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Incorporating **safety, health and environmental risk issues** in undergraduate engineering courses

A document provided by the **Joint Institution Group on Safety Risk - JIGSR**)



Summary

The teaching of Safety, Health and Environmental (SHE) risk issues to undergraduates studying engineering courses is an important part of the education of future engineers at all levels. It is the generally expressed view amongst UK practitioners in industry, business and other organisations that the management of SHE risks in the workplace is not adequately covered in the current taught-course syllabus and content of many engineering courses.

As an integral part of their competencies all engineers need to be equipped to appreciate, understand and implement the requirements of SHE management and practice to meet the working needs of industry and of their company (or other organisation). Whilst the level of risk and degree of control is dependant on the industry sector concerned the basic principles do not change.

This paper from the “**Joint Institution Group on Safety Risk**” (formally the Inter Institutional Group on Health and Safety) provides fundamental information for teaching of Safety, Health and Environmental Risk Issues. It is principally a template for use by all those involved in the process of course design and accreditation of engineering courses.

The purpose of this initiative is to ensure that all students who complete their engineering course have a basic understanding of safety, health and environmental risk issues relevant to their specific course of professional study.

The **Joint Institution Group on Safety Risk** commends this approach to all of those bodies and individuals involved in the process of educating engineering students to become competent in their chosen subject and career.

Joint Institution Group on Safety Risk (JIGSR)

The mission of the group is to enhance awareness and knowledge of health, safety and environmental risk issues in the interests of the engineering profession. The aims of the Group are:

- to raise awareness of health, safety and environmental risk issues by joint action
- to act as a forum for the exchange of information of the member organisations
- to promote and co-ordinate initiatives, activities and other developments originating in member organisations which may be of interest and benefit to the engineering community
- to work jointly on an agreed basis on health, safety and environmental risk related issues where there is benefit to the engineering community

The group seeks to involve all Institutions represented by the Engineering Council. The current organisation membership is listed on the last page of this document. The Health and Safety Executive is also represented at meetings and has supported this work on teaching of HSE risk issues at undergraduate level.

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Cover images

- bottom left - image of the Hertfordshire Oil Storage Terminal, Buncefield by courtesy of Hertfordshire Constabulary

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Template for Incorporating Safety, Health and Environmental Risk Issues in Undergraduate Engineering Courses

Introduction

This paper provides a template for use by all those involved in the process of course design and accreditation. If used it should enable engineers to graduate with a basic understanding of safety, health and environmental risk issues relevant to their specific course of study.

The template is principally intended for accredited undergraduate courses leading to chartered or incorporated engineer status in those engineering disciplines that come under the umbrella of the Engineering Council. However, the principles should apply equally well to related courses. For example, in the construction industry to potential CIOB, RICS and RIBA membership.

Use

The use of the template should enable safety, health and environmental risk issues to be incorporated into an undergraduate engineering course without the addition of further modules to the current syllabus, (although basic introductory material could be taught to avoid repetition across the syllabus).

It is designed to be used within a system, which has the following requirements and features:

- the Engineering Council and professional institutions should include the requirement for courses to address SHE issues, using this template in their accreditation process ultimately leading to the award of a professional qualification
- accreditation bodies should concern themselves with the achieving of SHE learning outcomes rather than rigid adherence to a standardised syllabus
- the HSE and the Environment Agency should be encouraged to maintain contact with institutions' accreditation bodies to promote adoption of this template
- teaching institutions should indicate target levels of attainment selected for a particular course using the following descriptions as exemplars
- as far as possible, teaching on safety, health and environmental risk issues should not be confined to a single module but be an integral part of all other teaching material
- the teaching methods used, whilst conveying the principles of safety, health and environment listed above, may also provide opportunities to develop other essential attributes such as presentation and writing skills
- teaching methods should take account of the fact that safety and risk issues involve deep and fundamental ideas concerning knowledge and behaviour. To be placed in a meaningful context they need to be related to the student's own experience.

Level	Description
A	Appreciation and awareness, be able to refer to something
K	Knowledge and understanding, be able to explain something
E	Experience, be able to do something with help and/or closely supervised
B	Ability - be able to do something without supervision

Principles

The overriding requirement of this template is that engineers are able to identify and control the hazards associated with their activities. To achieve this, the graduating engineer will need to demonstrate a basic understanding of the principles and issues involved:

- hazard identification and risk assessment
- hierarchy of risk control
- approaches to achieve risk reduction and the substantial direct and indirect business benefits this brings through better quality and loss control
- the role risk management plays in the decision making process and how it can be used under conditions of uncertainty
- recognition of the importance of human and organisational factors in the development of an acceptable management system
- the professional obligations placed on engineers by the UK and European approach to health, safety and environmental regulation; and
- the different legislation and different cultures that may affect the approach to managing safety, health and environmental risk issues

Relevant teaching material

The following examples of information and support material are included to show how course providers can fulfill the requirements envisaged in the template. It should provide teachers with an essential guide when preparing lectures.

- Annexe 1** Required learning outcomes
Annexe 2 Studies of successes and failures - published documents and reports
Annexe 3 Principal UK legislation
Annexe 4 Useful publications and sources

Annexe 1 - Learning Outcomes

Required learning outcomes

This Annexe gives a list of possible learning outcomes. The overriding requirement of this template is that engineers are able to identify and control the hazards associated with their activities. The most appropriate outcomes for a particular course should be selected from the list, together with levels of attainment¹. These should be adjusted in line with the academic aims and objectives of each course. They will be subject to variation for all courses, not just between MEng and BEng courses and between accredited courses for prospective corporate and incorporated engineers. For many learning outcomes the required level will be an appreciation and awareness only. This could be obtained while focusing on a detailed case study or looking at reasons behind a selection of engineering failures or successes.

Learning Outcomes

Listed below are some examples of possible learning outcomes, and in *italics*, the way that the student might achieve each of them.

- a. **Demonstrate** that at least one case study appropriate to the discipline has been studied in detail *by describing the hazards and risk concepts contained in one of the cases listed in Annexe 2*
- b. **Describe** the basic human error issues in a number (say 5) of famous failures *by selecting cases from Annexe 2 which can show that people are often the most unpredictable hazard and that poor communication may be the greatest hazard*
- c. **Design** simple engineering systems for safety *by being aware of the limitations and uncertainties in methods used, such as limit state design*
- d. **Define and discuss**, the critical importance of communicating clearly safety, risk and hazard issues *by appreciating that responsibility for safety rests with everyone - not just with management. For effective safety the role of each person needs to be communicated clearly to them, being careful to avoid jargon*
- e. **Identify and control** safety, health and environmental hazards *by addressing these issues when carrying out their project*
- f. **Describe** how risk is assessed even as part of everyday life and how this can influence the engineer *by comparing everyday risk decisions taken by the individual, such as crossing the road or smoking, to risk decisions taken for the individual, for example, rail transport or GM foods*
- g. **Define and discuss** critically, natural and technological hazards *by comparing the various demands on the capacity of systems introduced to reduce risks*
- h. **Explain the difference** between 'hard' and 'soft' hazards *by using examples such as corporate safety, health and environmental programmes, incentive schemes and training*
- i. **Describe** a systematic risk management process, including who owns a risk, as a learning process *by studying documents such as "5 Steps to Risk Assessment" by HSE or equivalent industry-specific publications*
- j. **Discuss critically** the balance between risk and benefit *by reference to financial, business, environmental and ethical issues*
- k. **Explain the interdisciplinary** nature of the management of safety, health and environmental issues *by showing an understanding of the roles played by other professionals*
- l. **Explain the importance** of learning from failure *by, for example, appreciating that the hypothesis that all swans are white is true - until you find a black one!*
- m. **Explain** that there are limits to what we know and what that may imply for safety *by appreciating that, in engineering, uncertainties always exist and solutions must account for those uncertainties if design of the system is to minimise risk. There is no such thing as perfect safety*
- n. **Behave responsibly** *by knowing how to conduct oneself when exposed to hazards, such as on site or in the laboratory*
- o. **Describe relevant** basic legal and professional responsibilities for safety, health and environment and their history of development *by reference to principle relevant legislation. Annexe 3 lists some examples of UK legislation from which appropriate examples may be chosen*
- p. **Define safety culture** and be aware of its influence on a project *by being aware of cultural issues, for example, the 'macho image', the 'way we do things round here'. Also by being aware of the accident history of the relevant industry sector*
- q. **Carry out a risk assessment** *by putting the theory into practice during their project and when in the laboratory*
- r. **Carry out typical risk** and reliability calculations *by reducing a risk as low as reasonably practicable (ALARP) through the use of event trees, fault trees, first order and second order reliability methods (FORM, SORM)*

¹ Item d) under the heading 'USE' suggests descriptions for four levels of attainment (**A**, **K**, **E** or **B**).

Annexe 2 - Case Studies

Studies of failures

This annexe gives a list of documents and reports that describe successes and failures.

Documents and Reports

1	Dangerous Maintenance	ISBN 0118839578	HMSO 1987
2	Deadly Maintenance - A Study of Fatal Accidents at Work - Plant and Machinery	ISBN 0118838059	HMSO 1985
3	Deadly Maintenance - A Study of Fatal Accidents at Work - Roofs	ISBN 0118838040	HMSO 1985
4	Deadly Maintenance - A Study of Fatal Accidents at Work	ISBN 0118838067	HMSO 1985
5	The Fire at Hickson and Welch Ltd	ISBN 071760702X	HSE 1994
6	The Fire at Allied Colloids Ltd	ISBN 0717607070	HSE 1993
7	The Peterborough Explosion	ISBN 0118855727	HMSO 1990
8	The Putney Explosion	ISBN 0118838180	HMSO 1985
9	The Brightside Lane Warehouse Fire	ISBN 0118838466	HMSO 1985
10	The Abbeystead Explosion	ISBN 0118837958	HMSO 1985
11	Fire & Explosion at Manro Products Ltd, Stalybridge	ISBN 011883715X	HMSO 1983
12	Fire & Explosion at Cory's Warehouse	ISBN 0118837850	HMSO 1984
13	The Rutherglen Explosion	ISBN 0118838709	HMSO 1986
14	The Fire Explosions at B & R Hauliers, Salford	ISBN 0118837028	HMSO 1983
15	The Explosion at Cardowan Colliery	ISBN 011883644	HMSO 1982
16	The Explosion and Fire at Chemstar Ltd	ISBN 0118836668	HMSO 1982
17	Leakage of Propane at Whitefriars Glass Ltd	ISBN 07176 00831	HSE 1981
18	The Fire and Explosions at Permaflex Ltd	ISBN 0717600734	HSE 1981
19	The Fire and Explosions at River Road, Barking	ISBN 0717600602	HSE 1980
20	The Fire on HMSO Glasgow	ISBN 0118830759	HMSO 1978
21	The Explosion at the Dow Chemical Factory	ISBN 0118830031	HMSO 1977
22	Fire at Dudgeons Wharf	ISBN 0101447000	HMSO 1970
23	The Fire and Explosion at BP Oil (Grangemouth) Refinery Ltd	ISBN 0118854933	HMSO 1989
24	The Fire and Explosion at Braehead Container Depot, Renfrew, 1977	ISBN 0118832204	HMSO 1979
25	Corn starch dust explosion at General Foods Limited, Banbury, Oxfordshire, 1981	ISBN 0118836730	HMSO 1983
26	Explosion on 15 June 1984 on MV Pointsman at Milford Haven	Available from HSE	HSE 1987
27	Explosion at Appleby Frodingham Steelworks, Scunthorpe, 1975	ISBN 011880331	HMSO 1976
28	Explosion at Laporte Industries Ltd, Ilford O/P	ISBN 0118803336	HMSO 1976
29	Report on gas explosion, Longshaw Street, Warrington, 1988		HSE 1989

30	Report on a petroleum spillage at Micheldever Oil Terminal, Hampshire, 1983	ISBN 011883768	HMSO 1984
31	Fatal accidents in construction, 1978	ISBN 0118834193	HMSO 1981
32	Fatal accidents in construction, 1977	ISBN 0118832387	HMSO 1978
33	One hundred fatal accidents in construction	ISBN 0118830716	HMSO 1978
34	Blackspot Construction	ISBN 0118839926	HMSO 1988
35	Management's responsibilities in the safety operation of mobile cranes	ISBN 0118833014	HMSO 1980
36	The hoist accident at Littlebrook 'D' Power Station, 1978	ISBN 0118832735	HMSO 1981
37	Report on the collapse of falsework for the viaduct over the River Loddon, 1972	ISBN 0102425736	HMSO 1973
38	Summit tunnel fire	IR/L/FR/85/26	HMSO 1985
39	Extensive fall of roof at Seafield Colliery, Fife, 1973	ISBN 0101548508	HMSO 1973
40	Incident at Staveley Chemicals Ltd, Derbyshire, 1982		
41	Inrush at Lofthouse colliery, Yorkshire, 1973	ISBN 0101541902	HMSO 1973
42	Outbreak of coal and firedamp at Cynheidre/Pentremawr colliery, 1971	ISBN 0101480407	HMSO 1971
43	Outbreak of fire and explosion at Coventry Mine, Keresley, Warwickshire, 1982		
44	A report of a train accident that occurred at Hyde North junction in the London Midland region of British Railways, 1990	ISBN 0118863045	HMSO 1992
45	A report of the collision that occurred at Cannon Street Station, 1991	ISBN 0118863037	HMSO 1992
46	A report of the inquiry into the accident that occurred at Chorleywood on the Metropolitan Line of London Underground Limited, 1990	ISBN 0118863819	HMSO 1992
47	A report on the enquiries into the collisions between passenger trains that occurred on 20 August 1984 near Leyton station and on 11 December 1984 at Kilburn on the railways of London Regional Transport		
48	Flixborough disaster, 1974	ISBN 0118832468	HMSO 1975
49	The Cost of Accidents at Work	ISBN 0118863746	HMSO 1976
50	Human Factors in Industrial Safety	ISBN 0118854860	HMSO 1989
51	The Hillsborough stadium disaster, 1989	ISBN 0101096224	HMSO 1989
52	Investigation into the Clapham Junction railway accident	ISBN 0101082029	HMSO 1989
53	The public enquiry into the Piper Alpha disaster	ISBN 0101082029	HMSO 1989
54	Investigation into the Kings Cross underground fire	ISBN 010113102X	HMSO 1987
55	'M.V. Herald of Free Enterprise'. Report of Court No 8073. Formal Investigation	ISBN 1015508287	HMSO 1973
56	Inquiry into the basis of Design and Method of Erection of Steel-Box Girder Bridges (Milford Haven)	ISBN 015502793	HMSO 1973
57	Collapse of flats at Ronan Point, Canning Town, London	ISBN 117501212	HMSO 1968

Annexe 3 - References

References

This annexe provides a selection of principal UK statutory legislation, some of which is supported by codes of practice and guidance. The publications are listed in original date order.

The full listing is available from Health and Safety Executive and the Environment Agency, or on their Websites at <http://www.hse.gov.uk/> and <https://www.gov.uk/government/organisations/environment-agency> respectively.

Principal Statutory Legislation

- The Factories Act 1961
- The Power Presses Regulations 1965
- The Fire Precautions Act 1971
- The Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972
- Health and Safety at Work etc. Act 1974
- The Wildlife and Countryside Act 1981 amended 1991 etc.
- The Ionising Radiations Regulations 1985
- The Electricity at Work Regulations 1989
- The Noise at Work Regulations 1989
- The Pressure Systems and Transportable Gas Containers Regulations 1989
- The Environmental Protection Act 1990 with various amendments and prescriptions
- The Simple Pressure Vessels (Safety) Regulations 1991
- The Water Resources Act 1991, schedule 10
- The Management of Health and Safety at Work Regulations 1999
- The Workplace (Health, Safety and Welfare) Regulations 1992
- The Manual Handling Operations Regulations 1992
- The Supply of Machinery (Safety) Regulations 1992
- The Personal Protective Equipment Regulations 1992
- The Health and Safety (Display Screen Equipment) Regulations 1992
- The Clean Air Act 1993
- The Noise and Statutory Nuisance Act 1993
- The Construction (Design and Management) Regulations 1994
- The Control of Substances Hazardous to Health Regulations 2002
- The Environment Act 1995
- The Construction (Health, Safety and Welfare) Regulations 1996
- The Noise Act 1996
- The Work in Compressed Air Special Regulations 1996
- The Air Quality Regulations 1997
- The Provision and Use of Work Equipment Regulations 1998
- The Lifting Operations and Lifting Equipment Regulations 1998
- The Town and Country Planning Acts 1995 & 1999
- The Control of Major Accident Hazards Regulations 1999
- The Pollution Prevention and Control Regulations (England and Wales) Amended 2003

Annexe 4 - Publications

This annexe lists some useful publications and sources of publications.

1	Safety by Design - An Engineer's Responsibility for Safety (This booklet contains six sets of notes, each providing a reference for use by teachers)	ISBN 0952510316	Hazards Forum
2	Lessons From Disasters - How Organisations Have no Memory and Accidents Recur (by Trevor Kletz)	ISBN 0852953070	IChemE 1993
3	An Engineer's View of Human Error (2nd edition by Trevor Kletz)	ISBN 0852952651	IChemE 1991
4	Major Hazards and Their Management (by Geoff Wells)	ISBN 0852953682	IChemE 1997
5	Don't Forget the Environment (Prepared by the Environmental Analysis Co-operative)	ISBN 0859254220	IChemE 1999
6	Management of Process Industry Waste (edited by Richard Bahu, Barry Crittenden and John O'Hare)	ISBN 0859253240	IChemE 1997
7	Hazard Spotting (an interactive multi-media CD-ROM-based training package)		IChemE
8	Competence Criteria for Safety-related System Practitioners	http://www.theiet.org/resources/books/policy/comp-crit.cfm	IET
9	Nuclear Decommissioning	http://www.theiet.org/factfiles/energy/nuc-dec-page.cfm	IET
10	Safety Related Systems: Guidance for Engineers	ISBN 0952510308	Hazards Forum
11	The Possible Harmful Biological Effects of Low-Frequency Electromagnetic Fields of Frequencies upto 300 GHz	http://www.theiet.org/factfiles/bioeffects/emf-position-page.cfm	IET
12	Nuclear Power	http://www.theiet.org/factfiles/energy/nuclear-power.cfm	IET
14	Engineering System Safety (by G J Terry)	ISBN 0852987811	IMechE 1991
15	Emergency Planning and Management	ISBN 0852989547	IMechE 1995
16	Process Machinery - Safety and Reliability (Edited by William Wong)	ISBN 01860580467	IMechE 1996
17	Pressure Systems: Operations and Risk Management	ISBN 0852989512	IMechE 1995
18	Railway Safety	ISBN 0852989415	IMechE 1994
19	Noise Control	ISBN 0852989431	IMechE 1994
20	Assuring it's Safe: Integrating Structural Integrity, Inspection, and Monitoring into Safety and Risk Assessment	ISBN 1860581471	IMechE 1998
21	Environmental, Health and Safety Auditing Handbook: Guide to Corporate and Environmental Risk Management (by Harrison, Lee)	ISBN 0070269041	McGraw 1994

22	Industrial Pollution Prevention Handbook (by Harry M Freeman)	ISBN 0070221480	McGraw 1994
23	Sources of Control of Air Pollution: Engineering Principles (by R J Heinsohn, R L Kabel)	ISBN 0136248349	Prentice Hall 1998
24	Pollution Prevention: Methodology, Technologies and Practices (by Kenneth L. Mulholland, James A. Dyer)	ISBN 081690782X	American Institute of Chemical Engineers
25	IET Health and Safety Briefings (a series of titles is available)	http://www.theiet.org/factfiles/ health/	IET

This document may be downloaded from:

<http://www.theiet.org/factfiles/health/general-health.cfm>

The **Joint Institution Group on Safety Risk - JIGSR** (formally known as the Inter-Institutional Group on Health and Safety) is made up of representatives (members and staff) from the following organisations:

- Hazards Forum
- Institute of Ergonomics and Human Factors
- Institute of Marine Engineering Science and Technology
- Institution of Chemical Engineers
- Institution of Civil Engineers
- Institution of Engineering and Technology
- Institution of Mechanical Engineers
- Institution of Occupational Safety and Health
- Institution of Structural Engineers
- Royal Institute of British Architects
- Royal Institution of Naval Architects
- Safety and Reliability Society
- Health and Safety Executive
- Engineering Council

Additional information can be found at the JIGSR webpage hosted by the IChemE

- <https://www.icheme.org/resources/joint-institute-group-on-safety-and-risk.aspx>

Documents produced by JIGSR can be downloaded from the IET website

- <http://www.theiet.org/factfiles/health/general-health.cfm>

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