Organisational Factors and Safety [1]

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Introduction

In the past, the inspection of major hazard plant has typically focussed on the technical aspects of safety. In recent years the emphasis has shifted towards organisational and management factors, with concepts such as "safety culture" and "safety management systems" receiving increasing attention. This can in part be attributed to inquiries into major accidents over the past decade having identified weaknesses in organisations as a primary underlying cause.

While much has been written about the effects of organisation and management on safety, there has been surprisingly little in the way of developing methods for investigating and improving organisational effectiveness. The Major Hazard group of the Dutch Ministry of Social Affairs (Ministerie van Sociale Zaken en Werkgelegenheid) recognised the importance of undertaking research in this area which would provide support for their Labour Inspectorate in the inspection of major hazard installations. The difficulty that the Inspectorate has is that they are faced with an increasing number and range of chemical installations, for which there are limited inspection resources. Currently there are about 400 installations and 17 inspectors. Besides the differences between installations in terms of the chemical processes, products, associated hazards and technical details related to hazard control which inspectors have to consider, experience showed that companies were also organised differently, and that this could give rise to different organisational strengths and weaknesses with respect to managing the risks. These are the risks associated with Loss of Containment (LOC) of hazardous materials.

The Ministerie van SZW commissioned Four Elements to investigate the production of a tool for use by the Inspectors which could make the inspection process more efficient. Inspectors already have an inspection system called AVRIM which provides for increased efficiency by enabling inspectors to apply effort commensurate with the extent of the problems revealed at

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[1] Presented at "De COMAH-richtlijn en het Major Hazardbeleid van SZW: een nieuwe inzet van beleid." Ministerie van Sociale Zaken en Werkgelegenheid, 3 Oktober 1995.

an installation (Oh, 1995). The idea of the new tool was to enhance the approach by reducing the world of organisations to a small number of types, each type being addressed by a particular inspection strategy with respect to investigating organisational aspects.

The target group was organisations which have to make one or more occupational safety reports, "Arbeid Veiligheids Rapporten" (AVRs). This is required by a Dutch regulation which came into force in 1982. It is part of the Dutch Working Environment Act (Arbowet) and implementation of the European Seveso Directive aimed at the prevention of major accidents which involve dangerous substances. This European Directive (82/501/EEC, 1982) has recently been revised as the COMAH Directive (CEC Draft, 1994), which puts much greater emphasis on management systems and organisational factors given the fact that 95% of all major accidents have management error as their underlying cause. Based on the AVR, it is possible for the Dutch regulatory authorities to assess and inspect the quality of the major hazard control system of an installation using a combined team of the SZW major hazards policy group, and the I-SZW Inspectors.

Inspectors have to take "snapshots" of an organisation and the condition of its management system. Unlike the technical aspects of safety, there are no specific standards like there are for the design of a pressure vessel, for example. Any intervention from inspectors is not, in any case, aimed at technical irregularities but rather on the overall system of major hazard control. To make the process more efficient and more consistent between Inspectors, it was thought to be of value if they could home in on the key organisational weaknesses of a particular installation using a common approach. They could then go on to investigate whether there are adequate systems in place for controlling the risks in those potentially weak areas. Support for this homing in activity and consistency in approach was considered to be the main functions required of a new tool. The tool was named as the "Organisational Typing Tool".

The aim of the tool was not to take over the inspection and reporting role, but to indicate to Inspectors areas of investigation which they might best concentrate their finite resources on. Inspectors would still be free to follow-up their own lines of investigation, based on their own experience, but support would be provided for:

★ Evaluation of strong and weak points in an organisation from examination of the safety reports submitted by the companies, in order to identify areas to follow-up;

★ Identifying strengths and weaknesses for inspectors to focus on during an inspection;

★ Requirements for improvement.

Approach

A number of ideas from previous work, as well as new research, were brought together to formulate an approach to developing the Organisational Typing Tool. Firstly, organisations needed to be categorised in some way to reduce the world of major hazard organisations to a finite number of types. Secondly, for the different organisational types the links to safety had to be identified.

These two aspects of the approach were achieved in the following ways:

1a Identify as many organisational variables as possible which could have a potential link to safety in order to develop an "Organisational Map" and, in doing so, to use both the literature and the knowledge of the experienced regulator;

1b Group safety-relevant organisational variables to obtain organisational "types" and the associated strengths and weaknesses with respect to safety;

1c Suggest the structure of a prototype Organisational Typing Tool, taking account of the potential users' needs.

2 Examine the links between the identified variables on the "Organisational Map" and safety through:

- loss of containment (LOC) accident analysis;
- survey of recognised safety performance indicators;
- matching Organisational Map variables with recognised organisational aspects of system failures;
- applying a systematic approach to identify the potential effects of Organisational Map variables on a major hazard safety management control and monitoring system;

The work is described in detail in Bellamy, Leathley and Gibson (1995a, 1995b). The key aspects of the approach, main findings of importance, and the structure of an Organisational Typing Tool are described in summary below.

The Organisational Map

Because this is a very new area of research, the beginnings have to be modest but as all embracing as possible. The best approach was felt to be one that would define a rich vocabulary to describe major hazard organisations, and to try to develop some form of categorisation. With this in mind, various sources of information were used to build up a map of organisational variables. The use of the term "map" was considered to be a more valuable concept than that of taxonomy because it conveys the idea of something which can be used to navigate the various features of an organisation, rather than simply grouping organisations on the basis of similarity of features. The idea was to develop a representation of the organisational world which could fit onto a single sheet of paper for easy reference. As it turned out, the map was too extensive to make this possible (see Annex I of this paper). The main areas of the Organisational Map are:

A - Nationality
B - History
C - Psychology
D - Physical characteristics
E - Organisation
F - System climate
G - Experts perceptions (SZW Inspectors and Policy Makers)
H - Hazards
I - Performance indicators

Each branch is elaborated, giving a specific map reference for each variable. For example, C2.1.4 is Learning, D3.2.4 is Level of Automation, E2.8 is Degree of Bureaucracy. The different perspectives from which one can view organisations are given under the heading COMPANY. For example, Branch E. ORGANISATION, made up of E.1 STRUCTURE and E.2 PROCESSES is the typical domain of the organisational theorist. Branch D. PHYSICAL CHARACTERISTICS, is much more concerned with the technical and task aspects of an organisation in terms of design and complexity. These physical characteristics in turn raise questions about, for example, the C.2 INTELLIGENCE which supports the performance of those tasks - the people "intelligence", the control process, the formalised systems of information etc. In turn, the intelligence in the organisation may be very dependent on its Branch B. HISTORY. Therefore, there are links between the different branches and their components which the development of the Organisational Map assists in raising questions about, even though these interrelationships between the branches are not currently fully understood (and therefore not shown on the map).

The basis of the map development was:

★Examination of the organisational psychology, human factors and safety literature, to find out which organisational variables could be considered to relate to safety performance either directly or indirectly.

★Review of organisational/sociological theory, to examine any evidence on how organisations are structured.

★Informal discussions with SZW major hazards policy group to find out what they saw as the distinguishing features of AVR installation organisations.

★A formal "Knowledge Elicitation" process using Repertory Grid technique (Kelly, 1955; Fransella and Bannister, 1997). In this process, the expert knowledge was captured of SZW major hazard policy personnel and the SZW inspectorate about organisational characteristics which distinguished between AVR sites and installations.

★Investigation of work on safety Performance Indicators.

★Review of installation typing variables used in frameworks for capturing statistical data on LOC accident frequencies, notably the UK Health and Safety Executive's RIDDOR database which contains reported dangerous occurrences for major hazard sites.

The Organisational Map sets a basis for being alert to the different dimensions of organisation and for asking questions about the relationship between organisational variables and safety. It is an empirically derived system (no attempt has been made to fit it to a particular theory), using the sources of information described above.

These are the necessary beginnings of putting Safety into an organisational context even if, at this stage, we do not know which variables are relevant in organising for safety.

Inspectors' Perceptions of Organisational Features Distinguishing Between Major Hazard Chemical Companies

Repertory Grid technique (Kelly 1955) is used to provide information on an individual's mental representation of their world. The dimensions of mental representations are known as "constructs". In the current work the idea was to generate a mapping of the constructs of experts (SZW Inspectors and Policy Makers) of the world of the organisational aspects of major hazard chemical installations, in this case Dutch AVR installations.

The method elicited the "contructs" by taking a group of 3 AVR installations, sites or companies and asking:

"In what ways are two of these the same and the third one different?"

Each difference identified was then represented as the ends of a continuum such as "centralised responsibility - front line responsibility", "procedure dependent - skill dependent", "big - small". These are the constructs of the expert by which he or she represents the organisational characteristics of AVR installations.

The process was repeated for each expert for a large number of such triads, where the elements of the triads were companies, sites or installations well known to the expert. A selection of AVR sites and installations from the sets of triads (about 20 for each expert) were scored by the experts for each of their own constructs. A grid was set up of AVR sites/installations along one axis, and an expert's constructs along the other. The grid was filled in by scoring the site/installation's perceived position on each construct using a 5 point scale, where 1 and 5 represented the extremes of the construct. Typically, each expert generated about 30 constructs.

These data were then subjected to a form of factor analysis which enables clusters of constructs to be identified which tend to vary together in their scoring. The clusters can be named according to the characteristics of the constructs which comprise them, such as "Large, Complex, and High-Tech". Each cluster accounts for a proportion of the variance within the data. Most experts had 5 or 6 clusters, with one accounting for the largest proportion of the variance. For example, the main cluster of one of the experts is given below. This accounted for 54% of the variance.

Table 1: The Main Cluster of Expert A

Expert A, Cluster 1 (54%):Humble, small, dull image, unautomated, low USA influenced companies - Arrogant, large, glossy, modern automated, USA influenced companies
Arrogant (not at all - very) Training policy (no training policy - well developed training policy) Automation (none - fully) Degree of local influence (high - low) Image (not glossy - very glossy) Style of control (flexible - rigid) Complexity of organisation (simple - complex) Nature of technology (old technology - modern high technology) Career development opportunities (poor - good) USA influence (low - high) Size of company (small - large)

What this means is that amongst the AVR installations known to this expert, there was a tendency for the following characteristics to appear together: larger companies with a high USA unfluence, good career development opportunities, modern high technology, complex organisation, rigid style of control, glossy image, low local influence, fully automated, well-developed training policy and very arrogant. The converse is also the case i.e. smaller companies have low US influence, poor career development opportunities etc.

Development of an Organisational Typing Tool

The constructs of the experts could be broadly divided into: 1) Organisational Typing factors, and 2) Strengths and Weaknesses. The nature of an Organisational Typing factor is that it is a descriptive rather than an evaluative measure of a particular characteristic of an organisation. So, for example, "size" is considered to be a typing factor whereas "attitude to safety" is considered to be evaluative. Being big or small, in itself, is neither good nor bad. However, a poor or a good attitude to safety has a definite association with a weakness or strength. In the example in Table 1, "no automation - full automation" is a typing factor and "no training policy - well developed training policy" is a weakness-strength.

Altogether the 17 experts yielded 93 organisational typing factors and 146 strength-weaknesses. Where a typing factor and a strength-weakness appeared in the same cluster, it meant that the two things tended to vary together. Typing factors could therefore be used to predict the covarying strengths and weaknesses eg. fully automated installations were likely to have well developed training policies. This formed the fundamental basis for an Organisational Typing Tool; by linking every typing factor to all its associated strengths and weaknesses, the typing profile of any organisation could be used to predict likely strengths and weakness. For example, perceived strengths and weaknesses associated with big companies were:

Good hardware safety, a lot of reliance on written material, high adherence to written procedures, too much reliance on paperwork, good use of procedures, strict adherence to safety procedures, high skill of management, a lot of chemical knowledge, high skill of workforce, many skills required for the job, a lot of training provided, well developed training policy, high level of on the job training, well qualified and capable workforce, high level of formal training, good organisation of training, safety knowledge from within company, high experience of hazard, high awareness of hazards by workforce, adequate qualifications of workforce, extensive use of contractors, high production pressure, unrestricted money available for safety, high pressure to work safely, attitude to safety "between the ears", careful attitude of workforce, very arrogant, good maintenance, high sensitivity to the amount of maintenance to be done, maintenance difficult, no language barriers that affect safety, systematic approach to control, good control of contractors, high "toezicht" - control of workforce, good career development opportunities, no fear of losing ones job, high motivation to produce an AVR, reliable information provided in AVR, high relevance of information provided in AVR, good organisation of safety, responsibilities well defined, detailed analysis of accidents.

The typing factors could be classified under the following map headings:

Table 2: The Organisational Typing Factors of the SZW Inspectors and Policy Makers

A. NATIONALITY*	E. ORGANISATION
B. HISTORY	E1 Structure
B1.2 Family Culture*	E1.1 Number of People*
B1.3 Family Growth/Change/Age*	E1.3 Number of levels
B2.1 Product Diversity/Experience*	E1.4 Location of decision-making/authority*
B2.2 Type of Process*	E1.5 Task Specialisation
C. PSYCHOLOGY	E1.7 Status/Responsibilities
C1.6 Climate	E2.3 Control Processes
C1.7 Culture	E2.4 Adaptation to Change
C2.1.2 Rules*	E2.8 Degree of Bureaucracy*
C2.1.3 Knowledge	
C2.3 Skills	F. SYSTEM CLIMATE
	F1 Economic Pressures
D. PHYSICAL CHARACTERISTICS	F5 Public Perceptions
D1.2 Proximity to Head Office*	
D2. Size*	H. HAZARDS
D3. Complexity*	
D3.1 Chemical Complexity	
D3.2 Physical Complexity	
D3.3 Task Complexity	

D3.4 Control Complexity

Of these, the most important typing variables (based on both frequency of occurence and the amount of explained variance) are marked with a *. They are (in order of importance):

1Size (of company, site, installation, workforce)(D2 and E1.1)
2Documentation (existence of, quantity of; rules, written documentation, paperwork, procedures) (C2.1.2 and E2.8)
3Complexity (of process, or operations)(D3)
4Age (of site, of installation, of the plant)(B1.3)
5Central - Local (eg centralised production of procedures compared to locally produced procedures; strong - weak influence of parent company)(B1.2, D1.2, and E1.4)
6Nationality (Dutch, USA, British) (A)
7Single - Multiple (product or hazard)(D3.1.1)
8Primary - Secondary Process (role in business) (B2.2)

The strengths and weaknesses could be sorted into categories as shown in Table 3:

Table 3: Strengths and Weaknesses of the SZW Inspectors and Policy Makers

1Design and Condition of Installation 2Procedures, Rules and Written Material 3Skills, Knowledge and Training 4Use of Contractors and External Expertise 5Pressures and Resources 6Culture and Attitudes 7Maintenance and checking 8Communication 9Control 10Care for Workforce/Job satisfaction 11Production of AVRs and Attitudes to the Labour Inspectorate 12Organisation and Systems 13Event Reporting and Investigation

For example, Table 4 gives strengths and weaknesses for category 1.

Table 4: Example of Typing Factors (plain type) and Strengths-Weaknesses (italics): Design and Condition of Installation

1Design and Condition of Installation	
Design for safety (good - poor) Size of installation (small - large) Number of people (few - many) Process (secondary - primary) ***Physical containment (poor - good)*** Age of installation (old - new) Flammable/explosive danger (low - high) Long term health risk (low - high) ***Look of installation (untidy - tidy)*** Age of plant (old - new) ***Layout of installation (cramped - spacious)*** Age of plant (old - new) ***State of installation (clean - dirty)*** Size of shift team (large - small)	***"Shape" of installation (poor-good)*** Number of internal staff for safety (none-many) Existence of procedures (few - many) ***Housekeeping (poor - fantastic)*** Number of internal staff for safety (none-many) Existence of procedures (few - many) ***Cleanliness (clean - dirty)*** Extent of sudden changes in workload (few - great) ***Hardware safety (poor - good)*** Existence of safety procedures (none - many) Size of company (small - large) Size of site (small - large) Background of workforce (agriculture - petro-chemical) ***Chance of making mistakes (high - low)*** Process (inflexible - flexible) Process (manual - automated)

In summary, the two sets of variables, the typing factors and the strengths and weaknesses, can be said to characterise the ways in which major hazard chemical installations can be distinguished from, and related to, one another.

Validation of the Organisational Typing Tool

An AVR installation was audited in depth in order to identify any weaknesses in its Safety Management System. Strengths and weaknesses were then generated using the prototype Organisational Typing Tool, based on what were considered to be the key typing factors of the installation:

- Old plant
- Method of working experience based

- Expertise in-house
- Weak link to parent company/low involvement of parent
- Low use of parent knowledge
- Flat organisation
- No company wide rules
- Highly toxic
- Losing money

From these, weaknesses-strengths were generated. The results are shown in Table 5. Those marked with an 'x' indicate those considered to be applicable to that installation as judged by an SZW Policy Maker involved in the AVR Assessment and one of the auditors respectively.

Fifty-six strengths/weaknesses were identified of which forty-two were considered relevant by one of other of the judges, and twenty five were agreed by both. Very few of the strengths/weaknesses were opposites to one another, and in general showed a consistency.
The exercise was considered to provide validatory support for the usefulness of the Organisational Typing Tool.

Table 5: Organisational Typing of An Actual Installation Showing Weaknesses Considered to be Present (x) by Two Judges

Design and Condition of Installation
Poor physical containment
Untidy look of installationx
Cramped layout of installationx x
Procedures, Rules and Written Material
Low reliance on written materialx x
Low adherence to proceduresx x
No document changes x x
Low quality of procedures x x
Skills, knowledge and training
High skill of management
A lot of chemical knowledge x
Low awareness of risksx x
High awareness of hazard x
Low awareness of dangers x
High hands on skill of managementx
High reliance on other companies x x
Use of Contractors and External Expertise
Engineering expertise contracted in x
Pressures and Resources
Safety dependent on the people x x
Restricted money available for safety x x
Safety Culture and Attitudes
Little carefulness of personnel x
Carefulness of personnel (when associated with in-house expertise)
Low interest of plant managers in safetyx x
Low concern for health risks x x
Low concern for major hazards x x
Low following of safety rules x x
Weak emergency preparednes x
Low worker commitment to safety x
Low management commitment to safety x x
Careless attitude of workforce x
Workforce not involved x
Poor approachability of managementx

Maintenance and Checking
Inadequate maintenance x x
Low maintenance needs
A lot of maintenance done
Bad maintenance
Minimal maintenance carried out x x
High sensitivity to amount of maintenance to be done x
Little task checking x x
Communication
Easy communication between management and workforce
Poor communication between management and workforce x
Control
A lot of delegation to lower levels x
High hands-on control by management
"Toezicht", control of workforce lowx x
Care for Workforce/Job satisfaction
Poor care for workersx x
A lot of fear of losing jobx x
Production of AVRs and Attitude to the Labour Inspectorate
Low motivation to produce AVR
Poor standard of AVRx ?
No willingness to make changes to AVR
Many people at AVR meetings
Reluctant to provide information
Not keen to involve the labour inspectorate
Organisation and Systems
Poor organisation of safetyx x
Low consistency between sitesx x
High flexibility within company rules x
Low quality standardsx x
Changing organisationx x
Event Reporting and Investigation
Poor incident investigationx x
Good event reporting

Organisational Relationships to Safety

1.Loss of Containment Accidents

The relationship between a particular typing characteristic and a strength or weakness indicates organisational differences, but not whether these are connected to safety. For this reason it was important to look for connections between Organisational Map variables and safety, where safety is the system of control of major hazards to prevent loss of containment.

One way to do this is to examine LOC accidents or near misses to see whether certain organisational characteristics are associated with a higher frequency of LOCs than others. For this purpose we used UK CIMAH site data (78 incidents), within-company data from two different companies (493 incidents), and Four Elements' pipework failure data base (921 incidents). All these data have been analysed according to a 3-dimensional system of Direct Cause (eg. overpressure) X Underlying Origin of Failure (eg. unsafe condition arose in maintenance) X Underlying Management Preventive/Recovery Mechanism Failure (eg. failure to conduct adequate hazard review). The methodology is reported elsewhere (Bellamy, Geyer and Astley, 1989; Bellamy and Geyer, 1992; Hurst, Bellamy, Geyer and Astley, 1991). Since organisational variables are not very well captured in accident data, it was difficult to cover more than a small range of variables as follows:

Company - Two different companies, doing different activities, showed marked differences in the patterns of underlying causes of LOC accidents, particularly in design, maintenance, and in routine inspection and testing.

Branch A: Nationality - The pattern of underlying causes in the UK (238 incidents) and Netherlands (240 incidents) are very similar, but different to those in the US (255 incidents). Maintenance failures dominated the picture for the UK and Netherlands, but not for the US which showed a much more even spread of underlying causes. The UK and Netherlands showed a much higher proportion of task checking and supervision failures.

Branch B2.2: Type of Process - Both primary and secondary process sites were dominated by maintenance failures. However, primary process sites showed more design related failures than secondary process sites, with hazard review as the dominant preventive mechanism failure. For secondary process sites, the preventive mechanism failures were primarily related to human factors issues.

Branch D2.1: Numbers of People - For UK CIMAH sites, between 1986 and 1992, small sites (less than 100 people) averaged 1.33 LOCs per site compared to 5.12 for big sites with a population between 600-1000. However, on a per person per site basis, small sites had roughly twice as many LOCs per person than large sites. The results are inconclusive as the operational and administrative components of the populations cannot be separated.

Branch D3.1.3: Different Process Operations - As might be expected, the pattern of underlying causes differed according to whether the activity was transfer of materials, storage, actions on a single substance, or reacting substances. Maintenance dominated as a cause for the last two activies, design for transfer of materials, and operations for storage.

There is some suggestion that certain variables are linked to different patterns of causes of accidents, but the results are not particularly revealing.

2.Proactive Safety Performance Indicators

Accident occurrence is a direct indicator of safety performance but it is after the fact. The literature shows that there has been quite some effort to search for indirect safety performance indicators which are proactive in the sense that they might signal the current level of safety in an organisation eg. the frequency of unplanned automatic trips; size of maintenance backlog; number of procedures out of date.

Examination of the literature on proactive Performance Indicators was, however, also inconclusive. Identification of organisation and management linked PIs depends very much on the model of the safety system that is being used to generate them. Ultimately, all the models depend on some form of expert judgement (a "top-down" approach) to a greater or lesser extent (eg. Sweeney 1992; Schreiber 1992; Wagenaar,Groeneweg, Hudson and Reason 1993), as opposed to basing them entirely on an analysis of available data (a "bottom-up" approach). What this means is that the arguments which relate organisation to safety become rather circular when the bottom-up approach is missing. In this respect, examination of the PI literature was regarded as a dead end.

3.Theoretical Links to Major Hazard Control System Failures

Two approaches were taken to examine the potential for organisational variables to weaken the major hazard control system.

Firstly, an attempt was made to hypothetically link the Organisational Map variables to organisational failure modes associated with system failures. These system failure modes are: Poor control of communications; Inadequate control of pressures; Inadequate control of resources; Organisational rigidity (Bellamy 1983; Bellamy, Wright and Hurst 1993).

The links were made primarily in map areas C, E and F. The exercise of trying to link map variables with these failure modes provided a model of the hypothetical "ideal" organisation with regard to overall system safety. It would have:

A Characteristics:
High uncertainty avoidance, small power distance, individualistic.

B Characteristics:
Strong culture, adapting culture, modern.

C Characteristics:
Good personnel philiosophy, common language and terminology, explicit standards of behaviour, strong company values, membership rules, enriched and warm non-conflicting and unambiguous psychological climate, a support culture, good safety culture, good organisational memory, good organisational learning, good pattern recognition, good attention span, good and unblinkered filtering of required information, good communication skills, good broad skill base, sufficient people/skills/equipment.

D Characteristics:
Close to head office, smaller numbers of people.

E Characteristics:
Less people, large spans of control, few hierarchical levels, decentralised, decision making close to front line, low task specialisation, few communication boundaries, small numbers of communication nodes, small number of possible process failures/disturbances, conflicts openly resolved, roles and responsibilities and authorities clearly defined, tasks well defined and allocated to appropriate people and equipment, strict application of rules, adequate supervision and coordination, ability

to control matches need to control, control requirements covered by formal procedures, formalisation adapted to requirements, production and safety conflicts openly resolved, no conflicts between people and across role boundaries, adequate training, good socialisation processes, adapts well to change.

F Characteristics:
Resources available, good communications equipment, good communications with regulator, good contacts with other companies, flexible response to change, low economic pressures, adequate resources, easily complies with the regulations, good image in the public eye, readily adapts to the system climate.

I Characteristics:
Extensive use of indirect performance indicators, good safety performance shown by indicators, safety performance monitoring.

The ability to make safety links across the Organisational Map is an indication that it would be of value to pursue these relationships in more depth in order to obtain more supportive evidence. For this reason it was thought necessary to apply a rigorous approach that could guide expert opinion in a more systematic way.

In the second approach, it was decided to use a hazard control system model linked to LOC accidents, and to examine the way the control system could fail. The model was the Process Safety Management System Control and Monitoring Loop developed by Four Elements from the analysis of LOC accidents and large system failure accidents. This model has been the subject of a Commission of the European Communities research project started in 1993 under the Major Industrial Hazards research programme (CEC Project EV5V-CT920068), as described in Bellamy and Tinline (1993), Muyselaar and Bellamy (1993). The control and monitoring loop is shown in Figure 1.

A hazard identification method, HAZOP (Hazard and Operability Study), was used to investigate the possibilities whereby a particular organisational characteristic could either strengthen or weaken the process safety management system. The basic assumption was that, since the model was based on analysis of accident causes, if an organisational characteristic could be linked to the safety system model by identifying a possible strengthening or weakening effect on the links, then there is evidence of a link between that characteristic and the likelihood of loss of containment accidents. Weakening effects would increase this likelihood and strengthening effects decrease it.

The work that was undertaken is described in detail in Bellamy, Leathley and Gibson (1995b). The variables examined in the study were selected by SZW:

B1.1 Origins
D3.1.2 Chemical Complexity
E1.2 Span of Control
E1.3 Number of Levels
E1.6 Communication Channels

The idea was to work on the analysis in-depth rather than on a large number of variables since HAZOP is a very resource intensive method. Different "measures" of the organisational variables were defined. These were discrete categories within which a particular organisation could be placed, such as "Solely chemical tradition - Not solely chemical tradition" (B1.1 Origins). Each measure was treated as a possible underlying cause of strengthening or weakening a link in the control and monitoring loop, where the idea was to try to identify the way in which the organisation could have these effects, if at all. HAZOPs were conducted on the control and monitoring loop, investigating each organisational measure as a possible failure cause. The HAZOP variable was 'LINK' and the guidewords were 'STRONG' and 'WEAK'.

This resulted in questions being phrased in the following way: "Is there anything about a company with traditional chemical origins that could cause a WEAK LINK between level 3 and level 4 in hazard review of design?" Where links were found to be weak, the HAZOP team came up with Handling Strategies for the most severe cases.

Potential causes of weak or strong links were given a label, as were handling strategies. For example, failure to define or understand roles and responsibilities with regard to the interface between contractor and site, or the mismatch between two bits of design added together were labelled INTERFACE. Table 6 gives some example results.

The most important results of the study are not so much the content of the specific weaknesses or handling strategies that were determined from the HAZOPs, but the fact that relationships between organisational factors and major hazard safety were being systematically identified. So, for example, for solely chemical tradition companies, a potential weakening effect on the level 5-4 link was CONSERVATIVE - an approach to safety which is resistant to change and narrow minded, particularly if the experience of staff is rooted in old technology. However, on the strengths side at this level, such companies were considered to have KNOW-HOW, particularly of hazards, and have contacts in the industry and be part of the information network in this sense. Conversely, the non-chemical tradition companies at level 5-4 were considered to have the potential weakness of LACK OF KNOWLEDGE about standards, hazards etc. but strengths in terms of being FLEXIBLE, more open to accepting ideas from the regulator and industry groups. This illustrates that in many cases a strengths-weakness balance can be found**.**

However, it was discovered that one of the organisational measures could not be subjected to HAZOP. This was a sub-variable of Communication Channels (E1.6), "Communication boundaries". The reason was not because there was no apparent link to safety. Communication failures across organisational boundaries are well known to feature as a contributory cause to many accidents .

The HAZOP team struggled with "Temporal Communication Boundaries", the time boundaries which communications have to cross in order to function. The problem encountered was that it was not possible to place an organisation into a discrete category, such as "Those with communication channels-Those without", "Those with temporal boundaries -Those Without". For example, at Level 5>Level 4, "difficulties in predicting the onset of economic pressures" was identified as a weakness, but this is because economic pressures are difficult to predict, not because of a time boundary. For Level 3>Level 2, "delay in implementing procedures" was a potential weakness, but the time boundary was the location of the effect, not the underlying cause of the delay. Additional variables have to be introduced to explain the delay effect.

By inspecting the whole of the Organisational Map, a view was formed as to which variables could probably be subjected to HAZOP, and those which could not. These were called 'Discrete Typing Variables' and 'Inherent Organisational Properties' respectively, as listed below. The results are shown in Table 7. It was considered that all the Discrete Typing Variables would all have weakening or strengthening effects on the control and monitoring loop.
On inspection, the Discrete Variables appear to be one step more remote from the direct causes of LOC accidents than the Inherent Properties. They tend to be more associated with the Organisational Typing variables than they are with strengths and weaknesses. The latter tend to be

Inherent Properties.

Table 6: Examples of Weaknesses at Different Levels in the Control and Monitoring Loop From HAZOP of a company with a tradition in the chemical industry

WEAKNESS	LINK	POSSIBLE EFFECT ON LINK IN CONTROL AND MONITORING LOOP	HANDLING STRATEGIES TO OVERCOME WEAKNESSES
LEADING EDGE	5 > 4	A company with a long chemical tradition may be at the LEADING EDGE of technology, or dealing with rare (and relatively unknown) chemicals, and have new processes or instrumentation. It is difficult then for regulations to keep up with the technology - current regulations may be inapplicable to the site.	1.Use good resources and techniques to ensure safety. 2.Put money into research of hazard review and design. 3.Learn from other areas (eg from aviation.)
NON-EXISTENCE OF PROCEDURES	4 > 3	Procedures not formally created because knowledge is in people's heads. Reliance on people not procedures .	1.Take deliberate steps to formalise procedures 2.Provide formal training
ARROGANCE	3 > 2	Over-confident and therefore omit hazard review or do not believe in the importance of hazard review.	1.Increase enforcement of rules. 2.Provide auditable trail for review. 3.Ensure hazard review is viewed as useful.
LOSS OF SELF-EXAMINATION	2 > 3	Bias in monitoring due to expectation of norm. Blind to possible improvements because surrounded by system all the time and believe too much in rule system	1.Bring in third party. 2.Freshen the views of existing people by providing training from outsiders. 3.Bring in a more detailed systematic review system.
OVER-CONFIDENCE	3 > 4	May not follow up incidents because of over-confidence in existing systems.	1.Increase enforcement of rules. 2.Provide auditable trail for review. 3.Ensure hazard review is viewed as useful. 4.Formalise procedures and training

Table 7: Discrete Typing and Inherent Properties of Organisations

Discrete Organisational Typing Variables	***Inherent Properties of Organisational Types***:
A. Nationality B. History D1. Location: D1.1 Place D1.2 Proximity to Head office D2. Size: D2.1 Numbers of people D2.2 Area D3. Complexity: D3.1 Chemical complexity D3.2 Physical complexity D3.3 Task complexity D3.4 Control complexity E1. Organisation Structure: E1.1 Numbers E1.2 Span E1.3 Levels E1.4 Location of decision making / authority E1.5 Task specialisation (ie high versus low) E1.7 Status/responsibilities E.2 Organisation Processes E2.3 Control Processes E2.8 Degree of Bureaucracy F. System Climate H. Hazards	C.1 Personality C1.1 Observed behavioural regularities C1.2 Standards of behaviour C1.3 Values C1.4 Philosophy C1.5 Membership rules C1.6 Climate C1.7 Culture C.2 Intelligence C2.1 Memory C2.2 Attention C2.3 Skills: Decision and Action E.1 Organisation Structure E1.6 Communication channels E.2 Organisation Processes E2.1 Communications E2.2 Coordination E2.4 Adaptation to Change E2.5 Conflict resolution/control E2.6 Role relationships E2.7 Socialisation I Performance Indicators

The value of these results is that they provide support for linking the discrete typing variables to LOC accidents. With these results, it is now possible to pull together all the findings to see the implications for improving inspection efficiency.

Conclusions

The programme of work described in this paper has identified a vocabulary of organisational factors which can be used to compare major hazard chemical installations. These can be summarised as follows:

1.The first dimension of division is based on apparent distinctions and relationships between variables, where 9 branches of organisational variables were identified, such as Nationality, Psychology, Physical Characteristics, Organisation etc. (see Annex 1).

2.From the perceptions of experts, the features of organisation which can distinguish between and group chemical installations, sites, and companies were identified. This second dimension provided Organisational Typing variables and Strengths and Weaknesses. This gave foundation to an Organisational Typing Tool for generating organisational profiles of chemical installations and providing associated potential strengths and weaknesses. It showed that there were certain key typing variables of chemical organisations - particularly their size, documentation and control characteristics, complexity of plant, process or operations, and age. An exercise which applied the prototype tool to an installation with known weaknesses indicated that the Organisational Typing Tool could produce coherent and meaningful results.

3.Examination of the link between organisational variables and failure in a major hazard control system provided yet another dimension for grouping. Hypothetical relationships were established with intermediate causes of system failure, such as communications failures. Systematic examination of possible organisational causes of control and monitoring failure in the safety management system for prevention of Loss of Containment (LOC) accidents showed that organisational influences could be extensive yet quite specific in their effects.

The process of examining these relationships revealed two types of variable. The first type, labelled Discrete Typing Variables, was a set of variables which would enable an organisation to be typed according to discrete measures of it objective characteristics, and from which it would be possible to generate causal connections to major hazard control system weaknesses. The second set, labelled Inherent Properties, were more associated with the nature of the strength or weakness itself, and so are one step closer to the direct cause of a LOC accident.

These different dimensions are valuable because they help to give a more sound structure to organisational variables and their relationship to safety. Also by comparing the results along the different dimensions it is possible for the groupings of variables to be made compatible with one another.

All the key Organisational Typing factors identified by the inspectors (Table 2) virtually mimic the discrete typing variables (Table 7) derived from the HAZOP, and considered to have potential effects on the major hazard control system. However, one aspect of Documentation (C2.1.2 Rules) occurs in the list of inherent properties while the other (E2.8 Degree of Bureaucracy) is a discrete typing variable. For consistency, it was decided that E2.3 Control Processes would therefore be a better home for typing constructs relating to number of procedures than C branch.

With this reorganisation, the common elements between the Inspectors' perceptions of key typing variables and the discrete typing variables identified from the HAZOP approach are the ones which differentiate between and relate major hazard installations in the Netherlands, and which can been demonstrated to have a strengthening or weakening effect on the major hazard control system. These must therefore be the ones for Inspectors to focus on. By also identifying the Inspectors' constructs which appear in these areas, the following profiling tool is obtained (Table 8):

Table 8: Organisational Typing Tool: Typing Constructs

A. NATIONALITY

USA Influence (low - high)
Degree of foreign influence (low - high)
Dutch /UK influence (low - high)

B. HISTORY

B1.2 Culture
Influence of mother company (weak - strong)
Company wide rules (none - many)
Close to mother company (close - distant)
Knowledge & support from mother company (low - high)
Local community influence (strong - weak)

B1.3 Growth/Change/Age
Age of installation (old - new)
Age of plant (old - new)
Age of technology (old technology - modern/high tech)
Age of workforce (old - young)

B2.1 Diversity/Experience
Number of products (single - many)

B2.2 Type of Process
Process (secondary - primary)

D. PHYSICAL CHARACTERISTICS

D2. Size
Size of company (small - large)
Size of site (small - large)
Size of installation (small - large)
Size of workforce (small - large)

D3.1 Chemical Complexity
Complexity of process/storage (simple - complex)

D3.2 Physical Complexity
Degree of automation (none/manual - a lot/fully automated)
Technical plant /installation complexity (low - high)
Complexity of engineering (complex - simple)
Number of control parameters (high - low)

D3.3 Task Complexity
Process (manual - automated)
Amount of work outside control room (a lot - none)
Extent of sudden changes in workload (great - few)
Nature of work tasks (simple - demanding)
Complexity of operation/activity (simple - complex)
Type of shift handover (general - detailed)
Hazard monitoring demands (low - high)

D3.4 Control Complexity
Process (inflexible - flexible)
Ease of stopping when things go wrong (difficult - easy)

E. ORGANISATION

E1 Structure
Complexity of organisation (low/simple - high/complex)

E1.1 Number of People
Size of shift team (large - small)
Number of internal staff for safety (none-many)
Engineering staff (many - none)
Number of operators (many - few)
Size of safety department (small - large)
Presence of technical specialist (none many)

E1.4 Location of decision-making/authority
Procedures Development (local - central)
AVR dealt with (centrally - locally)
Management influence (local - distant)
Delegation of responsibility (a lot - none)

E2.3 Control Processes
Style of control (flexible - rigid)
Structure of control (flexible - military)
Rules within company (few - many)
Existence/number of procedures (none/few - many)
Existence of safety procedures (none - many)
Method of working (Experience of people - procedures and rules)

E2.8 Degree of Bureaucracy
Size of AVR (small- large)
Procedures (not written down - written down)
Size of emergency plan (small - large)

Table 9 shows the relationship between these key typing characteristics, and the thirteen categories of strength and weakness from Table 3. The strengths and weaknesses appear in order according to the number of typing characteristics to which they are sensitive. This means that the Skills, Knowledge and Training aspects of an AVR installation are the most sensitive to organisational differences, whereas Communications are the least. The table summarises the areas upon which Inspectors concentrate their attention, and this finding can be built upon to enhance AVR assessment and inspection in those areas. The types of strengths, weaknesses and handling strategies identified from the HAZOP work provide a starting point for linking these Inspector generated strengths and weaknesses to the major hazard control and monitoring loop. By progressing to a more structured framework for evaluating the organisational and management aspects of major hazard control, greater consistency and coverage can be achieved within a focussed approach which makes best use of Inpsectors' knowledge and experience. This framework would be based upon:

1. Organisational Typing;
2. Strengths and weaknesses generated from the Organisational Typing Tool;
3. Linking of strengths and weaknesses to the major hazard control and monitoring loop, to support an information seeking strategy in those areas;
4. Identifying weakness handling strategies to provide the basis for recommendations for improvement.

From this firm basis, we are now able to progress towards integrating the tool with the package of AVR assessment and inspection improvements which are part of the SZW major hazard policy group's programme.

Table 9

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ANNEX I: ORGANISATIONAL MAP REFERENCES

COMPANY

1ORGANISATIONAL METAPHORS

1.1 Organisations as machines
1.2Organisations as organisms
1.3Organisations as brains
1.4Organisations as cultures
1.5Organisations as political systems
1.6Organisations as psychic prisons
1.7Organisations as flux and transformation
1.8Organisations as vehicles for domination

ANATIONALITY

A1Power distance
A2Uncertainty avoidance
A3Individualism/Collectivismist)
A4Masculinity/Femininity

BHISTORY

B1 Family History
B1.1 Origins
B1.2 Culture
B1.3 Growth, Change and Age

B2 Product History
B2.1 Diversity and Experience
B2.2 Type of Process
B2.2.1 Primary process: Chemical processing is part of the main line of the business.
B2.2.2 Secondary process: Hazardous chemicals are used in the business, but it is not part of the main line.

CPSYCHOLOGY

C1 Personality
C1.1Observed behavioural regularities
C1.2Standards of behaviour, or norms
C1.3Values
C1.4Philosophy
C1.5Membership Rules
C1.6Psychological Climate
C1.7Culture
C1.7.1 Power culture
C1.7.2 Role culture
C1.7.3 Achievement or task culture
C1.7.4 Support culture
C1.7.5 Safety Culture

C2 Intelligence
C2.1Memory
C2.1.1 Recognition
C2.1.2 Rules
C2.1.2 Knowledge
C2.1.4 Learning
C2.2Attention
C2.2.1 Capacity
C2.2.2 Filters
C2.3Skills: Decision and Action

Cont.

DPHYSICAL CHARACTERISTICS

D1Location
D1.1Place
D1.2Proximity to Head Office

D2Size
D2.1Numbers of people
D2.2Area of the site

D3Complexity
D3.1Chemical/Process Complexity
D3.1.1 Different types of substances
D3.1.2 Different reactions/properties
D3.1.3 Different process operations
D3.1.3.1 Transfer
D3.1.3.2 Storage
D3.1.3.3 Actions on a single substance
D3.1.3.4 Reacting substances
D3.2Physical Complexity
D3.2.1 Number of Control Loops
D3.2.2 The Number of Measurements
D3.2.3 Amount of Hardware
D3.2.4 Level of automation
D3.3Task Complexity
D3.3.1 Manual tasks
D3.3.2 Automation tasks
D3.3.3 Batch process tasks
D3.3.4 Continuous process tasks
D3.4Control Complexity
D3.4.1 Coupling
D3.4.1.1 Tight coupling
D3.4.1.2 Loose coupling
D3.4.2 Interactions

E.ORGANISATION

E1Structure
E1.1Number of People (Size)
E1.2Span of Control
E1.3Number of Levels
E1.4Location of Decision Authority
E1.5Task Specialisation
E1.6Communication Channels
E1.7Status/Responsibilities

E2Organisation processes
E2.1Communications
E2.2Coordination
E2.3Control Processes
E2.4Adaptation to change
E2.5Conflict Resolution/Control
E2.6Role Relationships
E2.7Socialisation
E2.8Degree of bureaucracy

FSYSTEM CLIMATE

F1Economic pressures
F2Resources
F3Regulations and guidance
F4Industry norms
F5Public perceptions
F6Environment

GSZW INSPECTORS' AND MAJOR HAZARDS POLICY GROUP PERCEPTIONS

G1Nationality
G1.1 USA influenced sites
G1.2Non-USA influenced sites

G2History
G2.1Age
G2.1.1 Old
G2.1.2 New
G2.2Type of Process
G2.2.1 Primary Process
G2.2.2 Secondary Process

G3Physical Characteristics
G3.1 Size
G3.2Chemical Complexity
G3.2.1 Single and multiple product sites
G3.2.2 Simple and complex chemical processes.

G4Organisation
G4.1Control
G4.1.1Central