HAZOP study training – a modern approach

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Many people find they need training in HAZOP in order to participate in studies, but they do not have time to attend a conventional 3 or 4 day training course. This paper presents a new on-line approach to HAZOP study training, which allows the student to work on the course when time permits, and where ever they are based.

The course leads the student though the stages of preparing for and carrying out a HAZOP study. The material is divided into self-contained modules, each requiring a final review from the user. It covers both continuous and sequential processes.

A key part of the structure of the course are the many interactive elements including assignments, forums, quizzes and questionnaire. Each student has a designated tutor who follows their progress, provides individual responses to assignments and deals with any questions or problems. We firmly believe that HAZOP study is not learnt by just knowing the theory, so there are two substantial interactive online sessions between the user and tutor where, after preparation by the student, a section of a process is subjected to HAZOP analysis.

The course, approved and accessed via the IChemE, is mounted on the server of a specialist Moodle provider. Using Moodle software, the course includes text pages, diagrams and photos. It can be operated from virtually any device connected to the Internet. This paper illustrates the major elements of the course.

We consider the contrasts with traditional methods for training HAZOP team members, such as placing an individual into an existing team or on a training course over several days. These approaches use a mixture of presentations, group exercises, discussions and reviews. This online course uses comparable material but the interaction with the user is quite different. Here the user works as an individual, so their involvement with their tutor is important. The online sessions demonstrate how HAZOP study should be done and ensure its detailed working is understood.

Important contrasts between the two approaches include: involvement by the student with the course material and with the presenter, flexibility and availability, cost, introduction of related aspects, time requirements, and ability to meet individual needs.

Finally, we summarise the spread of origins, background and initial experience of HAZOP study of the users, as well as their feedback on the course itself. We then consider the potential for on-line training courses in other safety related topics.

Keywords: HAZOP study on-line training e-learning flexible course

Introduction

The HAZOP study examination method is now in worldwide use in many different industries. To be effective it requires a good team leader, an accurate scribe and, crucially, a set of members who understand how the process works and what is required of them to make the study effective and efficient. Training is needed to achieve this. The most common methods[1] used to train team members have been short courses, both open and in-company, or "on-the-job", i.e. by introduction and integration of new members into a working team where, after a simple introduction, the learning is done by observation and participation. In the last decade there has been a great expansion of web-based distance learning due to the development of versatile software for delivery of courses and the ready availability of internet access from computers, laptops and tablets. This offers an opportunity and a challenge for the delivery of HAZOP study training. We describe here the development, the delivery and early users' responses to a web-based HAZOP study training course for team members.

Background

The meaning of HAZOP study should not need restatement here as there are several authoritative descriptions, including an IChemE monograph[2] and IEC documentation[3]. However, to avoid misunderstanding, we make it clear that we follow this defined HAZOP methodology. (Other types of hazard studies may also be used where appropriate, and have other names - but these are not HAZOP). In summary, HAZOP is a study carried out by a team for a fully defined plant, existing or planned, done section by section seeking possible deviations from the design intention using combinations of guidewords with system parameters to identify causes of potential hazards. The consequences are evaluated and, if the existing safeguards are considered inadequate to reduce the risk to an acceptable level, an action for further investigation or improvement is noted.

The most common method of formal training of new HAZOP study members is by a short course, typically of 3 days duration. The important elements of such courses include presentations of the basis of HAZOP study, its objectives and overall place in the programme of hazard analysis normally applied to a project. Examples are likely to include continuous plant, batch plant and perhaps procedures. Practice will include group work on several case studies, ideally working in groups of 4 to 5 and including as leader an experienced user of the technique. In an open course the case studies will be generic but for an in-company course they may be based upon an actual company process. The course would cover the importance of recording and the essential factors for success. Possibly more specialised aspects such as human factors, risk assessment and ranking and computer controlled systems may be included.

Our online course has been devised to cover all of the essential aspects of HAZOP study delivered in a new way but based on sound underlying pedagogic principles, particularly learning by doing. It is, we believe, a fundamental principle that HAZOP study cannot be learnt simply by being told about it – it has to be experienced in practice. This is, of course, easily achieved during a short course in a training venue – but the key question for us was how to include this aspect in an on-line course. We have achieved this by

allocating a course tutor to each student who responds to the student's various assignments and participates in two on-line practical tutorial sessions actually carrying out a HAZOP workshop.

Delivery and access

Reliable and versatile software, mounted on a secure, readily available platform is an essential requirement for any web-based course. The format of the chosen software and the functions provided have a significant effect on the style and appearance of the course. Our course is presented in the Moodle software system, an open-source Virtual Learning Environment (VLE), available since 2002. It is in use worldwide with, to date, over 7 million courses and 75 million users. A major user is the Open University with over 6000 courses and 200 000 users. Our course is mounted on servers operated by an approved Moodle partner company, ensuring a high level of availability, with access possible from any internet connected computer, laptop, tablet or even a smart phone. It can be accessed through both Microsoft and Apple operating systems.

Features available in the standard Moodle package include

- content pages where the main material is displayed,
- assignments – work that is submitted online and which a tutor can grade and comment upon,
- discussion forums – where users can comment on a topic and see, and respond to, entries from other users,
- quizzes
- problems where the route through is determined by the user's responses,
- Wikis – where each user can enter ideas and see what other users have done,
- videos,
- glossaries,
- books - sets of related pages,
- instant messaging, a calendar and space for personal use.

In addition many "plugins" have been created by course users. These, if approved by Moodle, are made available for general use allowing the creation of individual versions of the software. All of the standard features are used in our course with the addition of a special "easy print" button and an evaluation questionnaire. The individual pages, including text, drawings, P&IDs and links to related files and other internet resources, are created using commercial web-page editing software.

Users are registered individually, given a personal username and password and allocated to a tutor group; they may then access the course as and when they wish. There is a short introductory section about the objectives and format of the course. Tutors are alerted by email whenever a user in their group submits work that requires review. In the introductory section there is a short description of Moodle and course navigation. Other optional sections are a short history of HAZOP study and a glossary giving definitions of frequently used terms and acronyms; any user may suggest additions to this.

The login page[4] of the course - which may be viewed by anyone with internet access – also offers guest access to the first module of the course to give a "taster" of the full course.

Course details

The material is presented in a series of 8 modules, the longest taking about 3 hours. The shorter modules can be completed in a single session although they may be paused at any time. Each module ends with an assignment where, in addition to an opportunity for general comment, there are several specific questions which ask the user to reflect on the content and key messages from the module, including its application and relevance to their own work. This reinforces the learning points as well as encouraging thought about its application. The tutor normally responds to each assignment.

The initial page of each module, as illustrated in Fig 1, summarises the content, defines the learning objectives, may give reference to useful texts and indicates the estimated time and required resources. Figure 1 also shows the navigation methods around the site. The top bar shows the present location within the site and allows the path to be retraced; the left hand section shows the available modules, any one of which could be accessed next allowing the user easy and quick access to all parts of the course.

Figure 2 shows another page from Module 1, the diagram illustrating the elements of HAZOP study. It sets out the main sequence for HAZOP study and the text shows one of the indicating markers – Read, Reflect, Web search, Task, Write – that are used throughout to indicate a required activity. Alongside the "Intention" box there is a smaller text box, brought up by clicking on "Intention", giving the purpose of that step. The user can download a copy of the page including all the definition boxes, by using the bottom link to a pdf file. Figure 3 gives examples of the use of diagrammatic material within the course.

The structure of the course, the aims of each module, the interactive elements offered to the users and the estimated times are shown in Table 1. The material covers the theory and practice of HAZOP study and provides a graduated introduction to its use. The initial examples are of simple, everyday problems where the description and design are straightforward so that the user can concentrate on the HAZOP methodology. In the early examples users contribute their own suggestions for choice of nodes, definition of the design intention and the selection of appropriate guidewords and parameters. After each step either a recommended version is provided or a tutor's response given. In the forums a user, after posting a suggestion, can see both our recommendation as well as the input from

other users. Comments may be posted to these forums by any authorised user. The merits of this approach over a conventional training course are that every user is asked to respond at every stage and gets quick feedback from a tutor, another user, or both. It is also possible for a dialogue to develop where the user has further queries.

The wiki in Module 3 is another instance where user input is shared. In this exercise users are asked to complete a line of HAZOP analysis for the given problem, starting from a deviation and going through cause, consequence, safeguards to action. They see, and add to, the lines put up by earlier users. Another optional forum is on Ground Rules for HAZOP study teams. This is set up with a simple definition of its aim and an invitation to any user to read, comment upon or add to the existing suggestions. Thus, overall, there is considerable sharing of experience between different users, despite not being physically present.

Table 1 Structure of the course modules

Module	Contents	Interactive elements	Time (hrs)
1	Overview of HAZOP method. Outline of course.	HAZOP flowchart Assignment	0.5
2	Over view of hazard identification methods and risk assessment. Place of HAZOP study	2 assignments 3 forums	1
3	Explanation of stages in HAZOP study with examples and exercises	Quiz + 3 exercises. Wiki	2
4	Preparing for a study. Selecting nodes. Team composition. Recording.	2 exercises. Assignment	2
5	Case study – continuous process. Planning and preparation. Interactive analysis session.	Forum – preparation work Videoconference session Assignment	3
6	Making decisions in HAZOP study. How teams work. Simple semi-quantitative approaches	Structured exercises Assignment	2
7	Case study – batch process. Planning and preparation. Interactive analysis session.	Forum – preparation work Videoconference session Assignment	3
8	Conclusions and reflections	Assignment Evaluation	0.5

Although it recommended that the modules are taken sequentially this is not an essential condition. Thus the batch case study could be done before the continuous example; module 6 could be covered earlier in the course or sections of it omitted by a user who is well informed on quantitative risk assessment. Our estimate of the time required if all modules are done is about 14 hours, roughly the contact time of a 2 day course.

Extremely important to the course are the two case studies, one continuous and one batch. These are similar to the case studies developed and used in many of our public and in-company courses. The user is given the information in stages and asked at each point to do appropriate preparation work for a study. In the continuous example a description of the plant and process and a P&ID are given and the user is asked to suggest a suitable node, write a design intention and identify the parameters that will be used in the analysis. This work is then reviewed by the tutor and an agreed version reached for use in the analysis session. Fig 4 shows the section page setting out the work required. Then, through the computer-based videoconferencing software provided by the IChemE, the student carries out a HAZOP analysis of the node with the tutor acting as mentor and facilitator. The P&ID, the process description and any of the other preparative materials are seen simultaneously on both computers. The tutor acts also as a scribe and as the analysis takes place the record is built up within a spreadsheet. This provides a final record for the student to compare with the standard example report issued after the meeting. Within the meeting, which may last from 60 to 90 minutes, the principles of HAZOP analysis can be demonstrated and explained and practice given in the use of the main guidewords. These sessions, being one-to-one, are intensive but very productive.

Every module includes at least one assignment where questions are posed to the user and a reply is sought, and each module ends with an assignment. This is an important learning tool in the course. It provides an opportunity for questions from the student about the material covered, perhaps seeking further explanation or an expansion. It also poses questions that require reflection about the content module and the possible applications in the user's field. This gives a very personal involvement that is difficult to include for everyone in a course attended by 12 or more students.

Another important feature of this web based course, which replicates and extends the individual queries that may be raised at an attended course, is the provision of links to other material stored on the course server as well as many links to external material. The use of these is optional to users. If they are of interest then an immediate follow-up is very easy. We believe this encourages users to pursue areas of particular interest to them and, we hope, encourages them to research the method and related areas in more depth. Occasionally it is suggested that a web search is done to look at alternative approaches or to get more details. Table 2 gives some examples of these links.

Table 2 Some examples of links, both internal and external, from Module 2

Section and link	Purpose
2.2 HSE page on Health & Safety statistics	A starting point for the forum task of identifying one's personal greatest risk
2.2 Item from Ben Goldacre's Guardian column	An amusing look at individual reaction to risk
2.3 HSE page on Risk Management	To encourage users to become familiar with the HSE approach.
2.3. Hazard analysis link, firstly to a note about the late Trevor Kletz and then to the IChemE website publications page	To credit Trevor for his memorable summaries and to show the wealth of further information available through the IChemE
3.2 R2P2 – Reducing risks, protecting people	An explanation of R2P2 and then a link to the HSE page that provides a pdf download of this publication
4 Process Hazard Analysis	Further details of PHA and explanation of its place in American legislation.

Pros and Cons of the different approaches

There are many parallels between this web based course and a conventional short training course but also some important differences. Table 3 sets out and compares the main features and capabilities of the two approaches

Table 3 A comparison of the web-based course with an attended short training course

Aspect	Web based course	Short training course
Timing	Always available. It can be started at any convenient time. This is useful if an urgent need for training arises.	Only available at a pre-determined time, with perhaps 3 or 4 suitable courses each year. This can be difficult for off-shore workers.
Cost	£650 for an IChemE member (as at 2013). Little loss of work time if the course is fitted into free slots during the normal working day.	A forthcoming 3 day course in 2014 is priced at £1480 for IChemE members. In addition there are travel and accommodation costs as well as loss of work time of at least 3 days.
Site	It can be done from the workplace or the home. Only an internet connection is needed.	It is delivered in a single short burst in a fixed place.
Multiple trainees	Possible, e.g. as an in-company course using an internal case study The video-conferencing could be done with a group of students.	An in-company course can be effective and may be less costly than by public course. It can use an internal example. But all trainees are away from work at the same time.
Tutor	Same tutor throughout responding by email, forum postings and as mentor in the case studies.	Probably more than one tutor with each responsible for 6 -12 students throughout the course
Group work	Individual and personal – student plus tutor	In team of 4 or 5 but probably without an experienced leader.
Participation	Strongly encouraged by the format. *Basically everyone does everything***.**	Depends on the individual and other participants. One person may dominate; another may withdraw.
Follow-up	Very easy to explore further any issue or topic. The course provides many starting links.	May get pointers from the leaders but further investigation likely to be deferred.
Reflection and reinforcement	The final assignment in each module encourages this practice.	Variable – usually by a team review after the group HAZOP sessions.
Certification	The tutor can confirm satisfactory performance and understanding.	Not realistic to give more than a certificate of attendance.

In summary, key advantages attributable to the web-based course are that it is

- cheaper,
- immediately available,
- operable from any workplace,
- easily fitted into a busy work schedule,
- with an experienced tutor,
- encourages participation in all aspects,
- thorough and thought-provoking,
- certificated.

Course users and feedback

Since it was launched in 2011 over 20 users from 8 different countries have taken the course. Most have been IChemE members able to take advantage of the preferential rate. The participants have come from a variety of employments including the HSE, major consulting and design companies, the nuclear industry, pharmaceutical companies, oil and gas production, instrument suppliers, a cement manufacturer as well as independent consultants. There have been no problems with access to the course material on the server and all the videoconference sessions have run successfully once the initial links have been established.

The comments from the evaluation questionnaire have been very positive. Users' estimates of the time spent on the course range from 12 to 20 hours. The average time of 16 hours is slightly longer than our original estimate. One user completed the course in 5 weeks but most have spread the work over a longer period, typically 3 to 6 months, with some taking a break due to pressures of work, returning to the course later. The course modules are reported to be of the right length and the content found to be very relevant. It is clear that having a personal tutor who responds to course work and any other questions is extremely useful. The online sessions within the two case studies are universally marked as invaluable or very useful whilst no-one marked the studies as not useful or unnecessary. Over 90% have said they would definitely recommend the course to a colleague. General comments from users include:

- I am generally an e-learning sceptic – but this course has been excellent. The examples have been very well selected and provide the most valuable learning points."
- This is my second online course – the first was with one of the Ivy League American Universities. I liked the flexibility of this course rather than the timed approach. The quiz was very useful.
- An excellent course, very concise and packs a lot of knowledge and simulates real HAZOP studies in a very short time.
- A very worthwhile course with good flexibility. Good communication/interaction from tutor. Overall a good training experience.

Grainne Kelly, Senior Consultant and Trainer for Clwyd Associates and an experienced HAZOP study leader and trainer, commented after reviewing the course "This course provides an excellent introduction to HAZOP for team members, giving them the understanding they need to have to work effectively as part of the HAZOP study team from the start - they can work systematically and contribute creatively."

Asked for suggestions about other topics that the IChemE might present by a web based course the most frequent were for LOPA and SIL review with risk assessment and QRA also mentioned.

Future developments

A simple and straightforward change would be to add additional, alternative case studies in order to give more choice to users. These might cover HAZOP study of a procedure or of a computer controlled process or relate to a specific area such as the oil and gas industry. If these were presented as alternatives a user could select the case studies that are closest to their area of interest and activity. Equally, they could be included as additional packages that could be bought as add-ons to the standard course.

As mentioned earlier, the course could easily be adapted to offer a customised package to companies who need to train significant numbers of team members. The minimum number for practical purposes is probably eight. After the basic material and introductory examples of the HAZOP study method the case studies could be based upon the processes and plant operated by the company. Also the video conference sessions could involve the tutor with 3 or 4 of the students. They would then more closely resemble a real HAZOP study as well as being more economical of time and facilities. We can be confident that this style could work since one of us has experience of an actual HAZOP study done this way with the team split between two sites several thousand miles apart.

It would also be possible, given funding, to develop a shortened, simplified version of the course for use by Chemical Engineering Departments within an undergraduate course. This would be a more general version of our initial development work which was for the School of Chemical Engineering and Analytical Science in the University of Manchester using WebCT as the VLE. This could provide a sound educational basis for HAZOP study at the undergraduate stage. However, a different approach would be necessary in the case studies as it is unlikely that sufficient tutorial effort would be available within our cash-constrained University system. A further issue is that not all universities routinely use the Moodle software, some preferring to purchase access to one of the alternative VLEs.

Our aim was to develop a package for learning HAZOP, but there may be other topics (for example, Layers of Protection Analysis) which would lend themselves for development in a similar learning environment.

Conclusions

This Moodle based package for learning HAZOP on-line has demonstrated its effectiveness in providing a student-focussed system, which allows the student to progress at their own rate and as their time permits. But the novel element is that they are supported by their own personal tutor who guides, encourages, provides feedback on assignments and, most significantly in this course, leads them through two practical on-line HAZOP sessions.

Moodle has proved a workable Virtual Learning Environment, and the course has been designed to make use of the many different aspects and learning tools that it provides (forums, quizzes, assignments, etc).

We plan further development of the course to include examples relevant to other industry sectors and types of process systems, with the additional possibility of using specific examples for multiple users from a single organisation or business.

References

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2. HAZOP: Guide to best practice, 2nd ed. 2008, F Crawley, M Preston & B J Tyler, IChemE, Rugby
3. IEC 61882 Guide to Hazard and Operability (HAZOP) Studies.
4. See at: http://www.hazopstc.com/

Figure 1 Example of an initial page for a module

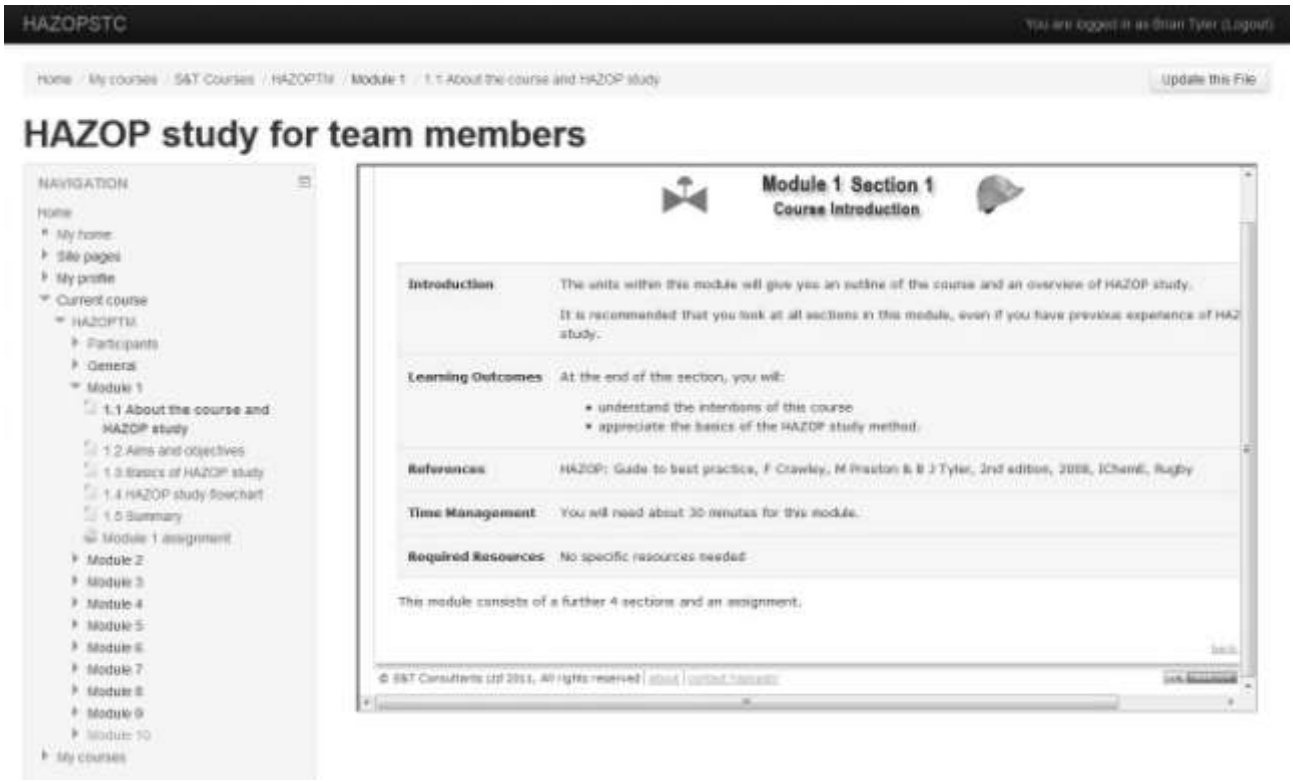

Figure 2 Module 1 Section 4

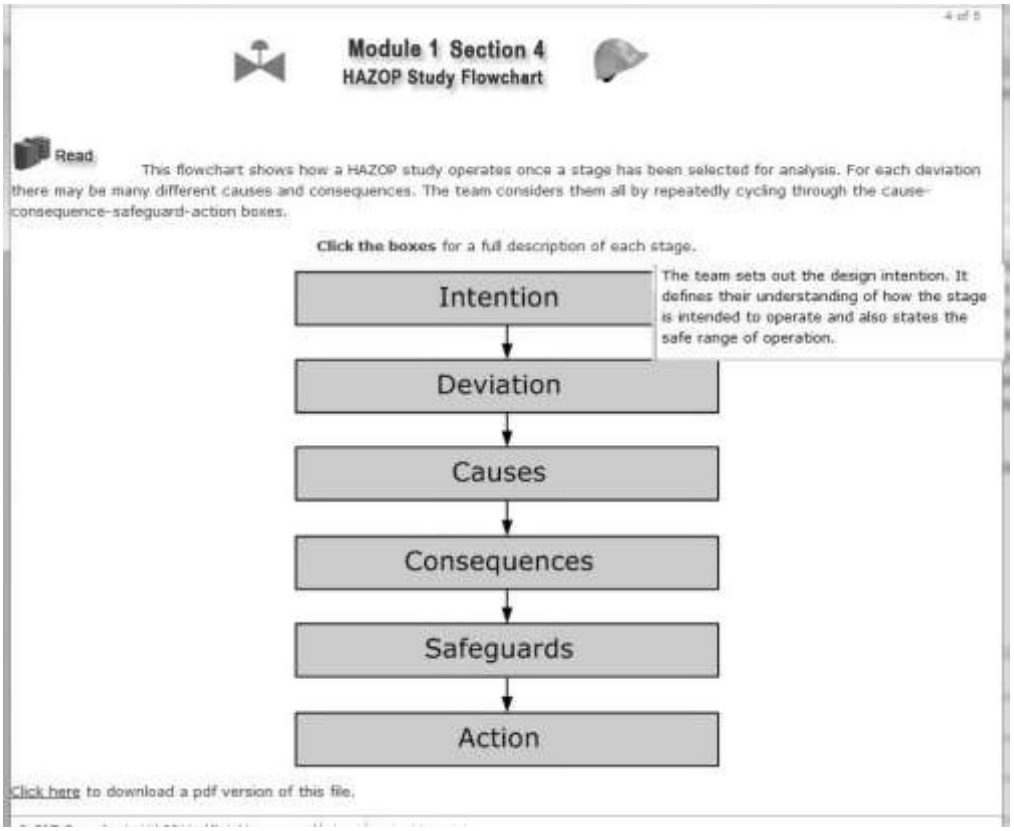

Figure 3 Introduction to Risk Assessment

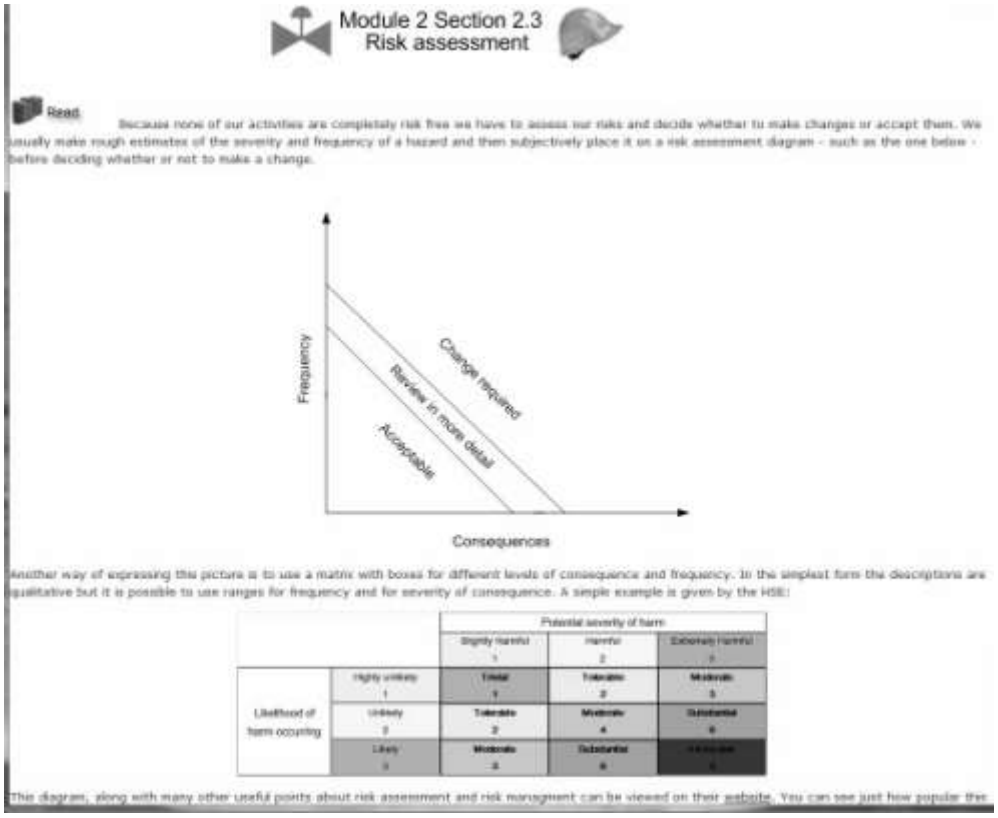

Figure 4 Preparation work for a case study