PROVISION OF GENERIC GUIDANCE ON THE HAZOP METHOD

By Paul Mann – Principal RAMS and Systems Assurance Advisor & HAZOP Chairman

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Abstract

The HAZOP process was initially developed by the chemical industry in the 1950's and has subsequently been successfully applied in many other industries to identify and control hazard potential to a residual level, which is judged tolerable. HAZOP is a structured technique for the identification of potential hazards and failure modes, using deviations applied to pre-determined keywords that describe the system, equipment or process or activities/operations being performed. It is possible also to perform risk ranking to coarsely assess the frequency and consequences of a hazard to make a coarse judgment of the level of residual risk posed by an operation.

HAZOP is normally used as a precursor to more detailed quantified risk assessment and is normally reported using a Hazard Log spreadsheet. This paper has been produced to provide some general insights and guidance on how to carry out and report a HAZOP. The paper is part of a suite of such technical guidance notes being prepared by PMSC Limited and posted on our web site for the benefit of industry in general see www.pmsafety.com

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Section 1.0 Background

This document has been prepared to provide a generic guide to the HAZOP method and to provide some advisory notes of caution when applying the technique. The paper has been prepared based on our experiences in carrying out many different types of HAZOP with a variety of client teams over a period of around ten years. Hence, most of the mistakes have already been made and this paper is basically about the capture of best practice so that newcomers to the HAZOP technique can have a basis to avoid previous mistakes and shortfalls thus deriving maximum benefit from the use of the HAZOP technique.

A HAZOP is a tool used to systematically identify potential hazards and ways in which these hazards are controlled and any resultant consequences mitigated. It provides an initial assessment of risk for each hazard using risk ranking and uses this information to determine the intolerable or undesirable risks and those that require reduction by means of implementation of additional risk reduction control measures.

This paper provides an over view discussion on HAZOP Planning and management; an outline of the typical roles and responsibilities within the HAZOP team members; a description of the HAZOP process and a detailed review of the format for a typical Hazard Log the main deliverable from the HAZOP process. There is also a discussion of configuration control in the HAZOP process and the use of bespoke software where appropriate and a description of some example control measures which might be identified in typical HAZOPs to distinguish between control measures which prevent accidents and those which mitigate the consequences of accidents. The concept of competency statements is developed and example HAZOP keywords are offered as a guide for various industries. Finally a typical HAZOP action sheet is presented as a guide and a list of do's and don'ts are highlighted to help new comers to the method avoid the normal pitfalls and mistakes.

It should be noted that the HAZOP technique works equally well on new build plant and existing plant. Although with new plant there is often uncertainty of operational concepts and as such level 1 HAZOPs which look at the inherent safety issues in the design are often performed initially followed by level 2 HAZOPs which look more closely at operational safety using keywords and deviations asking questions such as what would happen if the Pressure in a particular vessel used in a process went too high.

Section 2.0 HAZOP Planning and Briefing Note

Prior to the HAZOP meeting it is normal for the HAZOP secretary to put together a HAZOP briefing note package for the attendees to study prior to the HAZOP to ensure that all participants start the HAZOP process on a level playing field and understand the reason for the HAZOP; the HAZOP process and the roles and responsibilities of each player in the HAZOP process. The HAZOP briefing note will normally define the plant or facility or system to be subjected to a HAZOP and suggest key words and deviations to be followed by the HAZOP team. System boundary definitions are important for the briefing note to present to the HAZOP attendees, as is the type of information they must bring with them to the HAZOP.

One of the most important issues for the HAZOP team to manage is the supply to the HAZOP team of the latest design drawings or operational procedures. Without access to such information there will inevitably be many actions placed on the HAZOP team by the Chairman. As a general rule PMSC has noted over previous HAZOPs that if the action list for a HAZOP session becomes more than about a dozen it points towards poor preparation and lack of suitable information or perhaps lack of expertise in the HAZOP. All these shortcomings can be avoided by getting the briefing note right at the planning stage and making sure that the right mix of expertise is present in the HAZOP and that attendees are prepared for the HAZOP.

Section 3.0 Roles and Responsibilities of the HAZOP Team

There are several types of personnel who should be involved in the HAZOP process. The following personnel are usually involved:-

- The HAZOP Chairman
- The HAZOP Secretary
- Meeting Attendees from Design, Maintenance, Safety, Production & Operations
- HAZOP Observers

Each of the players roles and responsibilities are outlined further below:-

a) The Role of the HAZOP Chairman

Ideally the HAZOP Chairman should be selected to be independent from the team for the project being subjected to a HAZOP this allows the HAZOP Chairman to take a fresh and perhaps novel perspective on the project or facility being studied, he will be more likely to question regimes and assumptions from first principles thus uncovering the true hazard potential of the plant or facility by asking perhaps more fundamental and probing questions regarding the design basis. The HAZOP chairman is there to lead and direct the meeting and facilitate the best contribution from all of the participants of the HAZOP he also has sole responsibility to determine whether a suitable level of experience is available at the meeting and whether additional experience or input might be needed.

b) The Role of the HAZOP Secretary

The HAZOP secretary is present in the meeting to ensure accurate recording of the detailed technical issues, which are raised by the HAZOP team members. The Secretary will generally populate the Hazard Log spreadsheets with the information being discussed in the meeting. These days it is useful to use a laptop and LCD projector, projecting the Hazard Log spreadsheet onto a screen so all HAZOP participants can see what, is being recorded by the HAZOP secretary and therefore general consensus can be reached. On areas of disagreement the HAZOP Chairman's judgment is final and will be recorded on the Hazard Log. However, it is unusual for the HAZOP Chairman to impose his

or her judgment on the HAZOP meeting, as generally his role is to elicit enough information from all the HAZOP participants to be able to reach an agreed position within the team. The HAZOP Secretary's role is to manage the process in terms of keeping of the Hazard log. The Secretary is not present to run the meeting nor is he present to override the Chairman however if there is a point of process which the HAZOP Chairman has missed for example he is inadvertently missed out the consideration of a particular key word, the Secretary acts as a completeness check on the process and can raise such issues via the Chairman.

c) The Role of the Meeting Attendees

The meeting attendees have a duty to think laterally about the hazard potential in the facility or system being considered. All too often in a HAZOP, the words " that cant happen on our plant " are uttered by attendees, the HAZOP Chairman then responds by saying " well what if it did happen?". The key aspect of a HAZOP is to explore fully hazard potential and how the hazard potential can be managed and what control measures currently exist or are proposed through design to prevent or mitigate the hazard. The emphasis is on attendees keeping an open mind and brainstorming the potential hazards and potential consequences arising from such hazards. Attendees who sit in a corner and don't say anything all day are not entering into the spirit of the HAZOP method and need to be encouraged by the Chairman to contribute to the meeting if they have useful information to offer, otherwise they should not be invited for future HAZOPs (the except to this being for observers).

d) HAZOP Observers

Occasionally, independent observers are also invited to the HAZOP particularly if the overall safety engineering process is being subjected to a Verification and Validation exercise as is sometimes the case in railway projects following the RAMS standard EN50126 or an Independent Safety Assessment in the nuclear industry. The role of the observer is normally to verify that due process has been followed and thus the basis for the HAZOP is not flawed. The observers are not there to run the meeting nor are they there to take any actions.

Section 4.0 The HAZOP Process

The HAZOP process was developed by the chemical industry in the 1950's and has subsequently been successfully used in other industries. It is a structured technique for the identification of potential hazards and failure modes, using deviations applied to pre-determined keywords that describe the system, process or activities.

A group of experts are selected to attend the HAZOP meeting where a discussion takes place, facilitated by the HAZOP Chairman and recorded by the HAZOP Secretary. Typical HAZOP attendees might include members of the design team, mechanical, electrical or even software engineers, members from operations and maintenance and members from production and plant managers might be invited if the plant being considered is operational. It is important to record, which members attended the HAZOP session and the HAZOP Secretary has a duty on behalf of the HAZOP Chairman to ensure that each attendee completes a HAZOP competency statement. The HAZOP Secretary is responsible for the recording of any actions

placed during the meeting and it is important that these are addressed and closed wherever possible within the allotted timescales. Evidence by means of data or references will always be requested when closing actions. Actions cannot normally be closed simply as a result of opinion or bland statements they must be backed up with properly referenced material.

The hazards can be categorized using the frequency and consequence criteria described in Tables A, B, C and D. The intolerable or undesirable risk scenarios may then be assessed further using quantified techniques such as Fault Tree Analysis or Failure Modes & Effects Criticality Analysis (FMECA). The following flow chart describes the HAZOP process.

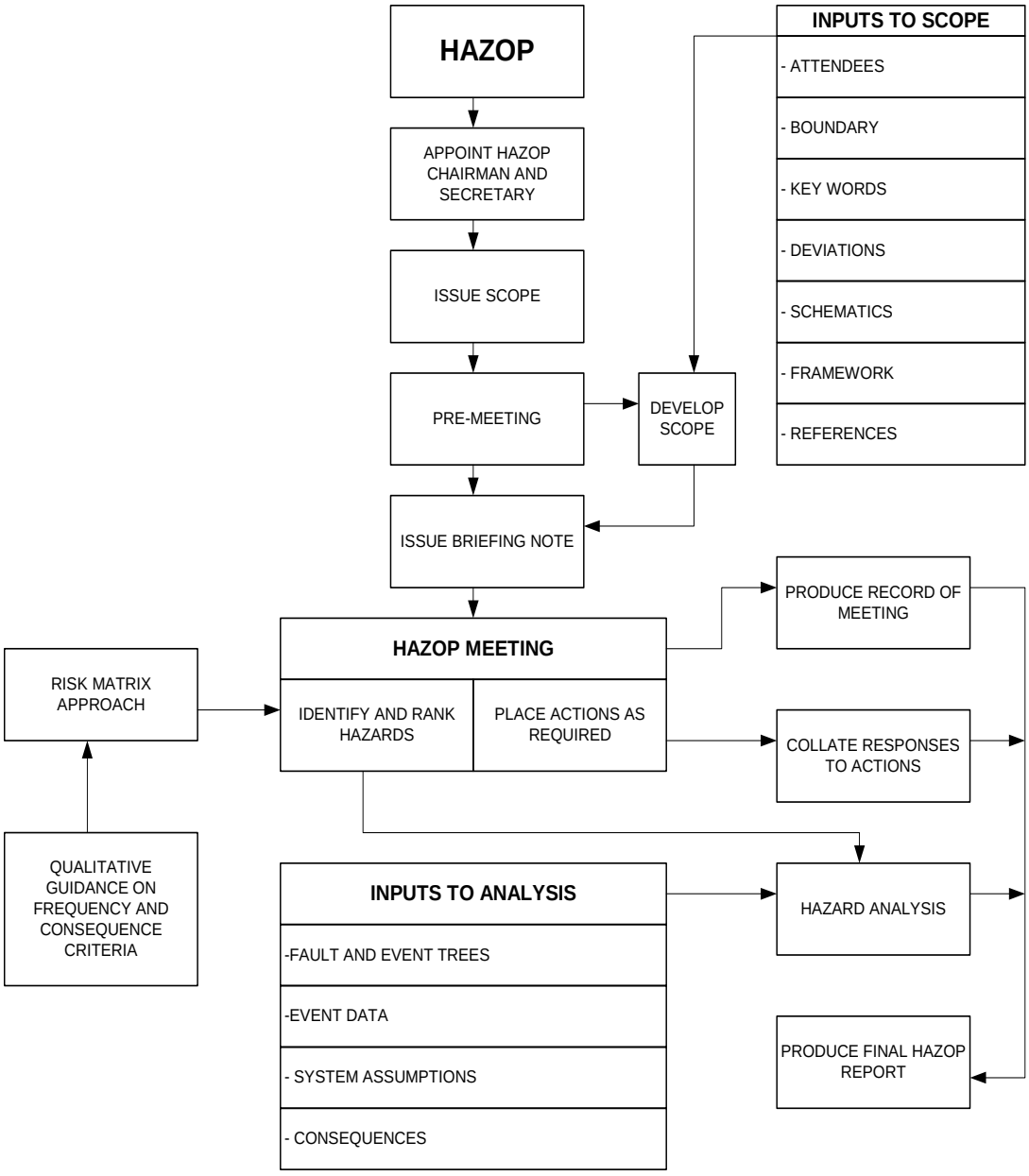

Figure 1 - Flow chart for a typical HAZOP Process

Section 5.0 The HAZOP Hazard Log

The Hazards Log is the main deliverable from the HAZOP process and takes the form usually of a spreadsheet supported on occasions by a HAZOP report to explain any major findings or design changes posed by the results of the HAZOP. Typically the Hazards Log may take the following overall format in an excel spreadsheet form or in a format dictated by bespoke software (see later):

Reference
Unique identifier for each hazard

Keyword or Activity
This is the keyword used to represent a task or activity, which may be performed and which may have hazard potential associated with it. On chemical plant operations the keywords may also be selected in terms of parameters such as temperature, pressure, flow, viscosity. On nuclear processing plants keywords such as criticality, shielding, contamination might be used for a level 1 HAZOP.

Deviation from Normal/ Safe Operation
These are the factors for consideration that 'deviate' from the 'normal' or 'safe mode' of operation, that are likely to cause an 'unsafe situation' or hazard potential.

Root Cause of Deviation (Initiating Event)
These are the 'root causes' or the 'initiating events' that have contributed to, or led directly to, a 'deviation' from the 'normal' or 'safe mode' of operation.

Potential Hazard
These are the 'inherent hazards' that could be 'exposed to personnel' (and including exposure to equipment, materials, or the environment), as a result of the 'unsafe situation' during the operation

Frequency Category
The frequency category is selected from Table A. It should be noted that this guidance is broadly consistent with that provided in EN50126 and the Network Rail Yellow Book. However, the numerical figures should be used as a guide only and as a coarse filter.

LIKELIHOOD	DEFINITION	FREQUENCY GUIDE (Point Estimates for Guidance only)
Frequent	Continually occurs during operational life-cycle (assumed to be a daily event)	100 / year
Probable	May occur a few times during life-cycle (assumed to be typically monthly)	10 / year
Occasional	May occur several times during the operational life of a system (assumed typically annual basis)	1 / year
Remote	May occur at some time in the system life-cycle (assumed typically once every decade)	1 / 10 years
Improbable	Unlikely to occur during operational life (assumed once every century)	1/ 100 years
Incredible	Extremely unlikely to occur (assumed to be once per millennium)	1 / 1000 years

Table A – Frequency Matrix

Frequency of 'Potential Hazard' per Year (A)
The numerical frequency associated with the frequency category as shown in Table A is inserted under this heading

Coincident / Trigger Event
The coincident event is an event, which propagates the hazard to become an accident. For example if the hazard is a hot surface, the trigger is the event whereby an individual may touch a hot surface and get burned. Generally accident triggers and usually as a result of either (1) the 'exposure to personnel' as a result of the 'unsafe situation', or (2) a 'coincident event or failure' that could lead to the possible 'contact' by site personnel (and including contact with equipment, materials, or the environment) with the 'unsafe situation', during the operation.

It should be noted that the trigger event' (in the form of a 'coincident event or failure') may not always be required for the 'potential hazard' to materialise. For instance, where the 'potential accident may arise as a result of normal operation.

Probability Category
The category relating most to the probability of occurrence of the coincident/ trigger event is selected from Table B below, please note that the table below is only intended to represent a typical example.

Probability Category	Probability
Frequent/ Continuous (FQ)	1.00E+00
Probable (PRB)	1.00E-01
Occasional (OCC)	1.00E-02
Unlikely (UL)	1.00E-03
Very Unlikely (VUL)	1.00E-04

Table B – Coincident Probability Categories

Probability of Coincident/ Trigger Event (B)
The numerical value of the coincident probability associated with the selected category will be inserted under this heading.

Accident Scenario Frequency Category
The category will be automatically generated from the frequency and probability information previously supplied as shown in the table below, again these are typical examples only:-

Probability	**Frequency**					
	Frequent	Probable	Occasional	Remote	Improbable	Incredible
FQ	BB	BB	CC	DD	EE	FF
PRB	CC	CC	DD	EE	FF	FF
OCC	DD	DD	EE	FF	FF	FF
UL	DD	EE	FF	FF	FF	FF
VUL	EE	FF	FF	FF	FF	FF

Table C - Accident Scenario Frequency Matrix

Likelihood of Accident Scenario: C = A * B
This is the likelihood of an accident occurring, obtained by multiplying the frequency of the hazard by the probability of the coincident/ trigger event

Consequences
This describes the consequence of the accident occurring.

Severity Category
This category is selected from the table shown below:-

SEVERITY	PERSONNEL	PHYSICAL	ENVIRONMENTAL
Catastrophic	Multiple deaths and/or widespread fatal illness	Loss of a critical physical asset and potential danger to passengers and trains	Significant, prolonged or widespread damage to a habit or species
Critical	Single death and/or multiple severe injuries or occupational illnesses	Major system loss resulting in operational disruptions	Major damage or medium-term damage of a habitat or species
Marginal	Single severe injury or occupational illness and/or multiple minor injuries	System damaged, partial loss of function	Small-scale, short-term damage to a habitat or species
Negligible	Minor injury or occupational illness	Minor damage to system, system not functioning as intended. However, negligible or no effect on the operational railway	Minor local damage to a habitat or species

Table D - Severity Matrix

Risk Category
The risk category is automatically generated from the combination of the severity and risk frequency categories and is based on the matrix shown below:-

RISK/TOLERABILITY	SEVERITY			
Frequency * Probability	Catastrophic	Critical	Marginal	Negligible
AA	A	A	A	B
BB	A	A	B	C
CC	A	B	C	C
DD	B	C	C	D
EE	C	C	D	D
FF	C	D	D	D

Table E – Tolerability/ Risk Matrix

Tolerability Key:
A = Intolerable
B = Undesirable and only accepted when risk reduction is impracticable
C = Tolerable subject to ALARP discussion (see note 2 below)
D = Negligible

Note 1 : It should be noted that the above guidance on risk ranking is consistent with both the Network Rail Yellow Book and the European Norm (EN) 50126 which considers RAMS in railway systems. Additional control measures should be

evaluated to demonstrate whether the risks are As Low As Reasonably Practicable (ALARP).

Tolerability (Y/N)
If the risk category is found to be either A or B then the hazard is defined as not being tolerable and further action will be required and the activity will not be allowed to continue. If the risk category is either C or D, the hazard is judged to be tolerable pending an ALARP review for category C items.

Further Action Required
Any actions resulting from the discussion surrounding the particular hazard will be recorded here and ownership and delivery of action responses assigned.

Comments
Any further comments surrounding particular hazard which need to be recorded

HAZOP Chairman
Name of HAZOP Chairman

HAZOP Secretary
Name of HAZOP Secretary

HAZOP Meeting Venue
Venue where HAZOP took place

Date
Date HAZOP took place

Section 6.0 Consideration of Control Measures in a HAZOP

It is worth adding a few notes on the treatment of control measures in HAZOPs as this is often an area of considerable discussion and misunderstandings during the HAZOP process.

A control measure can be an engineered safety feature of the design such as for example emergency brakes on a train or crane or an engineered interlock which prevents two valves being opened at the same time on a typical process plant and thus for example avoids misrouting of radioactive liquor. Generally control measures of the engineered type are present to prevent a hazard turning into an accident. The above is a general guide but is not always true as for example crashworthiness in a railway vehicle might be considered by some design teams as an engineered safety feature however the feature, which may be a crumple zone or an energy absorbing device acts to mitigate the effects of an impact or collision and so the control measure is generally considered a mitigation feature. Therefore engineered safety features can be provided to both prevent accidents, and to provide mitigation against the effects of an accident after it has occurred. Some examples are shown below:-

Industry Type	Prevention Control Measures	Mitigation Control Measures
Nuclear	Provision of Emergency Boronation to absorb thermal	Secondary Containment to provide containment any release of nuclear

Industry Type	Prevention Control Measures	Mitigation Control Measures
	neutrons to shut down a nuclear reaction.	particles in the event of premature criticality or a Loss of Coolant Accident.
Nuclear	Uninterruptible Power supplies	Standby Diesels to start on Loss of grid
Rail	Automatic Train Protection to avoid collisions between trains	Signal Overlap distances between Signal and junctions
Rail	Trips provided for high energy devises on the under frames of rolling stock to ensure devices trip if they are faulted thus avoiding a fire starting, typically such trips might be found on Traction Converter Inverter units or Transformers.	Smoke Detectors or Fire Wires and Hand Held Fire Extinguishers
Automotive	Anti Locking Brakes Feature	Crumple Zones to absorb energy in case of impact.
Automotive	Speed Limiting proximity monitoring (to avoid collision)	Air bags which activate on collision
Nuclear Lifting Cranes	Automatic Safe Working Load Indicators, which apply brakes to the Crane movement in the event of excessive % SWL being experienced.	Provision of Break fall Towers during lifting of heavy items
Nuclear Lifting Cranes	Provision of Dual 2x100% Load Paths to avoid or prevent dropped loads.	Careful planning of load paths to avoid serious consequences of a dropped load hitting something, which could cause larger perhaps nuclear release type consequences.

It is important when HAZOPing to ensure that a clear distinction is made between any engineered safety features, which already exist in the design (clear design basis references should be recorded by the HAZOP Secretary) and those which are on the drawing board for evaluation. All too often control measures are included in HAZOPs which turn out in the cold light of day to not be part of the design basis ie they are on the wish list of design features designers would like for their system but they never materialise. It is of paramount important therefore to ensure that only existing control measures or those for which design basis information can be provided are claimed in the HAZOP Hazard Log.

Other control measures can be administration control processes and the provision of warning labels or maintenance activities to avoid a failure occurring.

In general the HAZOP teams are always requested to look at engineered safety features in preference to the softer managerial administrative controls as these often place an additional burden on the operators.

Section 7.0 HAZOP Competency Statements

Competence statements will need to be completed by everyone who is present at the HAZOP study. As the HAZOP involves a brain storming process it is important that the expertise provided by the people present at the meeting is recorded so that, the process can be audited by 3rd parties such as customers, insurers or regulators who were not necessarily present at the original HAZOP meeting. The competency statements should be included in any HAZOP report as they confirm that the right people with the right knowledge and skills were present at the HAZOP meeting. Examples of a few competence statements have been included for information.

Example Competence Statement for Mr Paul Mann

ACADEMIC AND PROFESSIONAL QUALIFICATIONS
Mr. Mann holds a Batchelor of Science degree in Physics from Leeds University. He is also a Fellow of the Safety and Reliability Society (FSaRS) and a Member of the Institute of Mechanical Engineers (C.Eng M.IMechE)
PAST EMPLOYMENT HISTORY (RELEVANT TO HAZOP ROLE)
Mr Mann has worked in the field of safety engineering since graduation 1980. He has worked on safety and reliability projects in the Railway, Oil & Gas, Defence and Nuclear sectors and has acted as a HAZOP Chairman and HAZOP Secretary on a number of occasions within the railway sector and other business sectors as indicated below:- - HAZOP Chairman on a railway axle assessment LTF25 - HAZOP Chairman on a Gas Compression Station Project for TRANSCO - HAZOP Secretary for the temporary station for Heathrow Express Service - Preparation for HAZOP guidance document for a railway engineering company - HAZOP Chairman and Secretary for Railtrack on railway infrastructure change projects on (ECML) and Boat Train Routes - Independent auditor for Network Rail Thameslink 2000 project - Preparation of HAZOP training for a Nuclear Utility - HAZOP Chairman on TETRA Radio System for a driverless railway in Singapore (NELP) - HAZOP Chairman and part time HAZOP Secretary on Taiwan High Speed Railway Project - HAZOP Chairman for on a 25kV substation replacement project (Examples Only)
ROLE WITHIN PROJECT:
Independent Safety Advisor
PURPOSE OF BEING AT THE HAZOP
HAZOP Chairman

Section 8.0 HAZOP Configuration Control and Use of Software

There are several software packages for the recording of HAZOPs on the market some of the leading ones are listed below for information. These packages have one main benefit in that they maintain the configuration control of the HAZOP process. Configuration control is important when conducting a large scale HAZOP study which may have many sessions running of a calendar period of several months.

For smaller scope HAZOPs it is probably ok to use standard Excel software however as the HAZOP becomes more complex with a larger scope a bespoke HAZOP package is much more advisable in that a more accurate record of when issues were recorded and edited can be maintained. The software packages also enforce a strict regime in the HAZOP process as they enforce a rigorous consideration of all HAZOP keywords and headings in the Hazard Log.

Some software packages which are currently available are as follows:-

Supplying Company	Name of HAZOP Package	Comments
Isograph Direct Warrington http://www.isograph-software.com/hazover.htm	HAZOP Plus	Used extensively in the rail and other aerospace sectors. Allows bespoke risk ranking tables to be defined by the user and provides normal configuration control.
Lihou Technical Services http://www.lihoutech.com/index1.html	HAZOP Manager Version 6	Used a lot in the oil and gas industry.
Dyadem http://www.dyadem.com/products/pha-pro/	PHA Pro	
Primatech http://www.primatech.com/	PHA Works	
Schlumberger http://www.oilfield.slb.com/content/services/ipm/loss/hazop_meeting.asp	Word Processing Software to record HAZOPs	More data available at their web site.
ABS in the USA http://www.absconsulting.com/leadersoftware/	Hazard Review Leader	

Supplying Company	Name of HAZOP Package	Comments
http://www.idi.ntnu.no/grupper/su/fordypningsprosjekt-2003/fordypning2003-Kristian-Marheim-Abrahamsen.pdf	HAZOP Software Tool	

Use Table of HAZOP Reference Material for further Reading

HAZOP Reference/Web Site address	Author/Title	Comments
Trevor Kletz Reliability Engineering & System Safety, Vol. 55, No. 3. (March 1997), pp. 263-266.	Trevor Kletz	Trevor Kletz is a leading light in the context of the introduction of the HAZOP method and is regarded in the industry as one of the founders of this type of methodology.
http://osha.4ursafety.com/bkpgs/gnrl-sfty/hazop.html http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0471982806,descCd-reviews.html	HAZOP and Software HAZOP	Useful reference text book on HAZOPs
http://www.acusafe.com/Hazard_Analysis/HAZOP_Technique.pdf	HAZOP Process Guidance Note	

Section 9.0 About PMSC Limited

PM Safety Consultants is a specialist Systems Assurance company offering Systems Safety advice and Reliability, Availability and Maintainability assurance support to a range of industries worldwide. Our web site is located at www.pmsafety.com . Over a period of 14 years we have conducted many HAZOPs in a range of industries some examples are presented as follows:-

HAZOP for a Gas Calorimeter for TRANSCO
HAZOP for a new type of low track force Bogie system
Several HAZOPs for a whole new high speed railway system
HAZOPs for the introduction of a new fleet of EMUs into Singapore's Metro system
HAZOP on the transportation of a new form of chemical energy device

HAZOP for a freight forwarding company sending major refinery parts overseas by Barge and by ship
HAZOP reviews for a nuclear processing plant

Appendix A Typical Sets of HAZOP Keywords

This appendix presents for reference and guidance some examples of typical HAZOP keywords, which might be used during any HAZOP session. Firstly Level 1 HAZOP keywords are presented then a series of lower level 2 HAZOP keywords, which include keywords and applicable deviations. The list is not intended to be exhaustive but rather indicative.

Railway Industry Level 1 Keywords
System Failure
Sub system Failure
System Interfaces
Manual Lifting
Touch Potential
Voltage/Current/Frequency
EMC/EMI
Water Ingress
Security
Loss of services
Hot surfaces
Compressed Air
Hydraulic fluid
Operator error
MMI
Maintenance.
Software Errors
External Hazards such as landslide, earthquake, high winds, lightening strike

Nuclear Industry/Process Level 1 Keywords
Radiation
Criticality
Effluent Discharge
Contamination
Shielding
Aerosol Production
Touch Potential
Manual Handling
Incorrect Routing/Valve alignment
Overfilling
System Interfaces
Loss of services (Cooling Water, compressed air etc)
Operator error
MMI
Maintenance.
Software Errors

Crane HAZOP Level 1 Keywords

Snagging whilst Slewing
Snagging whilst Traversing
Snagging whilst Luffing
Snagging whilst Hoisting
Snagging during simultaneous motions
Ledging whilst Lowering/ hangmans drop
Over hoisting /Double Blocking
Over traversing
Over slewing
Slinging
Unauthorised lift
System Interfaces
Operator/Driver Error
Banksman Error
Man Machine Interface
Maintenance
Software Errors

General External Hazard Level 1 Keywords
Aircraft Crash
High Winds
High Humidity
Torrential Rain
Snow
Flooding due to Rain
Extreme Temperatures
Tsunami
Tidal Wave
Earthquake
Lightening Strike

General Internal Hazard Level 1 Keywords
Fire
Flooding
Pipe whip
Failure of pressure parts
Touch Potential
Failure of rotating machinery
Dropped Loads
Failure of static structures
Electrocution
Explosion

Transportation of Hazardous Goods Level 2 HAZOP Keywords and Deviations

HAZOP Keyword	Deviation
Loading	Unsecured
Loading	Dropped
Loading	Use of inappropriate equipment
Loading	Manual Handling
Loading	Overloading

HAZOP Keyword	Deviation
Loading	Uneven loading
Loading	Missile Generation
Containment	Loss of Inappropriate Breach – human error
Electrical/Voltage	Fail to isolate/earth
Chemical	Spillage
Chemical	Reaction
Chemical	Leakage
Chemical	Release (gaseous)
Fire	Sources of ignition
Water	Ingress
Temperature	Too high Too low
Humidity	Too high Too low
Maintenance	Operator error
Support systems Electrical Pneumatic Hydraulics Compressed air Ventilation Shielding Cooling	Failure Failure at Interfaces

Appendix B Typical Example Action Record Sheet

HAZOP ACTION RECORD SHEET	
PROJECT:	
ACTION PLACED ON	
HAZOP CHAIRMAN	
HAZOP SECRETARY	
DATE OF HAZOP	
DRAWING REF: (if applicable)	
KEYWORD & DEVIATION:	
UNIQUE ACTION REF:	
CAUSE OF HAZARD:	
CONSEQUENCE:	
RECOMMENDED ACTION:	
ASSIGNED RISK SCORE:	
ACTION RESPONSE: (Person closing out the action shall initial and date the response)	
HAZOP CHAIRMAN COMMENT: (HAZOP Chairman shall initial and date his acceptance of the response)	

Appendix C Some Advice on Do's and Don'ts of running a HAZOP

HAZOP Issue	DO	DO NOT
Planning and Management	Make sure that a briefing note is issued to all participants and that all department heads have commitment to the process.	Do not limit the distribution of the briefing note all HAZOP participants will need to see it. Do not allow HAZOP to proceed with out a quorum of expertise as the results will be flawed and the HAZOP will likely either fail or generate many actions and loose credibility.
Information	Make sure that drawings and systems descriptions are up to date for the HAZOP	Don't be tempted to start redrawing diagrams and drawings and redefining systems in the HAZOP. If the base data is unclear reconvene the HAZOP when data has been better defined.
Resources	Do make sure that adequate time and resource is allocated to the HAZOP. A good mix of designers (mechanical and electrical and possible software) will be required together with operations and maintenance personnel and production personnel if the plant is a production plant.	Do not be tempted to use an in-house HAZOP Chairman to save budget it will be a false economy and will probably be rejected by any regulator or auditor worth his or her salt. Don't be tempted to limit the scope of the HAZOP unnecessarily many hazards exist at interfaces and by limiting the scope hazard potential to affect the system may not be properly identified rendering the HAZOP potentially flawed.
Length of HAZOP	Do allow sufficient time in the start of the HAZOP for all attendees to get up to speed with the HAZOP remit. The norm in HAZOPs is that the first few sequences take a disproportionate amount of time to complete as the team members explore the HAZOP remit and get to grips with the process.	Do not allow the HAZOP team to become distracted and ideally ensure that HAZOP sessions are no longer than an afternoon or a morning session – this allows personnel to retain their brainstorming ability, HAZOPs which run on too long at one sitting become tedious and tend to be counter productive.
HAZOP Keywords	Do invite HAZOP participants to add new keywords to the HAZOP process if they judge the existing list in the briefing note to be incomplete or inadequate.	Do not omit a description against a key word even if there were no hazards identified for quality control reasons it is equally important to show the completeness of the HAZOP by recording in the hazards log that no hazards were identified by a certain keyword.
Participation	Do allow a good cross section of discussion and constructive debate between the HAZOP	Do not allow one person or group of people to dominate the discussion. The HAZOP Chairman is there to

HAZOP Issue	DO	DO NOT
	members. Do ensure that HAZOP members are not distracted by use of mobile telephones in the HAZOP and attendees should refrain from leaving the HAZOP to deal with other issues and then returning as this disrupts the flow of the HAZOP and results in discrepancy later on. Do ensure continuity wherever possible in the HAZOP team between different sessions of the HAZOP meeting on any particular system.	facilitate a balanced discussion by all members. Do not allow management representatives to hijack the HAZOP process. The HAZOP is a meeting where even the lowest ranking person is allowed to have his or her say on a hazard if they have a point to make. Do not prevent personnel from attending the HAZOP just because they might have said something, which was unpopular to management in the HAZOP.
Control Measures	Do record engineered safety features that exist on the plant together with any administration controls or warning signage, which might help to either prevent a hazard becoming an accident or mitigate against the effects of an accident.	Only reference existing control measures. Do not take credit for control measures that do not yet exist and cannot be properly substantiated in the design basis of the plant or equipment being considered. Do not just HAZOP existing control measures if the risks are still coming our high. In such circumstances the HAZOP team has a duty to consider what additional design features or administration controls could be brought to bear to reduce the risk levels and demonstrate that risks are As Low As Reasonably Practicable.
Risk Ranking	Do make sure all members of the HAZOP fully understand the HAZOP risk ranking criteria prior to their application. This is important since it is crucial that all HAZOP team members have the same or similar mental understanding of the criteria being used to risk rank.	Do not allow management personnel to dominate the discussion during risk ranking as this will result in the HAZOP process being flawed. The HAZOP team must come to a consensus agreement on the categories of frequency, consequence and risk of any specific hazard.
Reporting	Make sure that the completed Hazard Log properly records all the discussion in the HAZOP which was relevant it is not necessary to record every single word spoken just the main points of agreement or dispute should be recorded. Do ensure that all participants produce a competency statement	Do not allow the Hazards Log to be edited by either participants of the HAZOP who wished they had made a certain point in the HAZOP but did not or by non- attendees of the HAZOP who didn't like what they saw in the HAZOP Hazards Log. The Hazard Log is a strictly controlled document, which can only normally be amended by reconvening the HAZOP team to reconsider a certain point or address

HAZOP Issue	DO	DO NOT
	and give this to the HAZOP Secretary for inclusion in the report.	the closure of a certain action.
HAZOP Actions	The HAZOP secretary should be retained after the initial HAZOP session to ensure that all HAZOP actions are properly closed out in an appropriate timescale and relay this information via the HAZOP Chairman back in to the Hazards Log. Closure of HAZOP actions should only be allowed once proper reference material or data has been identified which can substantiate the closure of the action to the satisfaction of the HAZOP Chairman.	Don't allow HAZOP actions to drift on in time, their swift and professional closure is important for the credibility of the HAZOP process to remain in tact.
Changing Design	Do allow the HAZOP Chairman access to the latest design information pertaining to changes since the last HAZOP so that he may take a judgement on what elements of the design need to be readdressed by the HAZOP team.	Do not allow design changes to become approved unless they have been subjected to the HAZOP process.