at weekends, though this may merely be due to a confounding factor (i.e. industries capable of more consequential, influential or spectacular accidents may be more likely to be operating on weekends and bank holidays).

When viewing the data classified by consequence (simply represented by number of fatalities), there may be a confounding effect in that weekend (or bank holiday) incidents may be less consequential than corresponding weekday events. For example, had the Flixborough disaster occurred during a normal working day (and been in other respects unchanged) the fatalities in that incident might have been ten times greater (Rushton, 1998).

There are, undoubtedly, some safety professionals who believe there is a "weekend (or bank holiday) effect". Perhaps this belief is mistaken, or perhaps it is based on sound (if unsubstantiated) intuition.

It is easy to conjecture how a weekend effect might arise. There may be fewer staff to detect incipient causes (accident initiators or barrier failures), supervise interventions, respond to incipient causes or diagnose 'leading' indicators. For example there may be more situations put "on hold" awaiting the attention of weekday staff or contractors. It is

easy to speculate on other features of bank holiday and weekend working which might weaken or remove barriers to the initiation of or escalation to an event.

It is possible there is a "weekend effect", that is too weak to stand out over other factors within the data available. Where common sense and/or engineering judgment indicates a greater propensity for initiation or escalation of events in some particular circumstances (including but not limited to weekends or bank holidays), then that propensity should of course be given proportionate attention in the management of hazards.

CONCLUSIONS

There are some safety professionals who believe there is a disproportionate incidence of accidents (particularly 'major' accidents) on weekend days or bank holidays (a "weekend (or bank holiday) effect").

Study of the day of occurrence of a large number of accidents in the process industries shows no statistical evidence of a weekend or bank holiday increase in the numbers of major accidents.

The main findings were:

- Analysis of the aggregated accident data from five sources and sub–sets of that data consistently failed to provide convincing evidence for either a weekend or bank holiday increase in the number of major accidents.
- Fairly consistent evidence was seen of a mid-week peak and a weekend dip in the number of accidents reported.
- Chi-Square tests consistently showed either 'no significant difference', or 'significantly more accidents occurring on a weekday' in comparison with accidents occurring on a Saturday, Sunday or bank holiday.

There is some weak evidence of a relative increase in incidence of accidents on weekends in the process industries compared to industry in general. There is weak evidence of a relative increase in incidence of 'major' accidents on weekends in the process industries compared to accidents in the process industries in general.

In essence, the work has shown either no evidence of an 'effect', or that the 'effect' is too weak to stand out over other factors within the data available.

Although evidence was not found in support of a weekend or bank holiday effect, at this juncture, such an effect has not been disproved. It is possible that a weekend or bank holiday effect may exist, but was not revealed in this study due to the masking effect of other factors.

A comprehensive understanding of the organisational factors underlying major accidents is vital in order to inform regulators and major hazard industries, regarding regulation and the prevention of major accidents. Where common sense and/or engineering judgment indicates a greater propensity for initiation or escalation of events in any particular circumstances, then that propensity should be given proportionate attention.

In recognition of the limitations associated with this research, it is recommended that these findings be considered as a foundation for further work, with a focus on addressing some of the limitations encountered in this research.

DISCLAIMER

The views expressed in this paper are those of the authors alone and are not a statement of HSE policy.

REFERENCES

EC, 1997, Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances, Official Journal of the European Communities, Luxembourg (also known as "the Seveso II directive"), as amended by Directive 2003/105/EC.

Fortson, K., 2004, The Diurnal pattern of on-the-job injuries, *Monthly Labor Review,* September 18–25.

Healey, N., 2007, An investigation into a weekend or bank holiday effect on major accidents. HSL report. RSU/RM/07/04.

HSE, 1985, Deadly Maintenance – A Study of Fatal Accidents at Work, ISBN 0-11-883806-7 HMSO.

HSE 1997, The explosion and fires at the Texaco Refinery, Milford Haven, 24 July 1994, ISBN 0 7176 1413 1.

HSE, 2005, Public report of the fire and explosion at the Conoco Phillips Humber Refinery on 16 April 2001 at http://www.hse.gov.uk/comah/conocophillips.pdf

Kirchsteiger, C., 2001, MARS 4.0 – An Electronic Documentation & Analysis System for Industrial Accidents Data, European Commission, DG JRC, EUR 19766 EN, Ispra.

Newton, Lord, 2006, Buncefield: Initial Report to the Health and Safety Commission and the Environment Agency of the investigation into the explosions and fires at the Buncefield oil storage and transfer depot, Hemel Hempstead, on 11 December 2005 at http://www.buncefieldinvestigation.gov.uk/reports/initialreport.pdf

Orsini, B.,Parliamentary Commission of Inquiry on the Escape of Toxic Substances on 10 July 1976 at the ICMESA Establishment and the Consequent Potential Dangers to Health and the Environment due to Industrial Activity, Rome (English translation, HSE, 1980)

Parker, R.J., 1975, The Flixborough Disaster: Report of the Court of Inquiry, HMSO, ISBN 0113610750.

Rushton, A.G., 1998, Lessons Learned from Past Accidents, in Risk assessment and management in the context of the Seveso II directive (Kirchsteiger C, Christou MD and Papadakis GA Eds.), Industrial Safety Series Volume 6, Elsevier.

DATA SOURCES

Institution of Chemical Engineers Accident database. A CD of Chemical and Processindustry accidents, created and maintained by IChemE.

Lees, F. 1996 Loss Prevention in the Process Industries: hazard identification, assessment and control. Volume 3 Appendices. 2nd Edition.
Large Property Damage Losses in the Hydrocarbon-Chemical Industries: A Thirty-Year Review. 13th Edition, 1990.
Large Property Damage Losses in the Hydrocarbon-Chemical Industries – A Thirty-Year Review. 19th Edition, 2001.
Major Accident Reporting System, accessed September 2006 at:
http://mahbsrv.jrc.it/mars/Default.html
http://mahbsrv.jrc.it/mars/MARS-Technical-Guideline-February-2001.pdf
MHIDAS (Major Hazard Incident Data Service) database. Enquiries directed to the Health and Safety Executive, Hazardous Installations Directorate, Business Assurance and Operations Analysis Team, Bootle.

SUPPLEMENTARY INFORMATION

Day of the week information accessed October 2006 at: http://www.searchforancestors.com/utility/dayofweek.html
Day of the week and 'Bank holiday' information accessed October 2006 at: http://www.timeanddate.com/calendar/
'Bank holiday' information accessed October 2006 at: http://www.bank-holidays.com/
World Commercial holidays, 1996. Business America, Dec 95, Vol. 116 Issue 12, p21

APPENDIX A: SAMPLE OF DATA SOURCES AND APPROPRIATE RELEVANCE CRITERIA

- ***Loss Prevention in the Process Industries. Lees.*** This is a personal selection/collection by the author (F.P. Lees) of major accidents reported by the process industry. The collection is in the form of a list. So, the inclusion criterion was the subjective discretion of Lees. All accidents in the list were effectively classified as 'major' by the author due to their inclusion in the selection, and were all considered in this analysis.

The sample of 551 accidents recorded in the Lees database were organised according to the day of the week they occurred on.

Figure 2 shows the breakdown of the Lees accidents, by day of the week, 'N/A' was used where information was 'not available'.

- ***Large Property Damage Losses in the Hydrocarbon-Chemical Industries: A Thirty-Year Review. Marsh McLennan.*** This is a list reviewing 100 large property damage or losses occurring in the hydrocarbon processing and chemical industries over a thirty-year period. (Information relating to an additional 15 accidents, taken from the latest version of the review was also included). All accidents were included in this analysis. The inclusion criterion was economic loss (in the qualifying period and limited by number).

The sample of 115 accidents recorded in the Marsh McLennan database were organised according to the day of the week they occurred on.

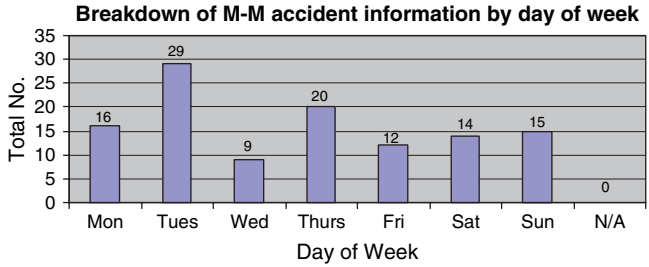

Figure 3. Breakdown of Marsh McLennan accident information by day of week (n = 115)

Figure 3 shows the breakdown of the Marsh McLennan accidents, by day of the week.

- ***MHIDAS. The Major Hazard Incidents Data Service.*** This is a collection of world-wide accidents recorded using information taken from the public domain. The collection is in the form of a database. The inclusion criterion is incidents involving hazardous materials that had an off-site impact, or had the potential to have an off-site impact. Such impacts include human casualties or damage to plant, property or the natural environment. All accidents in the database are effectively classified as major due to the offsite impact (or potential for offsite impact). The most recent 860 accidents recorded excluding those occurring in long standing members of the European Union, i.e. Belgium, France, (West) Germany, Italy, Luxembourg, Netherlands, Denmark, Ireland, United Kingdom, Greece, Portugal, Spain were considered for this analysis. This reduced set was used in order to minimise the number of accidents likely to be included within the remit of the other data sources, therefore minimising replicated incidents in the analysis. (The current work was limited to the inclusion of 860 accidents due to project resources.)

Figure 4 shows the breakdown of the MHIDAS accidents, by day of the week, 'N/A' was used where information was 'not available'. The graph shows a mid-week peak and a decrease in accidents reported as occurring at the weekend (Saturday and Sunday).

- ***EU MARS. The Major Accident Reporting System.*** This is a distributed information network compiling information from 15 databases in each member state of the European Union. All accidents in the compiled database are effectively classified as major accidents, as the reporting process relies on the major accident definitions in the Seveso directives (EC 1997). All accidents in the database were included in this analysis.

The sample of 603 accidents recorded in the EU MARS database were organised according to the day of the week they occurred on.

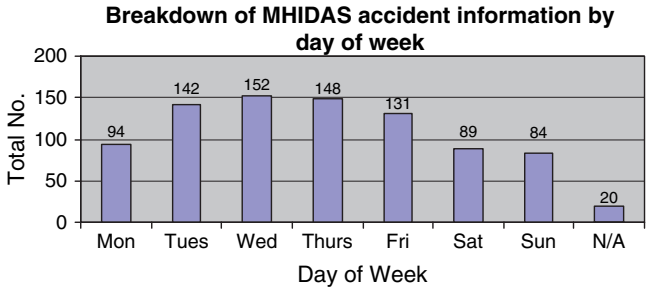

Figure 4. Breakdown of MHIDAS accident information by day of week (n = 860)

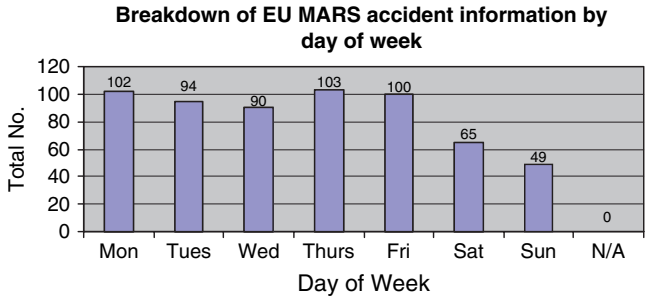

Figure 5. Breakdown of EU MARS accident information by day of week (n = 603)

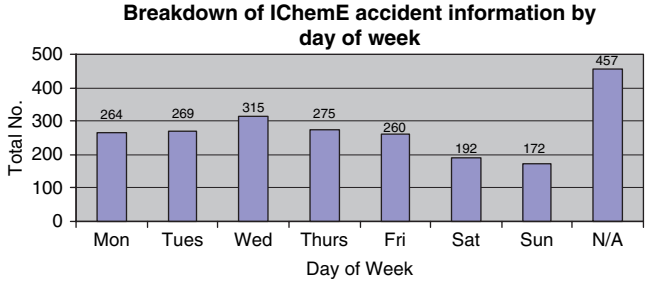

Figure 6. Breakdown of IChemE accident information by day of week (n = 2204)

Figure 5 shows the breakdown of the EU MARS accidents, by day of the week. The graph shows peaks on Monday and Thursday and a decrease in accidents reported as occurring at the weekend (Saturday and Sunday).

- ***IChemE Accident Database.*** This is an accident database used worldwide by chemical and process industries. The database was created and maintained by the Institution of Chemical Engineers and details the cause and effect of accidents and incidents. The inclusion criterion is broad, including any accident report in the process industry. The consequences of the accidents are many and varied and so it is unclear that all the accidents would meet a definition of "major" (such as in the Seveso Directives). All accidents in the database were including in this analysis.

The sample of 2204 accidents recorded in the IChemE database were organised according to the day of the week they occurred on.

Figure 6 shows the breakdown of the IChemE accidents, by day of the week, 'N/A' was used where information was 'not available'. The graph shows a mid-week peak and a decrease in accidents reported as occurring at the weekend (Saturday and Sunday).