

School of Public Health

**Extended Industrial Pollution Events: Analysis of Causal
Factors using Systems Approach**

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Doctor of Philosophy
of
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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material that has been accepted for the award of any other degree or diploma in any university.

Signature:

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ABSTRACT

An Extended Industrial Pollution Event (EIPE) not only causes devastating economic consequences, but also threatens human health and impacts our quality of life through degradation of the environment in which we live. Understanding the complex web of factors contributing to these incidents is necessary to produce effective mitigation measures. However, a review of the literature revealed an inadequacy of the present causation models to explain the multi-dimensional and non-linear aspects of a dynamically complex organisational system. Hence, the aim of this research was to investigate the systemic factors contributing to EIPEs and to develop preventive strategies to reduce the likelihood of their reoccurrences.

This research utilised a combination of the qualitative case study approach, systems methodology and Focus Group engagement to holistically address the underlying complexity and interaction of contributing factors in EIPEs. Drawing from across the practices of strategic business planning and the Health Safety Environment Management System (HSEMS), a conceptual framework was used to convey the fundamental principles and structure for an EIPE. Subsequently, this concept was applied to three EIPE case studies: Love Canal, Minamata Disease and Esperance Lead.

These EIPEs were not only impacted by external contributing factors: political; legal; economic; social; and technological, but they were similarly impacted by internal contributing factors: policy; planning; implementation; checking; and review in their HSEMS. Systems Dynamic (SD) tools such as Causal Loop and Stock-Flow diagrams, including system archetypes were used to elicit the inter-relationships among these factors. A Focus Group of academic, government and industry professionals affirmed the complex interaction of the contributing

factors found in these case studies, which closely aligned with the proposed conceptual framework.

Key contributing factors and themes included the alignment of political and HSE priorities, harmonisation of national policies with HSE outcomes, comprehensiveness of the Health, Safety and Environment (HSE) legislative framework, effectiveness of regulatory enforcement, clarity of roles among various government agencies, effectiveness of inter-government agency coordination, development of production and control technologies, industry knowledge and best practices, global market demand for industrial products and activities, extent of consultation or engagement between organisations and community, level of societal expectations and awareness, degree of HSE integration into the entire product life cycle, strength of the management's commitment to HSE, integrity of the risk management process, effectiveness of the checking and review system, and influence of safety culture in an organisation.

The knowledge and perspectives of different stakeholders in the Focus Group facilitated the identification of system archetypes, which provided insight into the common characteristics of the latent issues found in EIPes. Specifically, the research described the behavioural patterns between growth and investment, the tension between eroding goals and improving performance, and the tendency to apply temporal solutions that fail to solve underlying problems. Also, the research highlighted possible leverage points or opportunities where a small intervention could mitigate undesirable dynamic behaviours leading to EIPes. The most powerful leverage point would require the transformation of any organisation's mindset to not only focus on its bottom-line, but also to integrate HSE into every facet of the business.

The above-mentioned findings, including a clearer indication of the role of leverage points and systems archetypes, became the basis for the development

of the EIPE qualitative models and preventive strategies. Also, the cogent links between these recommendations and findings of the EIPE case studies and Focus Group were supported by a strategic planning guide, which provided organisations the ability to facilitate the integration of potential HSE issues into their business plans and strategies.

Other contributions of this research included the development of an EIPE conceptual framework and strategic business planning tool, integrating cross-disciplinary principles, application of a systems approach to an EIPE causation study, and a consultative approach using Focus Group to evaluate EIPE findings.

It is hoped that, through further development and application of this systems approach, greater understanding of other EIPE cases and, therefore, continual development of more effective preventive strategies can be achieved.

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LIST OF ABBREVIATIONS

AUD	Australian Dollar
CCC	Corruption and Crime Commission
CCM	Collaborative Conceptual Modelling
CEO	Chief Executive Officer
CER	Consultative Environmental Review
CERCLA	Comprehensive, Environmental Response, Compensation, and Liability Act
CLD	Causal Loop Diagram
CONTAM	Contamination Monitoring
DDM	Dodecyl Mercaptan
DOCEP	Department of Consumer and Employment Protection
ECRG	Esperance Community Reference Group
EIA	Environmental Impact Assessment
EIPE	Extended Industrial Pollution Event
EPA	Environmental Protection Authority
ETA	Event Tree Analysis
ETF	Ecumenical Task Force of the Niagara Frontier
FDAA	Federal Disaster Assistance Agency
FESA	Fire and Emergency Services Authority
FMEA	Failure Mode and Effect Analysis
FRAM	Functional Resonance Analysis Model
FTA	Fault Tree Analysis
GDP	Gross Domestic Product
GHS	Globally Harmonised System
GM	General Manager
GRI	Global Reporting Initiative
HHEMP	Health, Hygiene and Environmental Management Program
HIA	Health Impact Assessment

HRO	High Reliability Organisation
HSE	Health, Safety and Environment
HSEMS	Health, Safety and Environment Management System
ILO	International Labour Organisation
IPE	Industrial Pollution Event
IPO	Input-Process-Output
ISO	International Organisation for Standardisation
JMAMDRCG	Japan Medical Association's Minamata Disease Research Consultation Group
KPAFC	Kumamoto Prefectural Alliance of Fishing Cooperatives
KPG	Kumamoto Prefectural Government
LCHA	Love Canal Homeowners Association
LEAF	Local Environmental Action Forum Inc.
LED	Locals for Esperance Development
MAFF	Ministry of Agriculture, Forestry and Fisheries
MCA	Manufacturing Chemists' Association
MDGIRLC	Minamata Disease General Investigation and Research Liaison Council
MeHg	Methylmercury
MES	Multilinear Events Sequencing
MFPC	Minamata Food Poisoning Committee
MHW	Ministry of Health and Welfare
MITI	Ministry of International Trade and Industry
MMD	Man-Made Disasters
MORT	Management Oversight Risk Tree
MRALU	Minamata Regional Association of Labour Unions
MSDS	Material Safety Data Sheet (which is now known as Safety Data Sheet or SDS)
MSIA	Mines Safety and Inspection Act 1994
NAT	Normal Accident Theory
NCHD	Niagara County Health Department

NEPA	National Environment Protection Agency
NEPM	National Environmental Protection Measure
NPDC	Niagara Power Development Corporation
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
NYSDOT	New York State Department of Transportation
OCC	Occidental Chemical Corporation
OHS	Occupational Health and Safety
OHSMS	Occupational Health and Safety Management System
OPC	Occidental Petroleum Corporation
PCB	Polychlorinated Biphenyls
PDCA	Plan-Do-Check-Act
PETS	Political-Economic-Technological-Social
PLEIS	Political-Economic-Industry-Social
PLETS	Political-Legal–Economic-Technological-Social
PPE	Personal Protective Equipment
PPRR	Prevention, Preparedness, Response and Recovery
PRI	Principles for Responsible Investment
QMS	Quality Management System
RAG	Recherche Advisory Group Inc.
RCRA	Resource Conservation and Recovery Act
RED	Residents for Esperance Development
SD	System Dynamics
SFD	Stock and Flow Diagram
SHR	Safety and Health Representatives
STAMP	Systems-Theoretic Accident Modelling and Processes
STEP	Sequentially Timed Events Plotting
TML	Transportable Moisture Limit
UN	United Nations
USEPA	US Environmental Policy Act (USEPA)
WA	Western Australia

WADOE	Western Australian Department of Environment
WAEPA	Western Australian Environmental Protection Authority
WADEC	Western Australian Department of Environment and Conservation
WADEP	Western Australian Department of Environmental Protection
WADOC	Western Australian Department of Commerce
WADOH	Western Australian Department of Health
WADOIR	Western Australian Department of Industry and Resources
WADME	Western Australian Department of Minerals and Energy
WADMP	Western Australian Department of Mines and Petroleum
WHS	Work Health and Safety
WHO	World Health Organisation

Chapter 1

INTRODUCTION

1.1 Background to the Research

The twin engines of industrialisation and globalisation have caused profound changes in the way goods and services are produced and traded, which has led to unprecedented economic growth for many nations and has raised the income levels of millions of workers. These and other benefits are usually facilitated by national policies promoting the expansion and competitiveness of certain industries, such as steel and chemical. Up to and including the present day, societies are continually being transformed by post-industrial modernisation that brings about greater efficiency and productivity in human lives.

While industrialisation contribute towards Gross Domestic Product (GDP) and job growth, it is also a major source of pollution and hazardous wastes (Craft et al. 2003). High profile incidents such as the Deepwater Horizon explosion and oil spill in the Gulf of Mexico, the Fukushima nuclear disaster, the Varanus Island explosion off the north-west coast of Western Australia and the Exxon Valdez oil spill in Alaska have shown that their resultant pollutants or contaminants, released through air, water, land or a combination of these media, pose significant threats to public health and the natural environment if industrial practices are not properly managed. Moreover, these undesirable events are often accompanied by substantial economic loss. For instance, the Varanus Island explosion in 2008 cut the Western Australian gas supply by 30% and cost the state economy up to USD3 billion (Bills and Agostini 2009). As a result, the public demanded the imposition of severe penalties in response to industrial incidents or accidents with widespread human and environmental consequences.

Notice that the terms 'incident' and 'accident' are used interchangeably in this study, because there is no consensus in current research to distinguish between them. The International Association of Geographical Contractors and the International Association of Oil and Gas Producers both define accident as "any event which results in injury, and/or damage and/or loss," and incident as "an event or chain of events which has caused or could have caused injury, illness and/or damage (loss) to assets, the environment or third parties" (IAGC and OGP 1999). The Occupational Health and Safety Administration (OSHA 2012) defines accident as "an undesired event that results in personal injury or property damage," and incident "is an unplanned, undesired event that adversely affects completion of a task." The International Labour Organisation (ILO) defines occupational accident as "an occurrence arising out of or in the course of work which results in: (a) fatal occupational injury; (b) non-fatal occupational injury," and incident as "an unsafe occurrence arising out of or in the course of work where no personal injury is caused, or where personal injury requires only first-aid treatment" (ILO 2002). For the purpose of this research, these two terms will be used interchangeably.

Similar to the above-mentioned Industrial Pollution Event (IPE), an Extended Industrial Pollution Event (EIPE) not only causes devastating economic consequences, but also threatens human health and impacts our quality of life through degradation of the environment in which we live. EIPEs involve protracted (see Fig. 1: dotted red oval) or ongoing community and environmental exposures to harmful substances or harmful energy levels from industrial sources. They are characterised by long delays between causes and effects, multiple goals and conflicting interests among stakeholders, and other systemic failures (Goh, Brown, and Spickett 2010). Thus, to effectively mitigate the risk of EIPEs there is a need to conduct holistic and systemic examination of the underlying systemic factors contributing to these events.

As depicted in Figure 1, both IPEs and EIPEs are due to the failure of controls in preventing a range of systemic factors from resulting in undesirable consequences. The smaller rectangular boxes represent various controls that have been penetrated by the arrows, or the systemic factors, to cause industrial events.

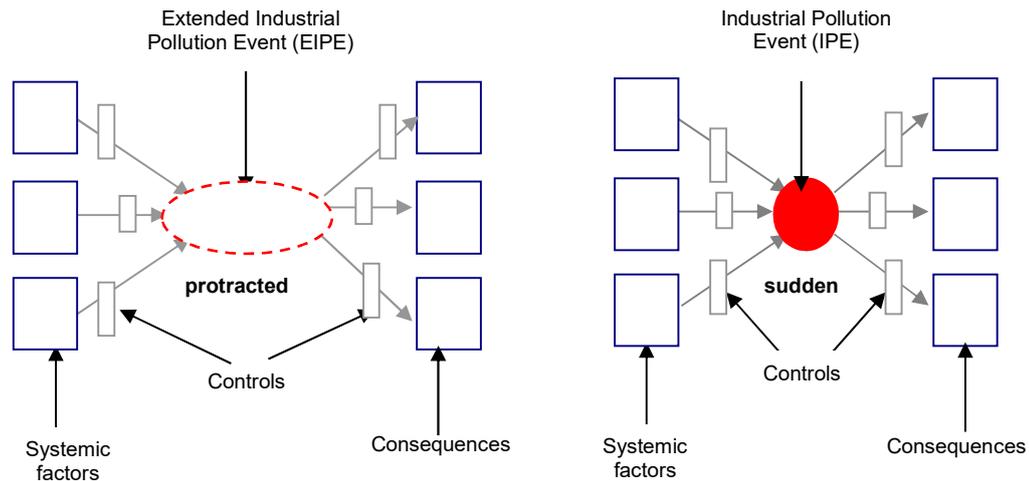


Figure 1: Differences in the Occurrences of Major Industrial Accidents

One of the most serious EIPEs was at the Love Canal dumpsite in New York. For more than 30 years, the dumpsite had been a source of hazardous chemicals entering the atmosphere, soil environment and groundwater. The resulting pollution triggered miscarriages, mental retardation, birth defects and other health problems (Environmental Protection Agency 1979). In addition, the clean-up of the Love Canal toxic waste site and the relocation of about 1,000 families cost the US Federal Government and New York State close to USD400 million (DePalma and Staba 2004).

More extended industrial pollution events are listed in Appendix A. In contrast, major IPEs are sudden (Figure 1: solid red circle) and discrete events that produce undesirable environmental and health consequences. One of the worst IPEs occurred on December 4, 1984, when methyl isocyanate was released from a Union Carbide chemical plant in Bhopal, India (Browning 1993). The

accident killed thousands of people living near the plant and left many more thousands with various degrees of physical impairment.

Despite the fact that EIPEs may not receive as much attention as the other high profile incidents with more immediate consequences, their impacts upon the economy, society and environment are just as serious. The adverse health and environmental impacts are often the indirect result of a vicious cycle of industrialisation and socioeconomic pressures, such as urbanisation (Quarantelli 1998; Rogers, Mehlhorn, and Schwarz 2010). Thus, uncovering the complex web of interdependent factors contributing to these incidents is necessary in order to develop effective prevention or mitigation strategies. In this study, the focus is more on the public health and safety impacts from these industrial events rather than their impact on the environment. For the purpose of this research, the widely accepted industry acronym HSE (Health, Safety and Environment) is used to describe both the workplace and collective public impacts.

1.2 Significance of Study

This study will provide valuable insights for affected stakeholders seeking to understand the complexities and inter-dependencies of contributing factors behind extended industrial pollution events. Especially when a community can continue to be exposed to detrimental environmental health risks long after an industrial activity has ceased, there is justification for such a study to not only examine the non-linear causation factors, but also to facilitate the development of tools for more effective preventive strategies.

Traditional sequential event-based, epidemiological causation and human factor models (Benner Jr 1975; Heinrich H. W. et al. 1980; Hawkins. F 2002) narrowly focus on a simple cause-and-effect chain of events, which is inadequate in capturing the multi-dimensionality and inter-connectedness of complex modern

systems (Goh, Brown, and Spickett 2010; Hovden, Albrechtsen, and Herrera 2010). Therefore, there is a need to employ a holistic model where structural deficiencies, management lapses, weak safety culture and a combination of other systemic causation factors can be presented. To encompass these systemic behaviours, a conceptual framework that combines key principles of business management and an organisational management system is proposed.

Moreover, this study will support the collaborative efforts of policy-makers, who need to increasingly integrate their policies on a national level and to coordinate their responses among agencies (Management Advisory Committee 2004; State Services Authority 2007; State Services Commission 2007; OECD 2008; Young et al. 2008). Moreover, the high costs of ineffective policies and late interventions necessitate such a study to anticipate the long-term impacts of different risk mitigation options.

Most government resources have been focused on the treatment of health consequences rather than their prevention (National Center for Health Statistics 2009; OECD 2009). By studying the underlying systemic factors associated with the risks to health, effective preventive strategies can be adopted to improve our environment and to enhance our quality of life.

1.3 Aim and Objectives of the Research

The complex systems of EIPes present significant challenges in the understanding of their causation and prevention. Therefore, the overarching aim of this study is to investigate the systemic factors contributing to EIPes and to develop preventive strategies to reduce the likelihood of their reoccurrences.

The objectives of the research are four-fold. Firstly (1), key systemic factors contributing to industrial incidents are identified. In order to effectively prevent the occurrences or reoccurrences of industrial incidents, there is a need to

investigate the underlying factors that usually drive the more obvious and immediate causes. Since most industrial incidents operate in a complex system, the simple cause-and-effect incident studies are inadequate in capturing the multi-dimensionality and inter-connectedness of complex modern systems. Therefore, special attention is given to incident causation studies that diverge from the linear approach towards understanding their contributing factors.

Secondly (2), the research allows for the development and application of a conceptual framework that represents the interaction of both internal and external organisational factors associated with selected EIPEs. Although there have been incident studies examining causes within an organisation, few of them have explored the contributions from wider systemic factors external to the organisation. Additionally, these causal models incorporate the characteristics of complex systemic behaviours, such as feedback loops, vicious cycles and time lapses, which are yet to become part of the mainstream incident causation research.

Thirdly (3), the research evaluates the conceptual framework and findings of the EIPE case studies through the use of a Focus Group consisting of industry and academic experts. Additionally, findings from the Focus Group and EIPE case studies facilitate the development of archetypes and qualitative models for presenting complex behaviours in EIPEs. Such input from professionals with specialised working knowledge about EIPEs enhances the credibility of the qualitative models.

Fourthly (4), the research develops a series of preventive strategies for EIPEs. By taking into consideration the systemic factors that can lead to their occurrences, organisations and policy-makers will be able to develop and implement more effective control measures. This is especially significant at a time when governments are facing various economic and social challenges to

come up with sustainable policies that can generate economic activities without compromising the community's health, safety and standard of living.

1.4 Structure of the Research

The thesis is structured in a way that any reader will be able to logically follow from the beginning to the end. The research starts with an abstract followed by twelve chapters and ending with appendices. Following is a brief overview of each chapter for this study.

- **Chapter 1 'Introduction'** introduces the background to this study, the significance, overall aim, specific objectives and structure of the study. Key terminologies, such as incident, accident, EIPE and IPE also are defined here.
- **Chapter 2 'Literature Review'** reviews the components and characteristics of an organisational system, elements of an HSE management system, mainstream incident causation models and modelling of organisational system, which provide a theoretical base for this study and how it relates to the current body of knowledge. These causation models are assessed for their respective strengths and weaknesses. As a result, gaps identified in this review assist in the development of better models.
- **Chapter 3 'Case for Research'** identifies the gaps in the literature and provides a brief description of how they will be addressed in different chapters of the study.
- **Chapter 4 'Research Design and Methods'** describes the research methodology, using a combination of instrumental case study, Focus Group and qualitative modelling approaches. It provides the rationale for choosing

materials, methods and procedures and explains how they relate to the research aim and objectives.

- **Chapter 5 ‘Conceptual Framework for an EIPE’** proposes a conceptual framework to facilitate a better understanding of the dynamics in a complex system. It discusses the attributes of the organisational and HSE Management Systems and the interaction between their associated components. Additionally, it describes the key features of the Causal Loop Diagram (CLD) that is used in this study to help explain the dynamic behaviour of a complex system.
- **Chapters 6 to 8 ‘Case Study – Love Canal Disaster,’ ‘Case Study – Minamata Disease’ and ‘Case Study – Esperance Lead Pollution’** use the conceptual framework to examine the three purposefully selected EIPE cases, namely Love Canal, Minamata Disease and Esperance Pollution, in chronological order. Data is organised into internal and external organisational factors, and CLDs are developed for each case study.
- **Chapter 9 ‘Case Comparison and Contrast’** uses the conceptual framework to compare and contrast the selected EIPE cases in the preceding three chapters. CLDs provide more insights into the differences and similarities found in these case studies. Also, a value judgment is made regarding the significance of each of the contributing factors to the EIPE.
- **Chapter 10 ‘Focus Group Evaluation’** evaluates the research by gathering real world perspectives from an assembly of professionals with valuable experience in EIPEs. It aims to gain a better understanding of the contributing factors leading to undesirable outcomes of EIPEs and how they can be mitigated.

- **Chapter 11 ‘Results and Discussions’** discusses key contributing factors and themes, EIPE archetypes and leverage points. It develops system archetypes and qualitative models for EIPEs.
- **Chapter 12 ‘Recommendations’** uses the findings from Chapter 11 and the understanding of leverage points, this study recommends possible strategies and the application of a useful business planning guide to mitigate the occurrences of EIPEs.
- **Chapter 13 ‘Contributions, Limitations and Future Works’** concludes with the findings from the case studies and Focus Group, presents contributions from the research, including possible applications of the systemic approach in the area of EIPE prevention, and highlights the limitations of this research and suggestions for future work.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter examines the existing research on organisational system, HSE management system, characteristics of an organisational system, incident causation models and modelling approach to organisational system. It begins with an examination of the complex characteristics of an organisational system. It is from this holistic perspective that the review of major causation models and their influences in the evolutionary understanding of industrial events is conducted. The incident causation models are classified as sequential, epidemiological and systemic. Their strengths and weaknesses, and gaps in the literature, are identified. The chapter concludes by discussing the characteristics of causation models that are suitable for a systemic approach to investigating complex organisational incidents such as EIPEs.

EIPEs are primarily due to the release of wastes and pollutants generated by the industrial activities into the environment. Unlike most major industrial incidents caused by fire, explosion, sudden release of hazardous substances, or a combination of these, EIPEs involve protracted community and environmental exposures to harmful substances or harmful energy levels from industrial sources. In order to develop strategies to prevent or to minimise the likelihood of an IPE or EIPE, there is a need to first understand the causes of these incidents. Whether it is the Deep Horizon explosion and oil spill in 2010 (US National Commission 2011), the Texas BP Refinery explosion in 2005 (CSB 2007), the Piper Alpha incident in 1988 (NASA 2013), the Chernobyl radioactive leak in 1986 (ANS 2012), the Bhopal chemical leak in 1984 (Browning 1993), the Three Mile Island radioactive leak in 1979 (U.S.NRC 2013) or other similar disasters, much research has already been conducted on major industrial incidents caused

by the sudden release of uncontrolled energy, but very little is known about incidents caused by the subtle and insidious release of hazardous energy.

Incident causation models not only provide a conceptualisation of the factors related to incidents, but also serve as a useful tool for developing better incident prevention programs. Depending on the worldview (Tepe and Barton 2009) and disciplinary approach of the research, there are several causation models that reflect various perceptions of such incidents. Incident causation models draw knowledge from organisational science, risk management, behavioural sciences, engineering safety and incident concepts. This literature review will look at the mainstream incident causation models that have shaped the understanding of how these undesired events occur. Causation models can be categorised into three broad groups: sequential, epidemiological and systemic. Also, the common characteristics of an organisation are examined to better understand how these models can be applied in such a complex system. Moreover, the strengths and weaknesses of these mainstream models are analysed. Findings from this literature review will assist in the development of both a theoretical concept and methodological instruments for the analysis of EIPEs.

2.2 Components of an Organisational System

A basic system is a collective of components that, together, achieve a goal. The entire system changes when one part of it changes, so examining only one part of the system does not explain the functioning of the whole system. By this definition, organisations can be considered as systems. As early as the 1960s, researchers began to view organisations as open systems where they not only interact among their interconnected components, but also externally with their environments (Katz and Khan 1966; Buckley 1967; Lawrence and Lorsch 1967; Thompson 1967; Aldrich 1979; Scott 1981). Traditionally, organisational systems are managed by their separate entities (e.g. sales, production, logistics), but the systems approach focuses on the inter-relationships of these

different functions and how they work together to achieve the overall organisational goals (Forrester 1994b; Sterman 2000; Senge 2006).

External to an organisation are factors that can similarly impact upon business performance and the achievement of organisational goals. To minimise these external impacts, businesses carry out a strategic analysis of the macro business environment. It involves identifying factors that have the potential to impact on business competitiveness, so that effective strategies can be formulated.

Political, Economic, Technological and Social (PETS) analysis is a well-established strategic tool for assessing the political, economic, social and technological forces at work in any business environment (Cadle, Paul, and Turner 2010). Also, this holistic perspective closely aligns with the socio-technical system that consists of social, technical and organisational elements (Richardson 1999). Earliest known proponent of this business assessment technique has been linked to a professor of the Harvard Business School named Francis Aguilar (1967).

Political factors, such as federal tax policy and political stability, have important influences on business incentives and growth (Keim and Hillman 2008). Economic factors like interest rates and cost of capital can impact on business operations, and the demand and supply of goods and services (Hawksworth, Audino, and Clarry 2017). Social factors, such as the population growth rate and community pressure groups can affect the market share and the approach to stakeholder engagement (Avidar 2016). Technological factors, including the advancement of technology, can enhance the efficiency of business operations and raise the barrier of entry for competitors (Silva, Styles, and Lages 2017).

Besides these PETS factors, changes in the health, safety and environmental laws impact the way in which organisations need to meet their legislative

requirements (Marsden, Tran, and Marsden 2012). In the following conceptual framework, a regulatory or legal factor is added to PETS. Legal factors are closely tied to political ones. For example, a government may decide to introduce changes to the HSE laws (Safe Work Australia 2013). Indeed, all these factors, or PLETS, offer insights to the underlying features beyond the immediate causes of industrial incidents (Britkov and Sergeev 1998). The blueprint of an external organisational system is shown in Figure 2, where it interacts within a dynamic economic, political, legal, social and technological environment.

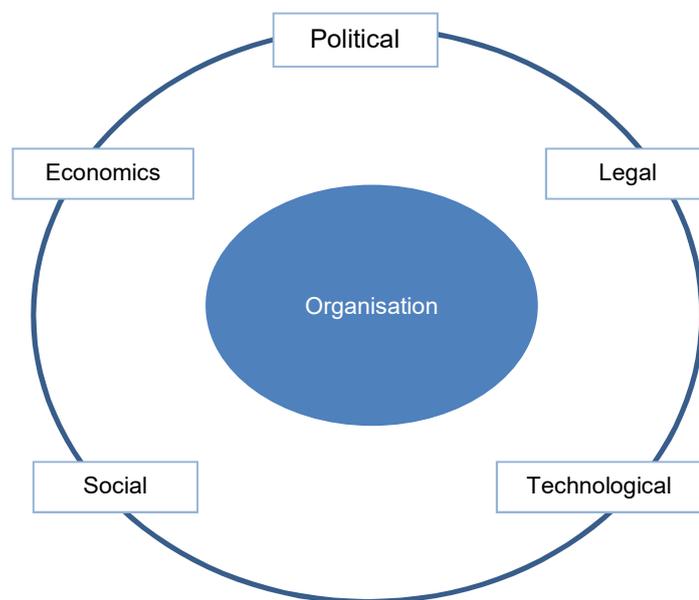


Figure 2: Macro Organisational Factors adapted from (Aguilar 1967)

Part of the formal organisation is the system in which individuals, groups and business units are organised to coordinate activities in ways that are designed to achieve certain strategic objectives. This arrangement serves as the basic framework for decision-making. For example, one of the organisation's strategic objectives can be its desire to increase its market share (Jones 2012). In order to meet such an objective, management may decide to restructure the company,

or merge with other organisations, or acquire other competitors (Reeves, Love, and Tillmanns 2012).

Within an organisation, the basic components include these: input or resources required for the system; process or conversion of the input; output or result of the input processing; and feedback that returns some or all of the output as input and/or process (Figure 3). Early Input-Process-Output (IPO) model (Steiner 1972; McGraft 1984; Hackman 1987) has evolved to include some level of feedback for a more complex system (Ilgen et al. 2005; Curry, Flett, and Hollingsworth 2006; Cornell and Nwoka 2015).

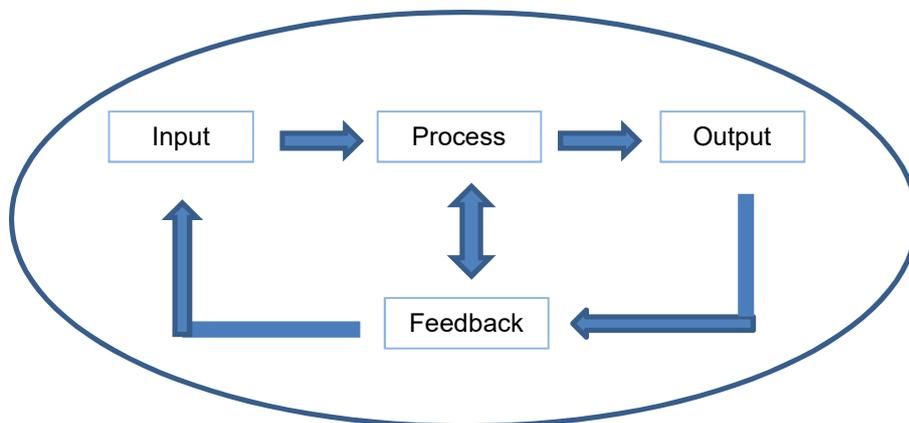


Figure 3: General System Components adapted from (Curry, Flett, and Hollingsworth 2006, pp. 106-108)

2.2.1 Inputs

To achieve corporate goals and to deliver the right products and services to their customers, organisations need to invest in critical resources, such as human, technological, capital, intellectual and other resources (Collis and Montgomery 2008). Other less tangible resources include a market brand name or reputation that helps to differentiate an organisation from its competition (Lev 2004). Most organisations will strive to use available resources in the most efficient and productive manner to achieve their objectives (Ireland and Schuh 2008; Snyman and Smallwood 2017).

2.2.2 Process

Without going through the necessary transformation phase, these inputs will not automatically produce the desired outputs. Therefore, the process phase is a systematic way for an organisation to define, organise and implement its operations. This involves planning, budgeting, training, manufacturing and other key processes that allow the organisation to meet customers' needs efficiently and profitably (Groover 2010; Mendling and Reijers 2013). Organisational policies, procedures, standards and guidelines are documents frequently used to ensure a common knowledge and consistent application of these activities (NSW government 2013). In the process of achieving its business objectives, sometimes productivity triumphs over safety. Despite popular safety taglines and politically correct phrases that say "Safety first" or "Safety is our top priority," the undeniable fact is that business needs drive safety decisions, and not the other way around (Rollenhagen 2013; Crutchfield and Roughton 2014). Therefore, the management of a workplace HSE system has to be ecologically examined in relation to the larger context of an organisation's business environment, and the macro forces that shape it (Wolstenholme 1993; Mazur 1998).

2.2.3 Outputs

Products such as cars, computers, medicines and chemicals are tangible goods that an organisation produces. Services, on the other hand, refer to work undertaken for customers that does not produce tangible deliverables; for example, services provided by hotel staff to customers in order to make their stay more enjoyable. Whether it is an actual product or an intangible service experience, these outputs have to be of value to the customers who need them (Inc 2017).

2.2.4 Feedback

Feedback is necessary to inform an organisation whether its actions towards a goal are on the right path. Within an organisation, it can come from the employees who carry out manufacturing activities and/or, customers using the products and services (Markey, Reichheld, and Dullweber 2009). Other indirect feedback can also come from the external organisational environment, such as changes in government policies, societal expectations, economic conditions and advances in technology (Reeves, Levin, and Ueda 2016). Ultimately, feedback enables businesses to adjust their management processes and systems to continually improve their services and product offerings (Kiran 2017).

2.2.5 Sub-Systems

An organisation is a complex system consisting of inter-related sub-systems. Examples of sub-systems are business units or functional departments within a larger system or organisation. For instance, the sales and production departments in an organisation can be considered as two individual sub-systems (Figure 4). The sub-system links then reflect how they are connected to each other and to other departments or sub-systems in the organisation. The sales department provides a sales forecast for the production of goods, and the actual orders from the clients are the feedback to the sales department.

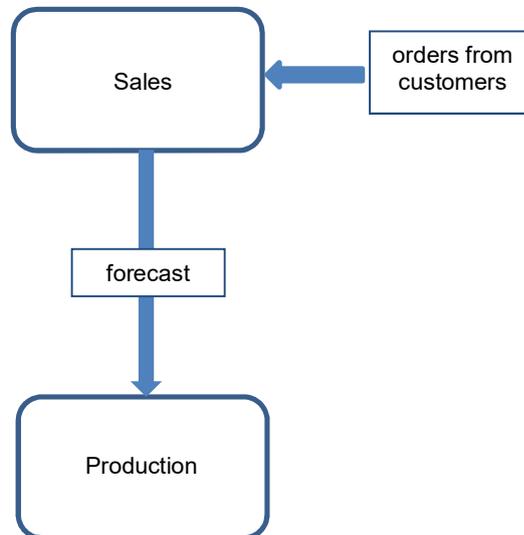


Figure 4: Sub-System of Functional Areas

2.3 Health Safety Environmental Management System

Beyond the structure and components of an organisational system, a set of guidance is needed to systematically manage HSE among business units. The application of an Health, Safety and Environment Management System (HSEMS) is based on the fundamentals of a Quality Management System (QMS), which is a formalised system of processes, procedures, policies, responsibilities and resource organisation to continually improve quality outcome (Standards Australia and Standards New Zealand 2016). QMS subscribe to the well-established management principle of Plan-Do-Check-Act (PDCA). This PDCA, or Deming Cycle (Deming 1982; Aguayo 1990), is designed to monitor business and HSE performance on a continual basis, which also encapsulates the input-process-output-feedback approach to business management mentioned earlier in Figure 3.

There are many HSEMS guidelines (International Labour Organisation 2001b; British Standard 2004) and standards (George 2001; Standards Australia 2001; American National Standards Institute 2005) that have been developed by industry and government agencies. Essentially, “an occupational health and safety management system is part of an organisation’s management system used to develop and implement its OHS policy and manage its OHS risks. A management system includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources” (British Standards Institution 2007, p. 3). Based on this definition, the principle underlying an HSEMS is applicable to the concept of an Organisational System. A model of this HSEMS is shown in Figure 5.



Figure 5: HSE Management System Model (British Standards Institution 2007)

Residing within the organisational model is the HSEMS, which is a systematic approach to managing safety and health risks within the workplace. OHSAS 18000 is an HSEMS Standard that was developed by the OHSAS Project Group, a consortium of 43 organisations from 28 countries. This consortium includes national standards bodies, registrars or certification bodies, OHS institutes and consultants. Although OHSAS 18000 was not developed by the

International Organisation for Standardisation (ISO), it is internationally recognised and is used by 15,000 companies or sites in 100 countries, and is increasingly being adopted as the national standard for an HSEMS (Khodabocus and Constant 2010; MCA 2014a).

For this OHSAS 18000 series, there are two accompanying standards: (1) OHSAS 18001:2007 – Occupational Health and Safety Management Systems – is a specification that can be used for certification audit; and (2) OHSAS 18002:2008 – Occupational Health and Safety Management Systems – is a set of guidelines for the implementation of OHSAS 18001. These HSEMS Standards can be adopted by any organisation that desires to achieve continual improvement in its HSE performance through a coordinated approach to eliminating or reducing workplace risks. Since the elements contained in these standards share common management system principles and methodologies, such as PDCA, they can be easily integrated with other management requirements (e.g. ISO 14001:2004 - Environmental Management Systems, ISO 9001:2000 - Quality Systems Management). Indeed, according to the European Agency for Safety and Health at Work (2002), the benefits of implementing an HSEMS include the creation and use of synergies in relation to other management systems. Five essential elements that underpin an HSEMS are Policy, Planning, Implementation & Operation, Checking and Management Review.

Various organisational factors could impact the effective implementation of the HSEME. Some businesses may treat these guidelines as nothing more than a paper compliance exercise, while others apply them at a more strategic level of integration within the overall organisational system (Gallagher, Underhill, and Rimmer 2001; Robson et al. 2007). Nonetheless, the adoption of an HSEMS has not only helped organisations to enhance their safety and health performance (Fernández-Muñiz, Montes-Peón, and Vázquez-Ordás 2007; Purse, Dawson, and Dorrian 2010), but also to improve their competitiveness

and financial performance (Fernández-Muñiz, Montes-Peón, and Vázquez-Ordás 2009).

2.3.1 Policy

An HSE policy is an expression of organisational commitment to high standards of safety and health (British Standard 2004; British Standards Institution 2007). It should be appropriate to the context, scale and HSE risks of the organisation. It spells out management's and employees' obligations to HSE. The policy may contain additional information, such as the broad strategies to be used to achieve the HSE objectives.

2.3.2 Planning

There should be a planned and coordinated approach to implementation of the HSE policy. This phase consists of the approach to risk management, compliance with relevant legislative requirements and meeting of planned objectives (British Standard 2004; British Standards Institution 2007). It usually involves the development of a strategic HSE management plan, by which activities based on the business risk profile are managed. Supporting the HSE management plan are the operational procedures and instructions to identify hazards, and to assess and control risks.

2.3.3 Implementation and Operation

In order to implement the HSE management plan, organisations need to allocate the necessary resources, define the roles, responsibilities, accountabilities and authorities of employees, and assess their competencies and training (British Standard 2004; British Standards Institution 2007). Additionally, organisations should establish, implement and maintain communication mechanisms, operational controls, emergency management plans, and systems for documentation and document control. All these components of this HSE

Management System need to be adequately maintained, inspected and monitored to ensure optimal operational effectiveness.

2.3.4 Checking

The existence of an HSE Management System is not enough to ensure the effective implementation of the risk management and incident prevention programs. Monitoring schedules are necessary to determine the level of HSE performance and the effectiveness of the management system. Performance is evaluated against defined standards to highlight opportunities or areas of improvement. This phase consists of components, such as performance measurement and monitoring, evaluation of compliance, incident investigation, non-conformity, corrective and preventive action, control of records and internal audit (British Standard 2004; British Standards Institution 2007).

2.3.5 Management Review

As part of the continual improvement process, top management should periodically review the HSE Management System to ensure it remains relevant and effective (British Standard 2004; British Standards Institution 2007). This review looks at opportunities for continual improvement and the need for rectifications in the HSE Management System, including possible changes to the policy, objectives and other elements of the system. The findings of the review should be documented and communicated to ensure appropriate implementation of actions. A comprehensive management review will help an organisation to develop its HSE Management System so that overall safety performance is improved.

2.4 Characteristics of an Organisational System

Incidents caused by organisations with multiple actors and complex inter-relationships are difficult to understand, and to foresee, because they have “multiple causes involving people at different levels” of the organisations (e.g. nuclear power plants, commercial aviation, petrochemical industry, chemical process plants) (Reason 1997, p.1). Since an organisational incident unfolds through many interacting causes, a conceptual framework is needed to examine these multiple interconnected causes within a theoretical context. Hence, a systemic causation model provides a framework through which the myriad of information can be organised and understood. Unlike the sequential model, where there are clear and direct links between causes, a systemic model contains a network of inter-dependencies of causes with consequences that are not immediately obvious.

A complex system like an organisation mobilises its resources to achieve a set of collective objectives. Generally, the complexity of the activities that are required to carry out these organisational objectives poses a difficulty in predicting their undesirable consequences. Unlike decomposing a technical installation to provide insights into the non-linear causalities and complex interactions of factors, the dynamic and evolving nature of the organisations cannot be understood through the use of decomposition or an analytical approach. All these characteristics of an organisation are especially amenable to the use of systemic models in studying the causation of incidents (Vaughan 2004; Coze 2005).

Early systemic studies of incidents began by looking at their causes, stemming from organisational behaviours and cultural issues. Turner (1976) identified a set of organisational patterns that preceded industrial incidents, and then applied the various stages of disaster development to three major cases from the mining, transport and construction industries. These incidents were studied

within their sociological contexts to better understand how the organisations had failed to foresee these incidents. The development of incidents consisted of graduating stages, from the subtle accumulation of non-compliance events without noticeable consequences, to severe consequences that required rectifications of the 'flawed' organisational beliefs and practices. It was found in all three cases that there were common preconditions (e.g. non-compliance with existing regulations, failure to identify risks due to entrenched organisational practices and culture, disregarding of feedback from external stakeholders, communication breakdown and failure to address emergent dangers) and other major organisational failures.

2.4.1 Control Failures

Depending on the nature of these organisational failures, Reason (1997) classified them as either latent conditions or active failures. Latent conditions, for example, poor design, impractical procedures, inadequate supervision, manufacturing defects, maintenance lapses, lack of training or wrong use of tools and equipment, may reside in the system for a prolonged period before interacting with local operational failures to breach the control barriers. These latent conditions are inherent in all organisational processes: designing, operating, maintaining, communicating, selecting, training, supervising and managing. They can be caused by the lack of ability to foresee the risk implications of the present management decisions.

While latent failures are embedded within the top organisational structure, with widespread and long-term possible impacts, active failures tend to be localised unsafe acts with immediate and short-term impacts. Unsafe acts are not necessarily the causes but rather the consequences of organisational incidents. When the gaps in the control barriers created by active failures align with those created by latent failures, then there is a greater chance of an incident happening. One way to enhance the system's protection is to put in place multi-layered barriers or redundant defences (Hollnagel 2004). However, these

multiple barriers may increase the complexity of their causal interactions, and conceal both the likelihood and consequence of their failures.

From the system perspective, human errors are seen as a result of system failure rather than the cause of it. Thus, system defences are put in place to prevent both active failures caused by unsafe acts and latent conditions caused by errors in management decisions, which may lie dormant before interacting with active failures to cause an incident (Reason 2000). Studies into High Reliability Organisations (HROs) offer important insights into a resilient system. One of the characteristics of an HRO is its preoccupation with failures rather than successes and a great resistance to status quo (Weick and Sutcliffe 2007).

Instead of modelling incidents as the result of component failure, they should be considered as a result of control inadequacies throughout the system's lifecycle. Central to the Systems-Theoretic Accident Modelling and Processes (STAMP) is the issue of control (Leveson and Dulac 2005). Prevention of incidents is viewed as the ability of a system to maintain control within a dynamically adaptive structure or regularly changing environment. Thus, to prevent the occurrence of an incident requires the development of an effective control framework that can be enforced within a complex socio-technical system (Leveson 2004).

2.4.2 Complex Interaction

According to Reason (1997), there are three levels of incident causes: unsafe acts, local workplace (situational) factors and organisational (systemic) factors. The process subsystems underlying organisational safety are safety-specific factors, procedural factors, technical factors, management factors, cultural factors and training. Reason's model is based on the principle of control barriers against the release of hazardous energy. Breaches of the control barriers are likely to be caused by human, technical and organisational factors. Identifying

the breakdown of the control barriers is critical to understanding the causes of organisational incidents.

Incidents caused by organisations with different functional roles and stakeholder interests are the result of multiple interacting factors. Within the organisation, a complex set of human (e.g. operator and managerial errors), organisational (e.g. policy failures, production pressures, communication failures), and technological (e.g. design faults, defective equipment) factors interact with the regulatory, infrastructural and preparedness failures in the external environment (Shrivastava et al. 1988). Other studies have used inputs from existing models to propose both internal and external factors of the organisations (Attwood, Khan, and Veitch 2006).

In complex and tightly-coupled systems (e.g. nuclear plant, chemical plant, space mission), organisational causes are multi-layered, dynamic and not clearly evident. Normal Accident Theory (NAT) applies to these complex systems, which are inherently vulnerable to the unexpected interaction of variables capable of defeating control barriers or preventive measures (Perrow 1999). This is a 'normal' outcome of dynamically complex systems (Perrow 2001). Reconstructing the 1986 Space Shuttle disaster, Vaughan (2004) uses analogical theorising to compare similar events, in order to provide social-political-organisational causes of the disaster. The combination of historical, political and economic forces, coupled with the entrenched institutional structure and culture, and ineffective regulatory environment, can lead to a gradually increasing tolerance of non-compliance or the 'normalisation of deviance.'

To address the unpredictable behaviour of complex systems that is caused by rapid technical and social changes, some studies present a combination of tools - AcciMap and Cause-Consequence diagram - to analyse hazardous work systems (e.g. organisational, social and technical factors) and to identify the interactions of these factors within a socio-technical system that contributes to

industrial incidents (Svedung and Rasmussen 2002). AcciMap is a multi-layered diagram that depicts the causal relationships ranging, from the individual factors to the larger societal factors (Branford and Hopkins 2009). It provides an analysis of the failures in the complex socio-system at various levels, from government policy and regulatory agencies to organisational management, as well as the processes, physical equipment and environment.

Among the studies that have used this approach to examine the causation of incidents are the investigation of a gas plant explosion (Hopkins 2000); the contamination of drinking water (Woo and Vicente 2003); the outbreak of diseases (Vicente and Christoffersen 2006); the risk management of food safety (Cassano-Piche, Vicente, and Jamieson 2009); and the accident analysis of an outdoor activity (Salmon et al. 2010). In recognition of the complex socio-technical interaction, recent studies also look at the development of complementary risk assessment tool that can holistically evaluate risks from the systems perspective and to provide a theoretical system for better OSH governance in a complex organisation (Tepe and Haslett 2002; Albery, Borys, and Tepe 2016).

2.4.3 Conflicting Interests

The conflict between safety and production has been highlighted in several studies (Shrivastava 1994b; Dorner 1996; Rasmussen 1997; Reason 1997; Goh et al. 2010). Such conflict is more pronounced in an increasingly globalised environment, where intense competition has compelled firms to cut costs in order to stay profitable. Organisations are under growing pressure to meet the demands of cost efficiency and market competition. This relentless pursuit of improvement in business performance is often achieved at the expense of safety and health (Shrivastava 1994a).

When managing various business objectives and operational pressures, organisations tend to operate within an acceptable zone between the boundaries of production efficiency, production volume and safety investment (Rasmussen 1997; Reason 1997). Contrary to the politically correct claim by many organisations that production and protection go hand-in-hand, the partnership between the two is rarely harmonious. Often the production interests take precedence over safety concerns. The occasional taking of shortcuts often leads to habitual trade-offs for production gains at the expense of safety. A prolonged period of safety neglect without serious incident can lead to complacency and the erosion of control barriers. The continued erosion of controls and the reinforcement of a safety-compromising culture can culminate in the occurrence of a serious incident.

Vaughan (1999) traces routine organisational non-conformities; for example, the taking of shortcuts as an inherent characteristic of the sociological system in which they operate. This systemic generation of non-conformities is the result of the interactions among the environment of the organisations, organisational characteristics and the behaviour of individuals. Hence, safety culture is necessary to sustain a high awareness of safety, with the holistic understanding that human, technical, organisational and environmental factors all have impacts on the safety of a system (Reason 1998).

2.4.4 Feedback Loops

Since incident prevention is a 'system property' and not a 'component property,' it must be addressed at the system level and not at the component level (Leveson 2011). The sequential causation models tend to oversimplify incident causes and do not take into account the non-linear interactions among events and components. Aside from the characteristics of non-linearity or a feedback loop, many complex systems have a "multi-dimensional multi-level structure,"

which makes the prediction of their behaviour, and therefore the management of risk, difficult (Johnson 2006).

Overcoming some of these drawbacks, recent studies using dynamic models of the system have incorporated feedback loops and non-linear relationships. Using System Dynamics (SD) models, Cooke and Rohleder (2006) developed an incident learning system to reinforce commitment to HSE and incident prevention.

Since the pioneering work of Forrester (1961) in industrial dynamics, the SD modelling technique for analysing complex interactions has gained wide acceptance in many research fields (Ruth and Hannon 1997; Sterman 2000; Sterman and Sweeney 2002; Vriens and Achterbergh 2006; Winz, Brierley, and Trowsdale 2009). Furthermore, the simulated performance of an SD model can build confidence by demonstrating its reliability and the repeatability of behaviours that are traceable to real-world cause-and-effect.

By using SD tools, such as Causal Loop Diagrams (CLD, Figure 6a) and Stock and Flow Diagrams (SFD, Figure 6b), we can visually present how the different factors interact with one another to contribute to extended industrial pollution events. The interpretation and development of a CLD is explained in more detail in Section 5.3.

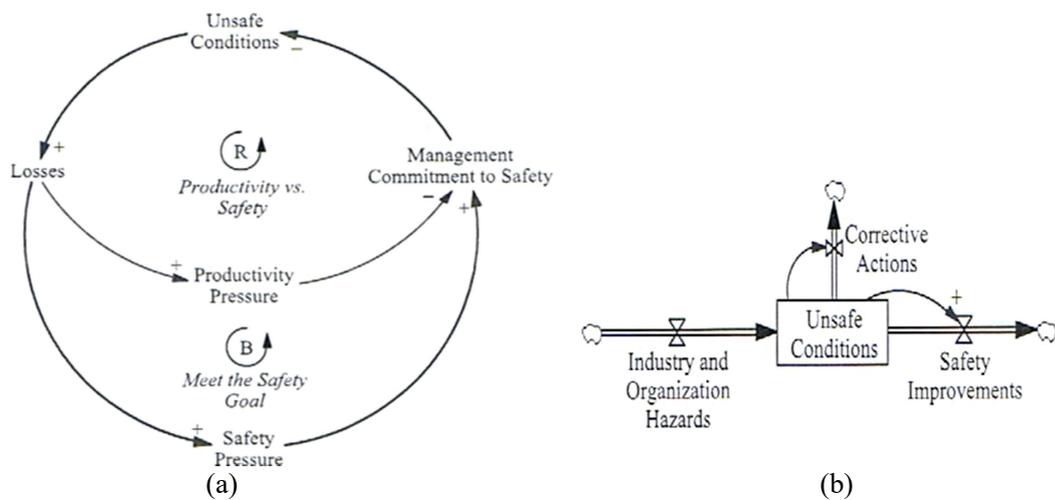


Figure 6: Causal Loop and Stock and Flow Diagrams (Cooke and Rohleder 2006)

These dynamic relationships are then quantified in an SD computer simulation model using mathematical equations. Such an approach is often the only practical way to develop and evaluate strategies in complex environments involving a large number of inter-dependent variables that vary across time. Essentially the SD simulation model allows policy-makers to compress time and space in order to perceive trends, causes and effects that would normally unfold over a lengthy duration of time (McIntire and Glaze 1999). Moreover, as new data becomes available, they can be incorporated into the simulation model to provide better insights for designing policy.

In Systems-Theoretic Accident Modelling and Processes (STAMP), “systems are viewed as interrelated components that are kept in a state of dynamic equilibrium by feedback loops of information and control” (Leveson 2004). Simulation of the perceived representation of reality by applying these tools provides valuable insights into the complex web of causes that can lead to incidents (Cooke 2003; Leveson 2004; Leveson and Dulac 2005; Cooke and Rohleder 2006; Dulac et al. 2007; Goh, Brown, and Spickett 2010; Goh et al. 2010).

2.4.5 Leverage Points

Some systems are simple and predictable, but most organisational systems possess the above-mentioned characteristics that are both non-linear and complex. Instead of focusing on the individual components and behaviours, a systems approach is more concerned with the patterns and underlying structures. Therefore, understanding these “driving forces” behind the occurrences of certain organisational events enables the strategic intervention in the most important places for effective changes to the long term behaviour of a system (Meadows 2016).

Not all interventions have the same effectiveness in changing behaviours in a system. Low leverage points are those interventions that address the superficial or immediate problems. An example would be using a bucket to collect water leakage from a broken water pipe. Obviously, the more effective intervention or higher leverage point would be to replace the broken pipe. This concept of leverage points for the development of more effective and sustainable solutions has wide applications from economy, to bio-system, to healthcare, to communication, to organisations and many other complex systems (Nguyen and Bosch 2012; Brown et al. 2013; Khan and Borgstrom-Hansson 2016; Priefer, Jörissen, and Bräutigam 2016; The Solutions Journal 2017). The leverage points or ways to intervene, organised from the least effective to the most effective in an interconnected EIPE system are discussed in Section 11.3 of Chapter 11.

2.5 Mainstream Incident Causation Models

This literature review does not attempt to capture every incident causation model in the body of knowledge, nor is it helpful to create a prohibitively large set of citations for the purpose of this study. Instead, prominent incident causation models that have made significant contributions to the understanding

of incident causes, and the way in which they have shaped the strategies for preventing such incidents have been selected for this literature review. The fact that incident causation research often involves cross-disciplinary collaborations makes it difficult to neatly compartmentalise various models. Nevertheless, mainstream incident causation models can be broadly categorised as: (1) Sequential causation; (2) Epidemiological causation; and (3) Systemic causation (Hollnagel 2004). This holistic categorisation represents the progressive development of early sequential models, which have provided the foundation for subsequent systemic models using more recent studies such as system theory and complexity theory. Though there are several variants of these theories not mentioned here, they rarely contribute more to the original understanding of accident causation and are seldom featured in contemporary literature on incident causation.

2.5.1 Sequential Causation Models

The major feature of the sequential causation models is the close chronological relationship between the causes and events of an incident. In some cases, the incident can consist of one event. In others, it can be a chain of multiple events that result in an incident. By back-tracking the logical order of incident causes in a sequential manner, the underlying causes can be uncovered and, thus, prevent similar incidents from occurring in the future. This is based on the assumption that there are clear cause-and-effect links with an identifiable 'trigger' or 'triggers' of the sequence of consequences.

The father of accident causation theories can be considered to be Herbert William Heinrich (1931) who suggested that injuries resulted from a series of sequential factors: ancestry and social environment; fault of person; unsafe act or condition; accident and injury (see Figure 7). The first domino in the sequence deals with an individual's personality. Unhelpful personality traits, such as impatience and recklessness can either be inherited or developed from a

person's social environment. These innate characteristics and acquired personality factors contribute to the second domino or 'faults of person.' The third domino, or 'unsafe act or condition,' deals with the direct causes of accidents. In this model, it is clear that the removal of this central domino breaks the link to the preceding factors, which then prevents accidents and injuries.

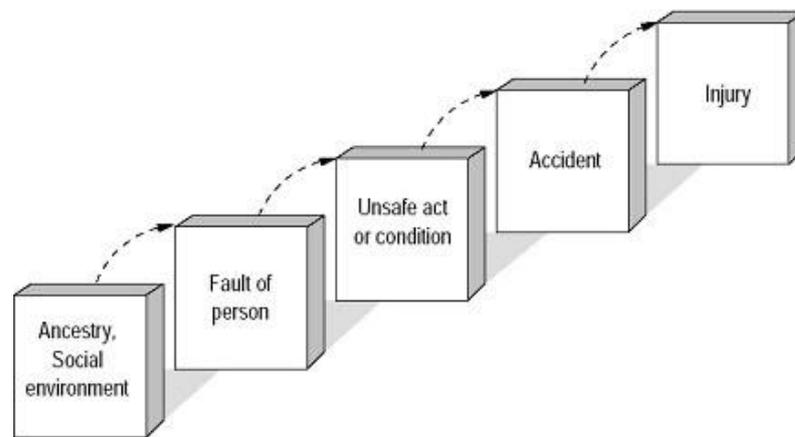


Figure 7: Heinrich Domino Theory (Heinrich 1931)

Heinrich's Domino Theory was further revised to incorporate new developments in safety theory and a changing socio-political environment. The dominoes illustrated in Figure 8 have been relabelled with these factors: Lack of Control; Basic Causes; Immediate Causes; Incident; and People-Property. Basic causes can be fatigue, lack of training and/or inadequate resources, which lead to 'Immediate Causes' such as substandard practices and conditions, or errors. These will ultimately result in incidents and losses. The underlying theme is that people, and not things, are the causes of incidents. Therefore, to prevent losses, the first domino of 'Lack of Control' has to be addressed (Bird and Loftus 1976). Whether it is a study on safety culture or the understanding of incident causation, Heinrich's work continues to have an impact in current occupational health and safety research (Hayes et al. 1998; Marcus and Nichols 1999; Cooper 2000; Zohar 2000; Shappell et al. 2007; Collins 2011).

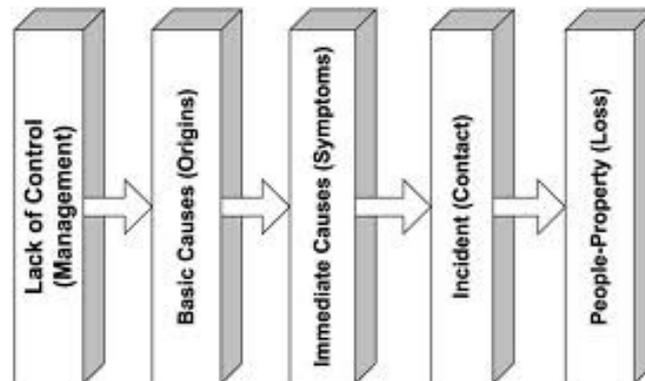


Figure 8: Bird and Loftus Theory (Bird and Loftus 1976)

At the height of an American industry that had been revitalised by war, rapid scientific and technological innovations included the US Air Force-sponsored development of Fault Tree Analysis (FTA) by H. A. Watson of Bell Laboratories, in 1961 (Grimaldi and Simonds 1989). FTA is a top-down logic model that represents the failures found within a physical system (see Figure 9). The diagram portrays branched events using the 'and/or' logic gates. Additionally, the model provides a qualitative and quantitative assessment of the complex relationships between humans, software and hardware. Coupled with the emphasis on probabilistic risk assessment and reliability engineering (Shooman 1968) in the 1960s, the aerospace and nuclear power industries have been the first to embrace its application for safety and reliability evaluation. The value of FTA received prominence through its application in the investigation of high profile accidents such as the release of radioactive gases at Three Mile Island on March 29, 1979, and the explosion of the Challenger Space Shuttle on January 28, 1986, (Ericson 1999). Techniques complementary to FTA are Event Tree Analysis (ETA) (Craft et al.) and Failure Mode and Effect Analysis (FMEA) (US Dept of Defense 1949), with applications mainly in the aviation, space and military programs.

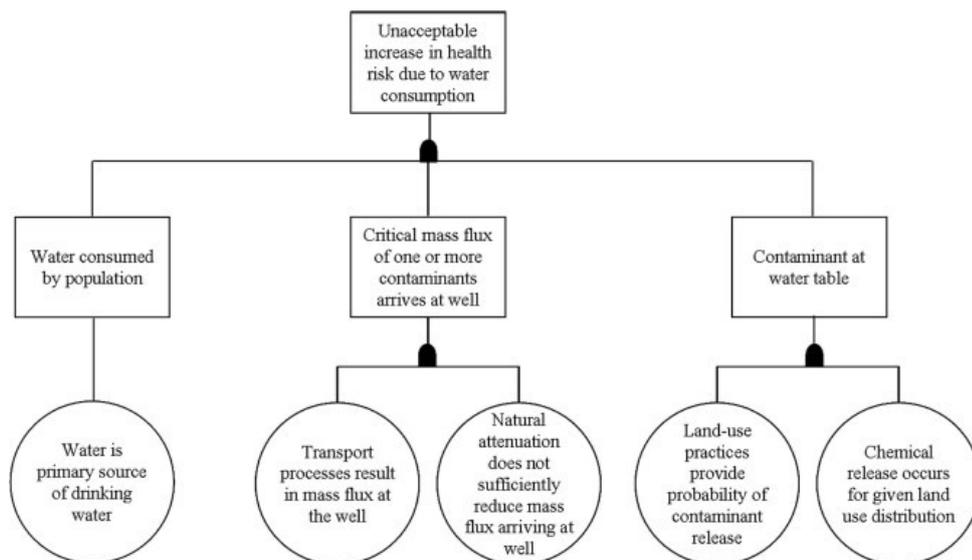


Figure 9: FTA for Planning Scenario (Gunningham, Robert, and Thornton 2004)

The development of safety engineering and reliability engineering analysis techniques, such as FTA, ETA and FMEA, was built from the concept of linear causation using branched-events-sequence-logic concepts. However, these logic tree models do not adequately capture management's contribution to major incidents. In 1973, William G. Johnson developed the Management Oversight and Risk Tree (MORT) as part of the US Atomic Energy Commission's effort to improve the safety management system in the nuclear industry (Johnson 1973). MORT is an analytical technique that uses the logic tree diagram to investigate the causes of, and contributing factors to, incidents (see

Figure 10

Figure 10). It consists of an unwanted top event, and below this top event are three main branches: S-branch, the particular circumstances and conditions associated with the accident being investigated; R-branch, those known but uncontrolled risks; and M-branch, the management system deficiencies that contributed to the accident. An established referencing system and risk analysis procedure are applied to assess the adequacy of the safety management system. At the heart of its application is the understanding that accidents are

caused by unwanted transfers of energy, which are the result of lapses in the management system in controlling them.

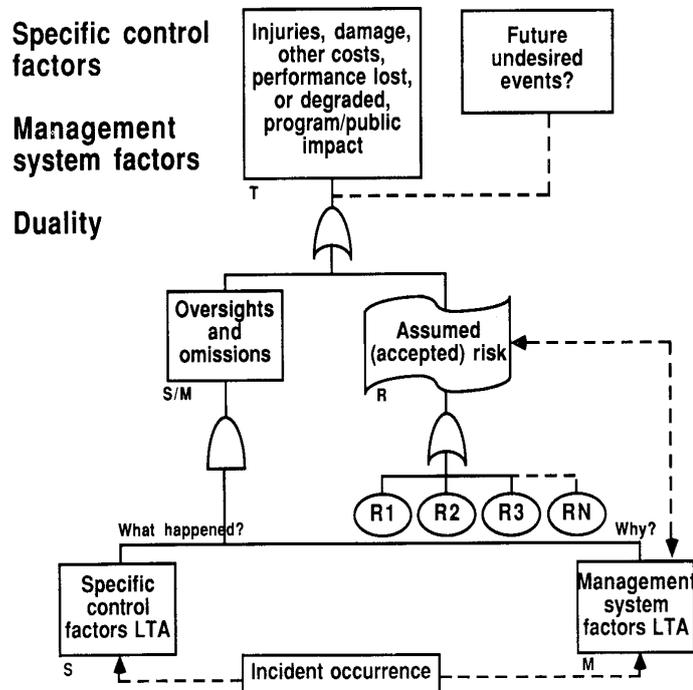


Figure 10: MORT Diagram for Causal Analysis (Stephenson 1991)

Despite improvements in the above-mentioned logic tree models, there remain weaknesses in that there is no structured approach for determining the start and end of accidents, for defining events and conditions, and for sequencing the time relationship of the events. To address these inadequacies, Ludwig Benner (1975) proposed an analytical technique called Multilinear Events Sequencing (MES). This technique takes into account the chronological relationships of multiple events, causes and contributing factors. As shown in Figure 11, this is achieved by displaying the linear chain of events with their associated factors along a horizontal line, and using arrows to indicate the flow of events or their relationships among each other. This technique allows the investigator to explore similar factors that occur in multiple accidents and to identify possible intervention points for the prevention of accidents. Subsequent improvement to

his earlier model resulted in the development of a systems-based MES called Sequentially Timed Events Plotting (STEP) (Kingsley and Ludwig 1987).

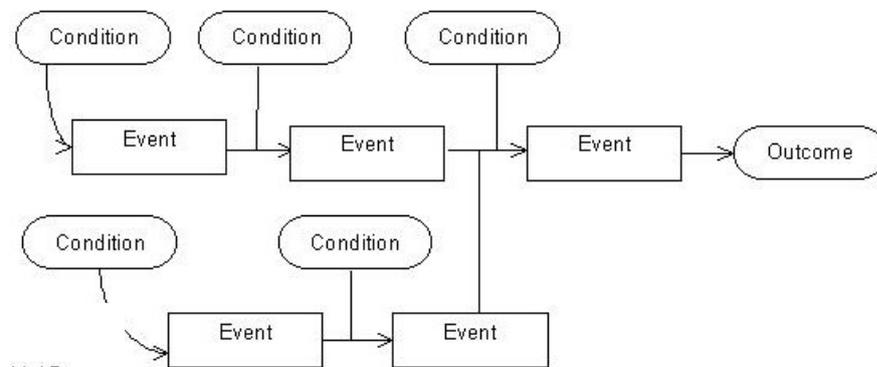


Figure 11: MES Diagram Presenting the Relationships between Conditions and Events (Ferry 1988)

As can be seen, the sequential causation models are very much focused on the linear causes and effects, whether one or multiple links of a chain of undesirable events that contribute to incidents. One of the assumptions is that ‘root causes’ can be logically traced to some specified time or defined conditions before the occurrence of an incident. However, in complex environments and systems, events are seldom organised in a simple, orderly cause-and-effect manner. Moreover, traditional sequential models are poor at uncovering organisational and socio-technical factors contributing to incidents, which are ill-equipped to analyse incidents that occur in complex socio-technical environments. Therefore, more sophisticated causation models are needed to address the limitations of sequential models in order to better understand the complex causes of EIPE.

2.5.2 Epidemiological Causation Models

In the same manner in which an epidemiologist studies how diseases can spread in a given population, an incident epidemiological causation model involves understanding how an incident can happen by taking into account the environment and the conditions in which an activity is carried out. If diseases are

the result of the interactions among the agent, the host and the environment, then incidents can also be seen as resulting from the interactions among these factors. Therefore, an epidemiological model is a significant departure from the sequential causation model because the interaction of these factors does not have to follow a defined order or sequence.

Gordon (1949) first suggested that accidents, as a health problem, conform to common known patterns, as do diseases. Whether the undesired outcome is a disease or an injury, the causation can be traced to a combination of sources, which are the host (man), the environment and the agent. The example of Gordon's model in Figure 12 is an epidemiology of accidents that seeks to identify the factors associated with the host, agent and environment (Gordon 1949). A similar epidemiological model, shown in Figure 13, has been proposed to include major accident factors: accident effects, accident conditions, situational factors and predisposition characteristics (Aldrich 2001; Japan International Cooperation Agency 2005). This epidemiological approach to accident causation has been widely used to investigate motor vehicle accidents, pedestrian injuries, farm incidents, home injuries, fires and explosions, etc. (Iskrant 1962). Yet other variants of the epidemiological model combine Gordon's model with the sequential causation model (WHO 2014).

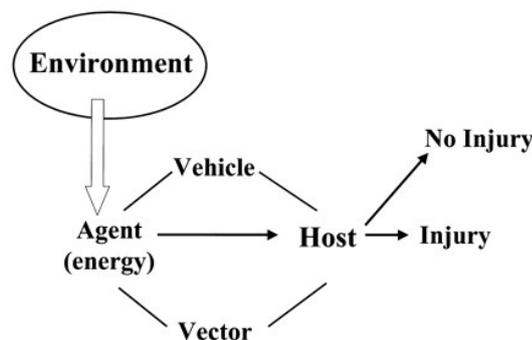


Figure 12: Epidemiological Model on Vehicular Accidents (Forbus 2008)

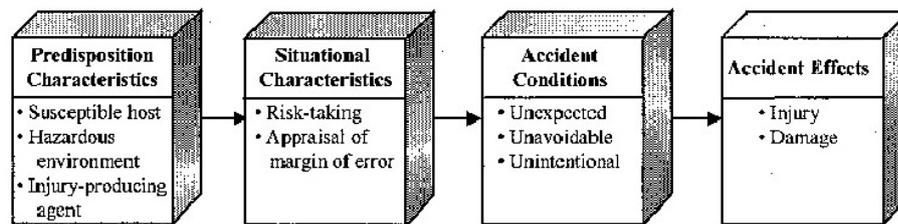


Figure 13: Adaptation of Suchman's Epidemiological Model (Wiegmann and Shappell 2003)

As much as Gordon's (1949) epidemiological model has been a revolutionary way of perceiving incidents, it is not always possible to identify the 'agent' in the model. Haddon's (1963) concept of injuries due to abnormal contact with energy (e.g. thermal, chemical, radioactive, electrical, ionizing, etc.) overcomes such difficulty. Therefore, a car that collides with a truck, resulting in the injuries of passengers in both vehicles, has their mechanical energies as the agents. The vehicles, in themselves, are not the 'agents;' rather they are vessels through which the abnormal energy is transferred to the passengers (Haddon 1980). Coincidentally, in another independent study during the same period, Gibson (1961, 1964) had, months earlier, come to the same conclusion, and had developed a formula suggesting the exchange of electrical, chemical, thermal and mechanical energy to injuries. Subsequent research reinforced the concept of energy sources as potential hazards in the workplace (Viner 1991).

To minimise the harmful transfer of these energies, counter measures have been proposed to address the source of energy generation, the path of transmission, the rate of transmission and the receiver (Haddon 1973). Haddon further built on Gordon's work by examining these contributing factors – host, man and environment – from the pre-event to the event and post-event stages. Haddon's Matrix (Figure 14) provided a 3-tiered approach to injury prevention by intersecting these contributing factors with the time dimension - pre-injury event, injury event and post-injury event (Haddon 1968, 1999). Since the landmark contribution of this conceptual framework in understanding incidents and

injuries, there have been several studies using Haddon's Matrix (Barnett et al. 2005; Eddleston et al. 2006; Varney et al. 2006; Ganczak et al. 2007; Mazumdar, Sen, and Lahiri 2007; Peck et al. 2008). Later studies have expanded on this conceptual framework by adding a third dimension of decision-making criteria to this matrix (Runyan 1998).

Component	Driver	Passenger	Pedestrians	Bicycles	Motorcyclists	Vehicles	Highways	Police
Phase								
Precrash								
Crash								
Postcrash								
Results	driver injury and death	passenger injury and death				property damage		

Figure 14: Haddon's Matrix for Identification of Traffic Injury Problems (Smith 1971)

The epidemiological model is an improvement on the sequential model, in that it no longer just looks at the close cause-and-effect relationship between events. It considers the web of factors in a host-agent-environment relationship. Instead of focusing on isolated events, epidemiological models look at the individual and situational characteristics that are predisposed to lead to incidents. Even though such models can be seen as a transition to more sophisticated systemic models, they still lack the ability to adequately address complex socio-technical factors that have significant impacts upon incidents with non-linear causes. While these epidemiological models may provide a semblance of the system approach to

understanding incident causes, they overlook the dynamic interaction of factors such as the feedback loop and vicious cycle within the system.

2.5.2.1 Human Contribution

Closely linked to the epidemiological causation models is the human (host) perspective of incident causation, which has its roots in industrial ergonomics and psychology. It is widely acknowledged that human errors, to varying degrees, contribute to most incidents (Reason 1990; Shappell and Wiegmann 1997; Granot 1998). The inexplicable link of the human role in incidents is best described in this statement: “In reality, all accidents can be attributed to human error due to error in design, construction, operation, or maintenance” (Crowl et al. 2007). Therefore, insight into the causes of human errors will support the formulation of strategies to prevent these errors from causing incidents. Jens Rasmussen (1982, 1983) categorised types of human error as knowledge-based, rule-based and skill-based. Since the mid-1980s, human errors have no longer been viewed as the root or primary causes of incidents. Instead, they are treated as a consequence of underlying systemic failures (Johnson 1999). These human factors can interact with latent factors to produce incidents. Just as a pathogen may remain dormant in the body before the onset of a disease, latent factors in an organisation can lie undetected until they come into contact with undesirable conditions (Reason 1990). Latent factors include inadequacies in design of plant and equipment, training, supervision and communications, and unclear roles and responsibilities. As illustrated in Figure 15, incidents are caused by combinations of active and latent failures found within multiple levels of controls (e.g., decision-makers, line management, psychological preconditions, productive activities and defences) of an organisation.

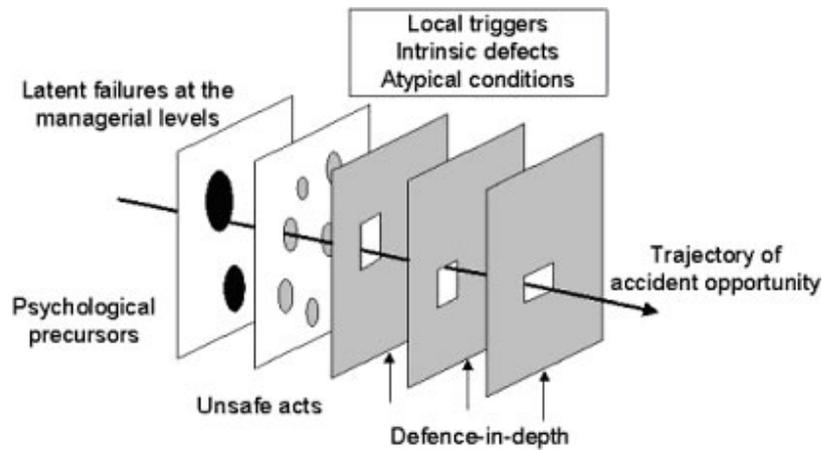


Figure 15: Swiss-Cheese Theory (Reason 1997)

Several studies have recognised that the impact of human factors on incidents cannot be narrowly studied outside of the context of their organisational and socio-technical environment (Rasmussen, Duncan, and Leplat 1987; Nielsen and Jorgensen 1993; Reason 2000; Noyes and Bransby 2001; Dekker 2006). ‘Sharp-end’ and ‘active failure’ are indicative terms being used to describe the human factors leading to incidents. At the other end of the spectrum are the ‘blunt-end’ or ‘latent failures’ (e.g. organisational, management, regulatory factors), contributing to the incidents (Reason 1997, 2000; Woods et al. 2010). Figure 16 shows the relationship between the narrowly focused human factors and the broadly viewed societal factors (Hollnagel 2004). Recent research has attempted to integrate human factors into the more holistic system models (Strauch 2004; Bellamy, Geyer, and Wilkinson 2008; Woods et al. 2010).

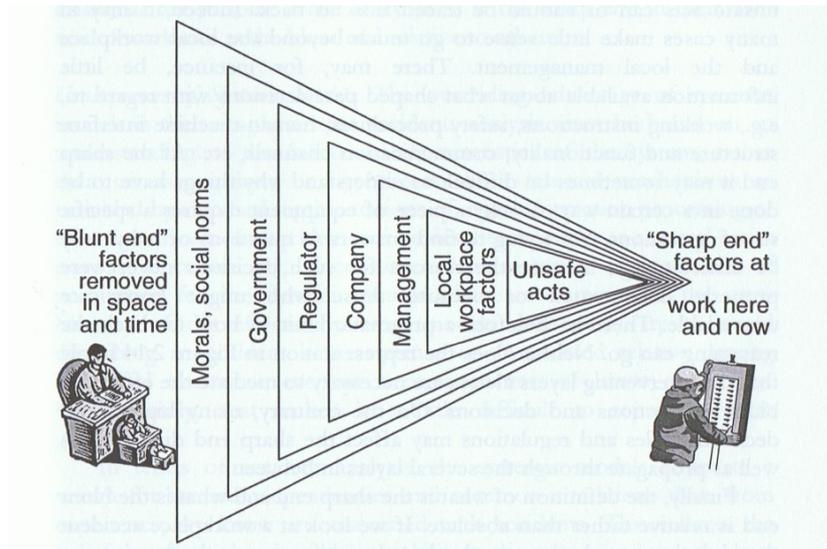


Figure 16: Sharp and Blunt End Factors (Hollnagel 2004)

2.5.3 Systemic Causation Models

A system can be defined as a set of things working together as parts of a complex network (Checkland 1997). Essentially, it is made up of inter-related components that are part of a unified entity (Robbins and Mukerji 1993). Appendix B is a list of 'system' descriptions adopted by Standards bodies and well-known institutions. Based on these definitions, examples of systems include business organisations, the environment, the human body, computer networks and other man-made or natural entities.

Reports of industrial incidents indicate that they arise from interactions among people, equipment and the environment that cannot be understood by simple chains of events, but more complex types of causal connections (Bellamy, Geyer, and Wilkinson 2008; Saleh et al. 2010) (see Appendix A). They seldom specify a single causal factor and they usually include organisational, management, social and cultural factors that are commonly omitted in the sequential causation models. Therefore, a systemic causation model consists of parts that are structured through a process to achieve an objective.

Due to the complex nature of industrial incidents, systemic models are usually derived from the multi-disciplinary fields of control systems, industrial engineering and organisational studies. Since the introduction of the general systems theory by Ludwig von Bertalanffy (1969), the advancement of technological innovations and the emergence of complex engineering networks have accelerated the adoption of the systems approach in several fields such as social sciences, organisational behaviours, systems engineering and cybernetics. Observing the need for systems engineering as the critical ingredient to modern development, Schlager (1956) states: “In a complex system it is often found that, even though individual components satisfy all specifications, the system as a whole will not work.”

Based on the above, it is evident that there is no consensus on how systemic causation models should be classified. By recognising the main themes in these models, they can be broadly grouped under (a) Systemic organisation - those that focus on the broad design and nature of the system as a whole; (b) Systemic interaction – those that focus on the inter-relationships between factors; (c) Systemic integration – those that not only emphasise on the interaction between factors, but also combine different concepts and models.

2.5.3.1 Systemic Organisation

Man-Made Disasters (MMD) are caused by the failures of interactions between workers and organisations operating in complex socio-technical systems (Turner and Pidgeon 1997). Normal Accident Theory (NAT) examines the complexity of the organisational system and the extent to which the processes are linked, and postulates that incidents in highly complex and tightly coupled systems are inevitable (Perrow 1999, 2001). However, this model, devoid of behavioural factors other than technological, has been criticised for its lack of preventive strategies that could be developed for a broad range of hazards and complex organisations (Hopkins 2001; Dekker 2004).

High Reliability Organisations (HROs) possess characteristics that make them able to sustain a strong safety culture and safety management system, even in highly hazardous operations, which is in contrast to the NAT (Rochlin, Porte, and Roberts 1987; Weick 1987; Bierly and Spender 1995; Bigley and Roberts 2001; Weick and Sutcliffe 2007). One of these characteristics is the preoccupation with failure. Such an attitude prevents the mindset of complacency from setting in and eroding the internal controls of a system designed to prevent incidents. Even in the absence of negative reporting, personnel in HROs look out for areas that can lead to failures, and opportunities for improvement.

2.5.3.2 Systemic Interaction

Incidents involving organisations need to be analysed using multiple interacting factors including 'Personal,' 'Technical' and 'Organisational' (Bowonder and Linstone 1987). Similarly, the socio-technical system presented in Figure 17 depicts the hierarchical interactions within an organisation, and with its external stakeholders (Rasmussen 1997). Complementing this risk management framework is AcciMap (see Figure 18), which captures the information flow structure within a socio-technical system (Hopkins 2000).

Compared to the sequential and epidemiological causation models, the systemic causation models more closely reflect the complex characteristics found in an organisational system (Section 2.4). In complex socio-technical systems, humans under cost pressures tend to seek the most economical and efficient way to carry out a task. In the process, violation of safety rules can be reinforced by previous similar behaviours that have not led to undesirable consequences. Competing dynamic forces present in such a complex, socio-technical system eventually cause its structure, and people's behaviour, to evolve through time (see Figure 19). The result is a "systematic migration toward the boundary of acceptable performance, and when crossing an irreversible boundary, work will no longer be successful due to a 'human error'" (Cliff 2012). Similarly, Woods

(2009) describes organisational and human failures as the erosion of controls under operating pressures and changes. Such migration towards the safety boundary, or habitual organisational non-conformities, are caused by activities operating in an inherently imperfect social system (Vaughan 1999). Closely linked to the concept of a shift from the original system design is Hollnagel's Functional Resonance Analysis Model or FRAM, which examines the functional variance from a normal system performance (Hollnagel et al. 2011; Hollnagel 2012). Since variability is a result of multiple interactions among functional components, risk assessment should focus on roles and operations of these functions within a system rather than on their failures.

In order to understand how all the factors within a system interface and interact, tools like System Dynamics (Winz, Brierley, and Trowsdale 2009) are used to represent dynamic and non-linear interactions with feedback loops (Cooke 2003; Cooke and Rohleder 2006; Goh et al. 2010); and conflicts within the interactions (Shrivastava 1994b).

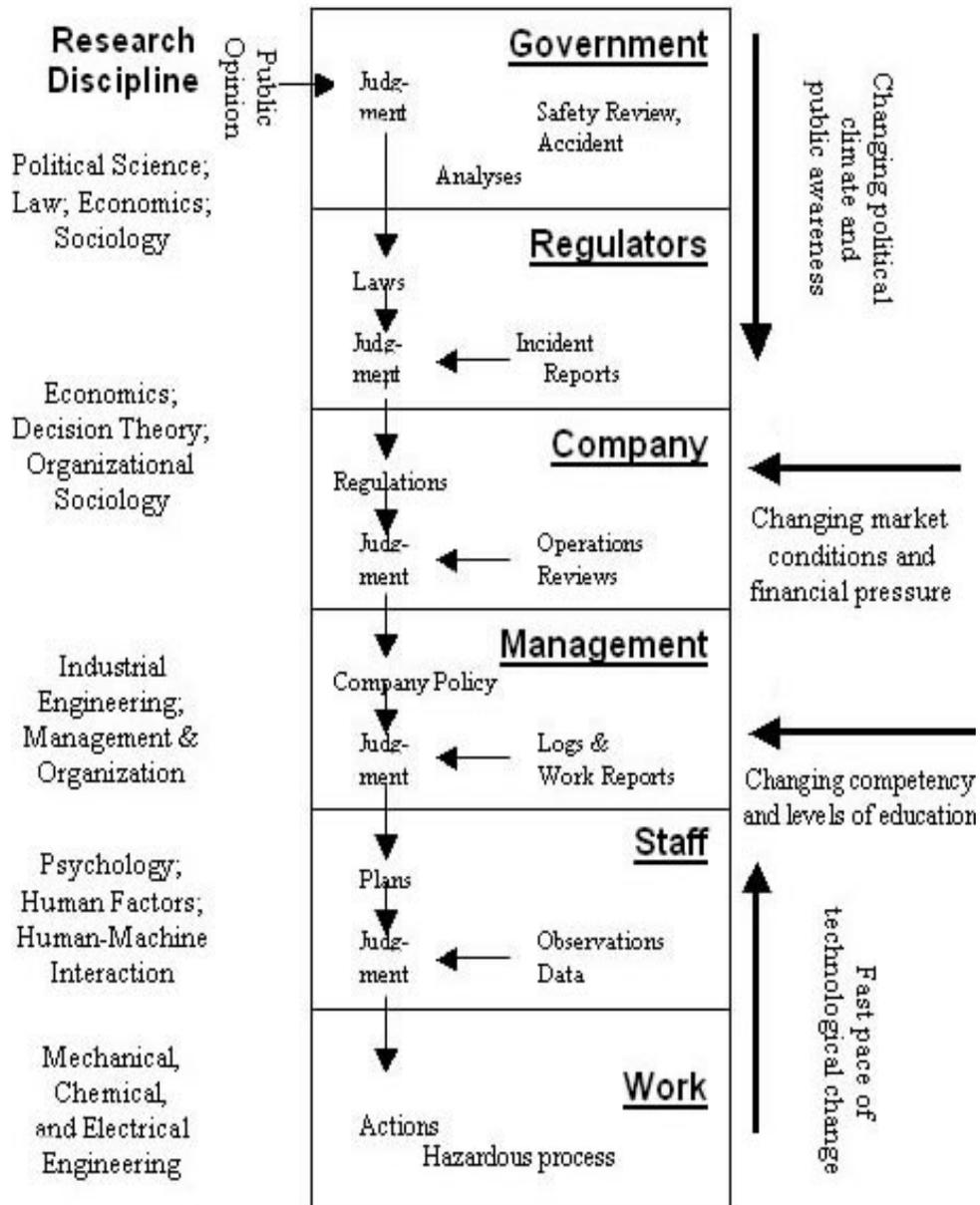


Figure 17: Socio-Technical System in Risk Management (Rasmussen 1997)

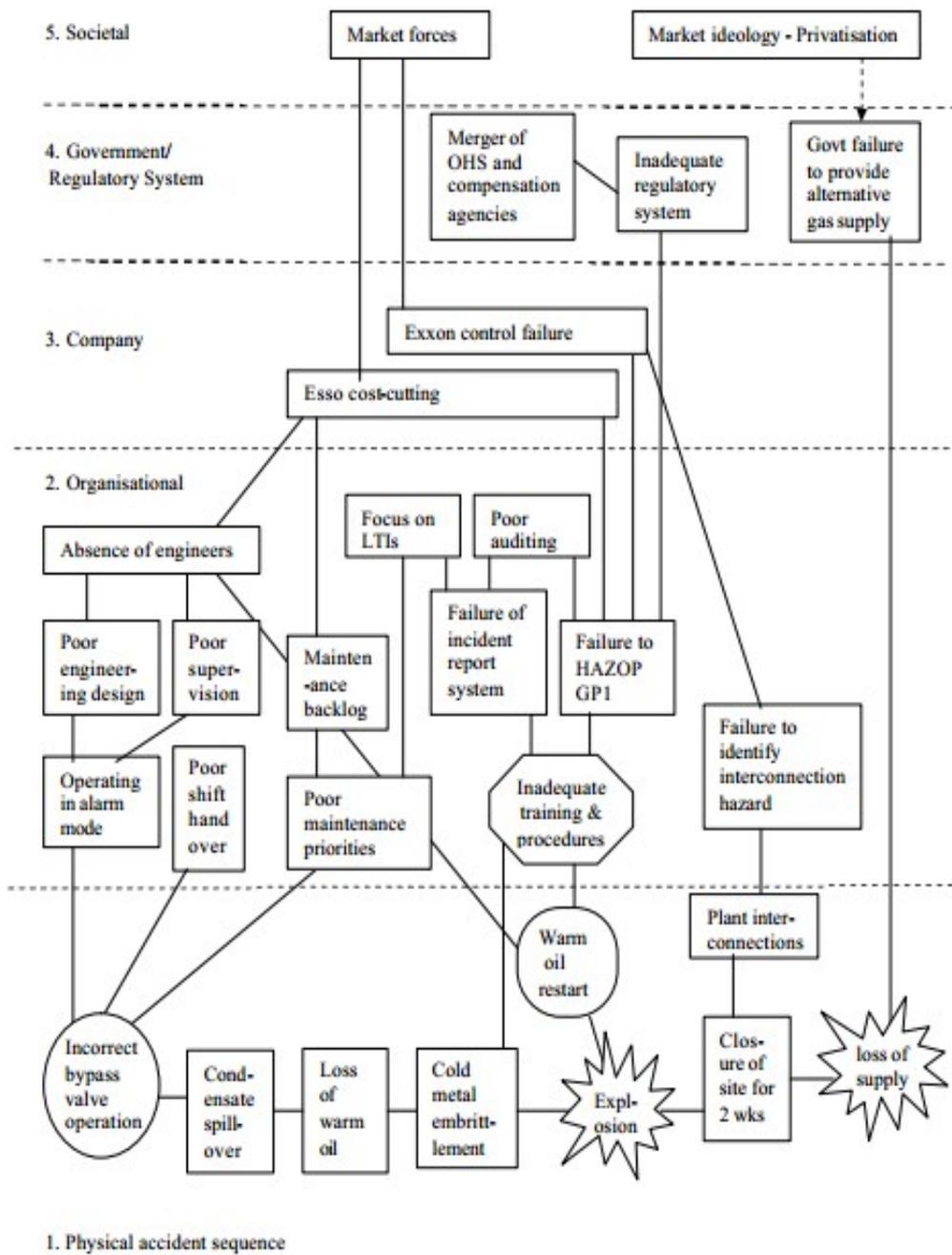


Figure 18: AcciMap of Longford Esso Plant Incident (Hopkins 2000)

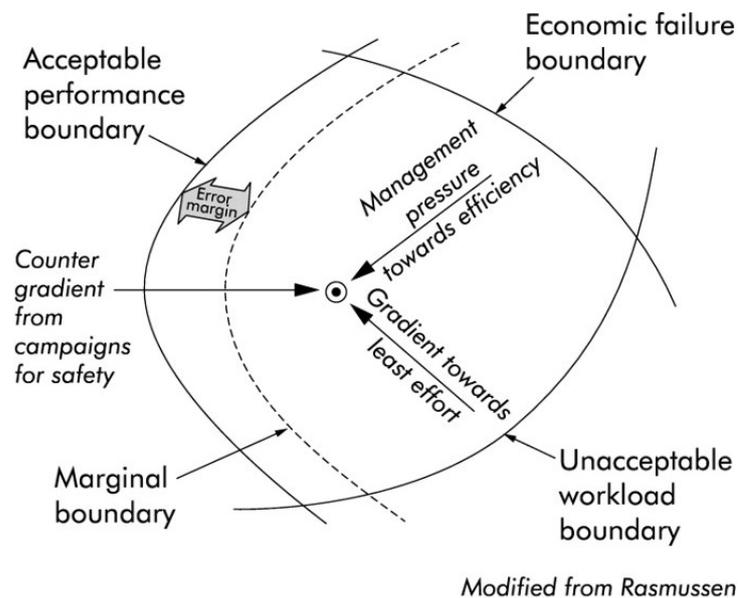


Figure 19: Dynamic Forces and System Behaviour (Hill and Jones 2001)

2.5.3.3 Systemic Integration

Rather than focusing on hazards or events as triggers of industrial incidents, Systems-Theoretic Accident Modelling and Processes (STAMP) provides a framework for understanding the role played by controls and constraints within an operating system. It is a model that combines multiple factors of risk - technical, organisational, social - with its theoretical roots in system and control theory (Leveson 2004). As a result of the complex interactions among these factors, significant levels of protection and redundancy design are built into a modern, socio-technical system. STAMP suggests that incidents are neither the result of independent component failures, nor a series of flawed events. Instead, they are caused by ineffective control over the entire lifecycle, from development and design to the eventual operation of the system. It integrates the principles of Rasmussen's (1997) socio-technical system, control process and System Dynamics, i.e., "Safety then can be viewed as a control problem, and safety is

managed by a control structure embedded in an adaptive socio-technical system” (Leveson, 2004: 250).

Models such as FRAM and STAMP not only recognise the challenges of managing inter-connected parts in a highly integrated socio-technical environment, but they are able to integrate with cross-disciplinary approaches such as NAT, business processes and system, risk assessment, system safety, process engineering, resilience engineering and SD to provide better insight into the causation of complex events.

2.6 Assessment of the Mainstream Causation Models

Incident causation models provide the basis for: (1) investigating and analysing the causes of incidents; (2) assessing the systemic risks for potential incidents; and (3) developing preventive strategies. Therefore, a good model needs to be able to capture the complex organisational inter-relationships and interfaces in today’s socio-technical environment. For wider acceptance and application, it should possess a strong visual representation, and require the understanding of a manageable list of other inter-related concepts. The most important quality of a good model is its ability to be applied to real world cases in order to generate preventive strategies for the reduction of incidents. Following sections discuss about the strengths and weaknesses of the various causation models mentioned in this research (see Table 2.1).

2.6.1 Strengths and Weaknesses in Sequential Causation Models

Traditional accident causation models, such as Heinrich’s Domino Theory, that use a chain of events are suitable for simple incidents and those caused by faults traced to physical components. One of the greatest strengths of these sequential models is their easy-to-understand and strong visual representations of the causation chain. Due to their generally simplistic, straight, chain-like

relationship, rarely are there underpinning theories or principles that are required for the application of these models. Therefore, they are easily accessible to a wider audience who do not need to possess expert knowledge in other disciplines.

The deterministic assumption about the causality of factors is a major weakness of sequential models when applied in a complex system where these factors are not necessarily well defined. Unsafe acts and/or unsafe conditions are narrowly focused in Heinrich's model, while other sequential models (e.g. the Bird and Loftus model) do not clearly explain how sequential factors, other than human causes, interact to contribute to incidents. Furthermore, important social and organisational factors, such as management's commitment and the safety culture of an organisation, are difficult to fit into the sequential causation models (Leveson 2004).

Other sequential models, like the logic tree models (e.g. ETA, FTA, MORT) provide a structured approach in organising events and displaying information in a logical graphic or flow chart. They are governed by a comprehensive list of symbols, codes and rules (e.g. MORT consists of 1,500 pre-defined items), which work well for clearly defined systems and processes. Another advantage of the logic tree models is their ability to apply probability assessments on varying levels of design details, which provides a more quantifiable and objective approach to decision-making.

Nonetheless, developing these models requires a thorough understanding of the system design and the anticipated operating pathways at the component level. Each pathway has narrowly defined decision options (e.g. 'success' or 'failure') and Boolean operators (e.g. 'AND' or 'OR') to determine the causality of other pathways. Only one undesirable condition or event can be addressed at any one time, i.e., multiple trees are needed for multiple events. Thus, logic tree models are not only rigid in their approaches, which do not reflect the dynamic nature of

the operating environment, but they can also be time-consuming to construct. Some level of practical training and relevant experience are required for the analyst to competently apply these models and to identify all hazardous energy sources.

Less technically demanding, but just as graphically oriented, MES and STEP models provide a structured method to identify the factors (combination of actors and their associated actions) that contribute to different events. This approach allows for the one-to-many and many-to-one relationships of the events to be investigated in a chronological diagram that shows their connections. These are major advantages over FTA, ETA and MORT models that do not show the “actors” and ordering of events. Despite the attempt to show the multiple contributing factors leading to incidents, MES and STEP as their names imply, are not able to capture the non-linear causality and dynamic nature of a complex system (Qureshi 2008).

Non-systemic models are limited in capturing the dynamic interactions and non-linear relationships between causation factors. Also, they are not able to cope with highly complex and technological service sectors and industries, such as nuclear energy, defence and aerospace, maritime, air traffic control, telecommunications, chemical and petroleum industries and healthcare. Incidents resulting from these highly complex systems have more than a single component failure and/or human error, the impact of which would be difficult to determine in isolation from the whole system. Therefore, incident preventive strategies from these sequential causation models are not adequate to address complex socio-technical systems.

2.6.2 Strengths and Weaknesses in Epidemiological Causation Models

The introduction of the epidemiological models helped to explain the causal relationships beyond the simple chain-event causation found in the sequential models. Essentially, incidents are viewed within the context of a causal network of factors including the host, agent and environment. Graphical representation of these factors allows for easy visualisation of their relationships, though multiple factors may complicate the clean host-environment-agent model. Established links between the incident and the causal energy source became a theoretical basis for preventive strategies and policy decisions (Gibson 1961; Haddon 1963, 1973, 1980). Such translation from research to practice is not uncommon for the epidemiological approach to disease prevention, health and well-being, which has a pedigree of well-cited publications in medical and public health research (Arthur 2000; Tong, Schirnding, and Prapamontol 2000; Frazer and Brown 2014; Ministry of Economy Trade and Industry 2014; Standards Australia 2014).

In adapting the epidemiologic triangle (Dicker 2008; Peller, LaPlante, and Shaffer 2008; Friis 2010), originally used to investigate the incidence of diseases and addictions, it is necessary to consider the susceptibility of persons (hosts) and hazardous conditions (environment) that are associated with certain types of incident before preventive measures can be recommended. Characteristics of both the people and the workplace in the host-environment-agent epidemiological model are easy to identify, but identification of the agent is not as simple. In the model's application within the medical discipline, the agent is clearly defined as either a unique virus or bacteria, or some biological unit. With intimate knowledge of the agent, the investigator then can deduce its potential impact upon the host and environment. However, in a complex socio-technical system, incident causation factors are seldom that evident. Therefore, in the absence of a theoretical framework for classification of accident types, the application of the epidemiological model for incident causation studies across industries may be limited.

The rise of complex socio-technical environment has also seen a noticeable integration of human factors in more holistic models, where they are viewed from a complex socio-technical perspective. These human factors at the 'sharp end' of the causation pyramid can interact with latent failures to cause incidents. However, without a clearly defined set of 'symptoms' to predict incidents, arbitrarily identified latent failures have little value in preventing undesirable events (Reason 1993).

Although epidemiological models have moved away from the few rigidly defined causation factors of the sequential models to consider other factors relating to the environment and people, they still reflect the characteristics of sequential models in that the causation factors are presented linearly (Hollnagel 2004). Despite the more sophisticated representation of causes, compared to the sequential causation models, epidemiological models are inadequate to explain the causes behind complex socio-technical systems.

2.6.3 Strengths and Weaknesses of the Systemic Causation Models

Modern complex systems consist of inter-relationships between the technical, human, social and organisational factors found within them. Instead of taking the reductionist approach by breaking down such a complex system into its individual components, it is crucial to examine the dynamic network of factors at play. Hence, there is an increasing recognition of the multiple paradigm nature of incident causation research. Indeed, many contemporary studies have called for a cross-disciplinary research approach in order to capture the complexity of today's socio-technical systems (Vaughan 1999; Moray 2000; Saleh et al. 2010; Pink et al. 2016). From this holistic perspective, the systemic model provides the benefit of examining incident factors within their socio-technical context, emphasising the functional characteristics of a complex system. Nevertheless, contributing factors, such as political, social, economic, technical and legal,

which are external to the organisations, have not been well understood in causation research. Additionally, there is a lack of management system approach to understanding the contributing factors within organisations.

To apply systemic causation models such as STAMP and SD requires a good understanding of the fundamental concepts of constraints, hierarchical levels of control, and process and systems thinking (Leveson 2004). The dynamic and non-linear causation factors in some systemic models are difficult to capture in the usual two-dimensional diagram. Even if it can be achieved, the resulting complex web of inter-relationships is most likely going to be counter-productive for retaining a holistic view of the system, and unlikely to be at a level which the mind can process. Since these models are developed by system and computer scientists (e.g. Jay Forrester and Nancy Leveson), they are not easily accessible to beginners or an audience coming from non-technical or non-engineering backgrounds. Furthermore, developing these systemic models can be time-consuming and often requires significant expertise in the use of specialised computer simulation software. The resource-intensive nature of implementing these models means that they face difficulty in gaining wide application in the real world environment.

From the review of the social and organisational contributions of theories such as Man-Made Disasters, Normal Accident and High Reliability Organisations (HROs), it was found that the focus on high consequence and low likelihood industrial incidents like Piper Alpha, Bhopal and Chernobyl have, in fact, hampered understanding of accident causation and system safety (Saleh et al. 2010). Since many incidents share the same combination of regulatory, organisational and technical failings, there exist fundamental limitations in the current understanding of accident causation and system safety. Various stakeholders, for example, regulators, shareholders, company management, operational staff and research staff, possess different levels of influence in safety performance, called 'safety levers', and they require different timeframes

to impact system safety. The emerging theme from the system safety research is the recognition of these incidents as a safety ‘control problem,’ and a system approach is needed to address them (Leveson 2011).

Table 2.1: Summary of Strengths and Weaknesses of Causation Models

Models	Strengths	Weaknesses
Sequential		
Heinrich Domino, Bird and Loftus	Easy to understand causation chain without a need for in-depth knowledge of underpinning theories. More accessible to a wider audience.	Too simplistic and not adequate in explaining interrelated, underlying contributing factors such as social, workplace and management factors in complex organisations.
FTA, ETA, FMEA, MORT	Easy to understand causation chain for more technical application, which can provide both qualitative and quantitative data for risk analysis of component or event level failure. MORT provides additional consideration of management factors that could contribute to incidents.	Most event type causation do not account well for human factor causes. These models may require detailed knowledge of the design, construction and operation of the system. They can be very large and complex and time consuming to apply. Commercial software may be needed to apply these models.

Models	Strengths	Weaknesses
MES, STEP	Systematic process for investigating and analyzing a wide range of desired and undesired processes before or after they happen. It is useful for displaying the relationship between the actors on a time basis.	Procedures may require detailed knowledge of the design, construction and operation of the system. They can be very large and complex and time consuming to apply. Commercial software may be needed to apply these models.
Epidemiological		
Gordon, Haddon, Dicker, Peller, LaPlante, Shaffer, Friis	Easy to understand epidemiological triangle. Broader scope than that of the sequential models to include host, agent and environment. Useful applications in the medical discipline where “agent” can be clearly identified.	May not be as easy to identify contributing factors in complex socio-technical system. Lack of a theoretical framework for a broad-based industry application. Still possess the linear causation characteristics.
Reason	Easy to understand with wide industry acceptance. Improved understanding of the active-latent concept not found in other causation models.	Still possess the linear causation characteristics.

Models	Strengths	Weaknesses
Systemic		
MND, NAT, HRO	They apply multi-disciplinary approach to understanding incidents. These models acknowledge the failures of interactions between workers and organisations operating in complex socio-technical systems beyond their simple linear causation. And to a certain extent the inevitability of a highly complex and tightly coupled system. The preoccupation with failures is one way of preventing incidents.	They lack a strong application framework and helpful guidelines for a consistent outcome.
AcciMap (Rasmussen)	Comprehensive coverage of multiple causes, including remote in a system by arranging them in a logical causal diagram. Also, high level factors such as social and government not usually found in other models can be investigated in this model.	The lack of the ability to visualise the non-linear relationship between contributing factors is one of the limitations of this model.

Models	Strengths	Weaknesses
FRAM	It looks beyond recognising the potential points of failures in a complex system by examining the underlying performance variability found in the functional inter-relationships. Focuses on the dynamic and non-linear interaction within a system. Rather than viewing safety from an adverse perspective, it provides opportunity to increase organisational resilience.	Require a throughout knowledge of the various organisational functions and possible variances of those functions in different operating conditions. Time consuming and process can be complex and difficult to understand. Software tools are often required.
STAMP	Promotes better understanding of how inadequate controls such as poor enforcement of safety-related constraints on the design, development, and operation of the system could lead to undesirable events. Systems are consisted of interrelated components kept in a state of dynamic equilibrium by feedback loops of information and control.	Users need to have a strong understanding of the fundamental concepts of constraints, hierarchical levels of control, and process and systems thinking. Visual representation can be complex and difficult to understand.

2.7 Qualitative Modelling of Complex Systems

It is not a mystery that mental models are often used to explain our surroundings and events (Anderson 2000). However, there is a cognitive limit to fully comprehend the underlying structures and dynamic behaviours of complex systems (Forrestor 1971; Moxnes 2004; Sweeney and Sterman 2007). Therefore, the development of qualitative models is necessary to overcome limitations in mental models.

The assessment of various causation models (Section 2.6) has shown that it is inadequate to use simplistic, linear, chain-of-events approach to present complex organisational system (Svedung and Rasmussen 2002; Marais, Dulac, and Leveson 2004; Coze 2005). Therefore, systems approach with its emphasis of examining the complex socio-environment as a whole, rather than the sum of its discrete parts, is appropriate for the purpose of this study. There have been studies using systems approach to the investigation of complex incidents, but not enough is done in the area of EIPE (Cooke 2003; Leveson 2004; Salge and Milling 2006; Minami and Madnick 2009; Goh, Brown, and Spickett 2010).

Since a major focus of the research is on better understanding the behaviours, motivations, trends and other intangible characteristics of EIPE, model quantification using computer simulation to determine precise relationships such as mathematical equations among variables would neither be possible, nor appropriate (Stake 2005; Corbin and Strauss 2008). Other challenges concerning model quantification include making assumptions and assigning values for the model parameters, which require substantial resources (Coyle 2000, 2002). Moreover, the results based on wrong assumptions could invalidate a quantitative model and lead to the implementation of ineffective policies. Therefore, overly complex models that require a high degree of technical knowledge or domain expertise may deter their widespread and useful application in the industry (Box 1976).

Some may argue that structure-linked behaviours or dynamic behaviours cannot be adequately appreciated without simulation (Wolstenholme and Coyle 1983; Wolstenholme 1985; Wolstenholme 1999; Homer and Oliva 2001), but studies have shown that qualitative models can yield useful insights without going through formal mathematical simulations (Goh, Brown, and Spickett 2010; Goh et al. 2010).

Besides the CLD and SFD, influence and pair-blended diagrams are also valuable qualitative modelling tools used to present an overview of complex systems (Goh et al. 2012). They help to guide this research, identify existing knowledge gaps and provide a platform for qualitative model development. Influence diagram is a broadly used term to indicate any visual representation of causal relationships in a system, which CLD can be considered a type of influence diagram (Howard and Matheson 2005; Robinson 2015). For the purpose of this study, influence diagrams are CLDs without their associated polarities and arrow directions. They simply represent the causal connections between components in a system. Essentially, high level conceptual models do not necessarily have assigned polarities, because the links can represent a range of variables which may not have the same polarity (Proust et al. 2012). A pair-blended diagram is the result of the collaborative effort of combining two individual influence diagrams (Newell and Proust 2012; Brown et al. 2013).

Through a collaborative modelling approach, the engagement with various stakeholders holding different perspectives, individual influence diagrams could be examined and synthesised into pair-blended diagrams and more complex CLD and SFD (Newell and Proust 2009, 2012). More importantly, the active engagement of multiple stakeholders across disciplines to draw on the wealth of experience from professionals and practitioners, in order to provide a shared mental model of a system, is important in understanding an interconnected

complex system (Andersen et al. 2007b; Visser 2007; Oyo, Williams, and Barendsen 2009; Stave 2010; Michaud 2012).

2.8 Conclusions

Causation models enable the careful examination of past industrial incidents, so that similar events in the future can be estimated and, hopefully, can be prevented. Nonetheless, possessing knowledge of past occurrences or hindsight does not mean that future events can always be accurately predicted. The fact that industrial incidents continue to occur, despite the long history of incident causation research and development, shows the need for a better framework to develop qualitative models that can be used to design more effective preventive strategies.

Despite the prevalence of incident research, there remains a struggle for better understanding of the causative nature of industrial events (Underwood and Waterson 2013; Henriqson et al. 2014; Underwood and Waterson 2014; Dekker and Pitzer 2016; Salmon, Walker, and Stanton 2016; Salom et al. 2016). Part of the challenge is due to the complex interactive nature of organisational systems, which not only interact among their interconnected components, but also externally with their environments (Katz and Khan 1966; Buckley 1967; Lawrence and Lorsch 1967; Thompson 1967; Aldrich 1979; Scott 1981).

Although the application of an HSEMS based on the quality approach to continual improvement (Deming 1982; Aguayo 1990) provides evidence of higher HSE performance, it is still susceptible to competing, interrelated forces within the organisations that can contribute to control failures and industrial incidents. Therefore, it is important to identify these “driving forces” and to implement strategic intervention for maximum effectiveness in changing the long term behaviour of a system (Meadows 2016).

Findings from the literature review suggest that the causation models most appropriate in gaining better understanding of EIPEs causes are those that are holistic and systemic in scope, where the inter-relationships of such causes are non-linear in nature and the indirect contributing factors can be traced to both internal and external organisational factors. Diagrammatic tools such as CLD, SFD, influence and pair-blended diagrams can be used to collaboratively develop a shared mental model of a complex system (Newell and Proust 2009; Brown et al. 2013; Robinson 2015). Nevertheless, there is a need to address gaps identified in the literature, in order to further build on the systemic models that can be used to prevent EIPEs. Strategies that will be used to address those gaps in the literature are detailed in Chapter 3.

The following chapter provides a summary of the gaps in the current body of knowledge and highlights where these gaps are addressed in various chapters throughout the research.

Chapter 3

CASE FOR RESEARCH

3.1 Introduction

As was illustrated in Chapter 2, a number of gaps in the current theory and practice have been identified in the literature review. These gaps are summarised below. This chapter addresses the key challenges within incident causation research that could make a positive contribution in the prevention of EIPEs. These challenges will be used to develop, demonstrate and validate the methodologies in order to fill the research gaps identified. The research aim and objectives arise from the current state of knowledge in incident causation development and from the gaps identified in the theory and practices therein.

3.2 Summary of Gaps in the Literature

The key gaps identified in the research literature are listed below:

- Organisations rely heavily on a framework of processes and procedures to run their business activities, yet there is a lack of management system approaches to understanding the contributing factors within organisations.
- Factors external to the organisations, and their contribution to industrial events, are important features that are not well understood in incident research.
- Most of the research data is derived from high profile IPEs, but few studies have examined EIPEs.

- Recent systemic models requiring specialised technical knowledge have become unnecessary barriers for their widespread application in the industrial setting.

Despite the long history of the quality management movement and the widespread QMS certification of organisations around the world, there has been a lack of incident studies applying the perspective of management systems. As a result, this research will apply the internationally recognised HSE Management System Standard ISO 18000, which is based on the fundamentals of PDCA. This will facilitate the development of a conceptual framework for gaining a better understanding of the behavioural dynamics within an organisational system. This conceptual framework is proposed in Chapter 5.

Most incident research has viewed events from the perspectives of individual, technological, organisational or social factors, or a combination of these perspectives. However, there has not been a clear framework for capturing those contributing factors that are external to the organisations. Since organisational activities are affected by their external business environments, which can indirectly impact upon an organisation's ability to manage its HSE risks, it is therefore significant to understand their contribution to such industrial incidents. The same conceptual framework was used in Chapter 5 to incorporate this well-established macro business environment analysis tool as the framework for the external organisational factors.

Given the widespread health, safety and environmental consequences of EIPEs, there have been comparatively less studies on their systemic causes than those of IPEs. Therefore, this research will examine data found in purposefully selected EIPE case studies. The proposed conceptual framework in Chapter 5 will be applied to individual EIPE cases, as detailed in Chapters 6, 7 and 8. In these chapters, the Systems Dynamic tools such as Causal Loop Diagrams (CLD) and Stock Flow Diagrams (SFD) will also be used to create a visual

representation of the systemic behaviours in these case studies. Although these EIPes represent some of the worst industrial incidents in history, the author has not found any literature where such systemic tools have been applied to gain more valuable insights into their causes. A cross-case comparison of the external and internal contributing factors is detailed in Chapter 9.

While recent systemic models have avoided the weaknesses seen in linear and event-driven approaches to understanding complex industrial incidents, they have also become more technically demanding in their application. Some studies have developed quantitative models using computer simulation, but uncertain assumptions, questionable model parameters and high levels of complexity have prevented their widespread application. As a result, there remains a considerable research-to-application gap for such models within the industrial setting. To minimise these gaps, this research formed a Focus Group of experts to evaluate the systemic approach to EIPes, which is detailed in Chapter 10. Key findings and results from the research are discussed, with recommendation for EIPE preventive strategies in Chapters 11 and 12. The thesis concludes with a summary of the results, current contributions and proposals for future works in Chapter 13.

In summary, this thesis will:

- develop a conceptual framework that is based on the findings from the literature review to gain valuable insights into EIPes;
- incorporate well-established HSE Management Systems and macro business analysis methodologies into the causation research;
- apply a systems approach in the analysis of complex behaviours associated with selected EIPes;
- form a Focus Group to evaluate the conceptual framework and findings from the EIPes;

- develop qualitative models and preventive strategies based on key findings and results from the research; and
- discuss the potential applications of the research and future works.

Chapter 4

RESEARCH DESIGN AND METHODS

4.1 Introduction

This chapter presents the research methodology for this study. Although there has been much research undertaken using the case study approach for industrial incidents with sudden releases of energy, such as those highlighted in the earlier chapter, limited studies have been carried out on EIPEs. Therefore, the philosophy underpinning this research methodology is along the lines of other incident causation studies. Additionally, the richness and complexity of the chosen EIPEs justify such an approach that allows for the analysis of a wide range of data. Combining this instrumental case study with a systemic framework for qualitative modelling, this process facilitates the development of an eventual model to be tested in future studies.

4.2 Design Overview

The main aim of this study is to investigate the systemic factors contributing to EIPEs and to develop preventive strategies to reduce the likelihood of their reoccurrences.

The design for this study consists of three major parts, which address the research objectives as stated in Chapter 1 (see Figure 20):

- Part I (Chapters 1 to 4): Background
- Part II (Chapters 5 to 9): EIPE Case Studies
- Part III (Chapters 10 to 12): EIPE Evaluation and Preventative Strategies Development

The first part presents the significance of this research, including a statement of the aim and objectives. Also, it reviews the existing literature on the organisational system, OHSMS, incident causation and qualitative modelling of organisational system. It highlights areas where this research can further contribute to the body of knowledge. Consequently, this foundational understanding facilitates the development of a methodology for the research.

The second part of the research provides a conceptual framework that is applied to purposefully selected EIPE case studies. These case studies include the use of Casual Loop and Stock Flow Diagrams to explain complex behaviours and systems concepts (see Figure 6). Additionally, a cross-case comparison of the external and internal contributing factors is carried out to examine the similarities and differences between the case studies (Eisenhardt 1989b; Yin 2003).

The third part of the research evaluates the conceptual framework and findings of the EIPE case studies, in order to gain a better understanding of the contributing factors for their occurrences. Findings from the Focus Group of industry and academic professionals are presented and discussed, with references made to earlier EIPE case studies (Morgan 1997). This evaluation, together with evidence from the case studies, leads to the development of EIPE qualitative models and recommendations for preventive strategies. The conclusion of the thesis summarises its contributions and proposes future works.

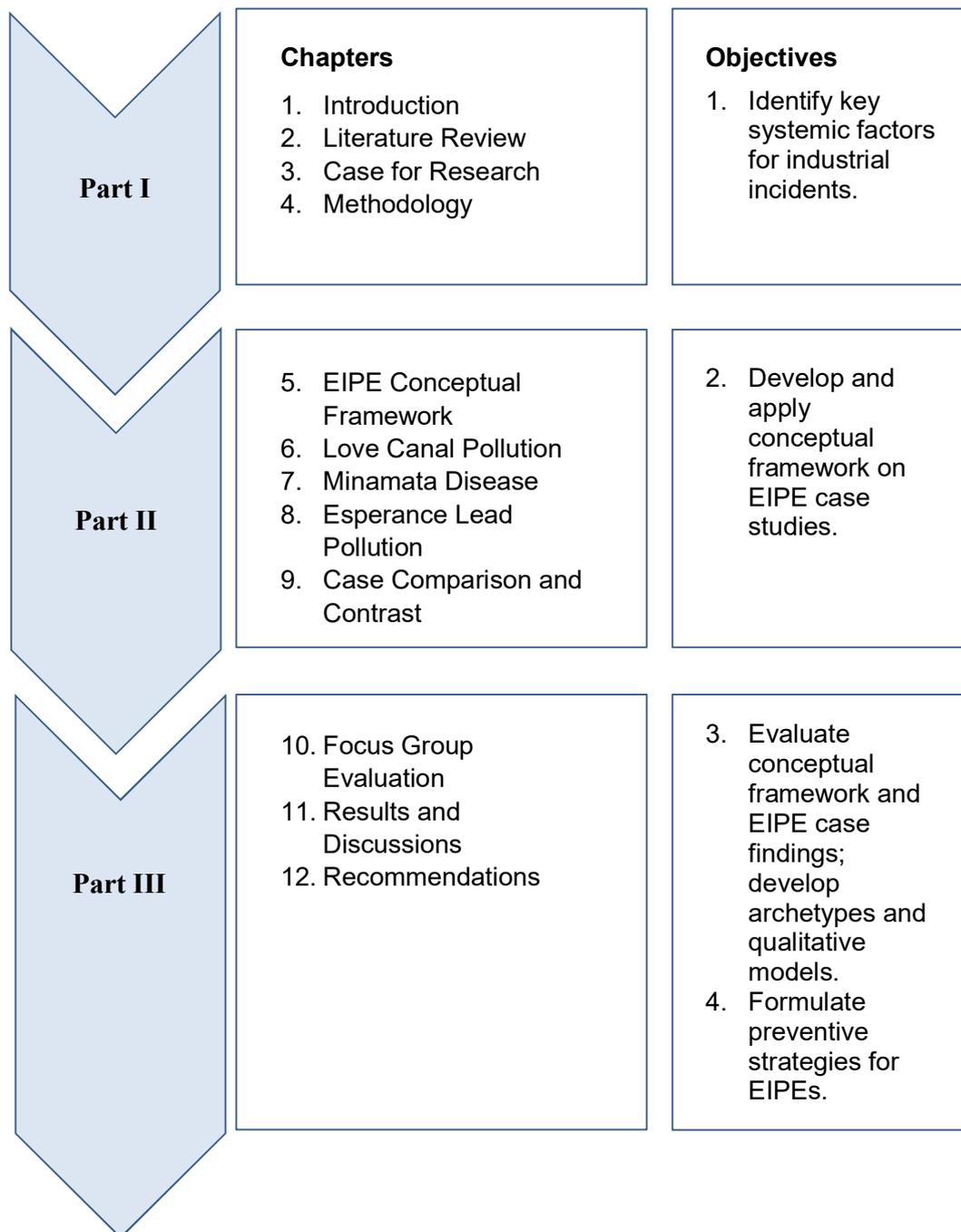


Figure 20: Research Design

4.3 Ethics

An application for 'Approval of Research with Low Risk (Ethical Requirements)' was made and approved by the Human Research Ethics Committee at Curtin University (SPH-14-2011).

4.4 Data Sources and Collection

Data collection in this study was guided by the research objectives, concepts and models. Main sources of data were documents that are accessible in the public domain. These included government documents, inquiry/parliamentary reports, organisational documents, annual reports, official websites and newspaper accounts (Mack et al. 2005). Additionally, books and journal articles about the selected cases, from popular multi-disciplinary databases such as Web of Knowledge, Science Direct and Scopus, were used in this study. Practical considerations about the authenticity, availability and objectivity of the documents were taken into account.

Usually such documents were the only means of studying the selected EIPes, because historical events could no longer be observed, or participants would no longer be available for interview, or organisational structures had changed since the occurrences of incidents. Therefore, the common approaches to qualitative data collection using interviews and survey questionnaires were not feasible for these case studies. In such circumstances, documentary sources of data are better and more valuable than those of observations or interviews. Moreover, evidence produced during public inquiries was especially useful because the rigorous and resource-intensive nature of such official investigations would have been beyond the scope of any individual researcher's efforts (Turner 1976; Hopkins 2006). For instance, public inquiry into the Piper Alpha disaster allowed for access to a team of lawyers, professionals and experts from a wide range of disciplines (Cullen 2007). In contrast to interviews and observations, the unobtrusive nature of the documentary data makes it immune to the research

process and likelihood of bias; thus, it enhances the validity and reliability of the findings (Webb et al. 2000).

Since the research was concerned with factors contributing to the EIPEs, data on the consequences or aftermath of the events (e.g. extent of HSE impact, liability payout by polluting organisations) was reviewed but not examined in great detail. This approach aligns with the objectives and scope of the research, which focuses on the inter-relationships of causal factors that exist in complex systems.

Another source of data came from the Focus Group activities where discussions were captured in visual diagrams and tables (see Appendix E, Appendix F and Appendix G). It is an adapted Focus Group approach using pair-blended and group discussions to providing greater insight to EIPE (Newell and Proust 2012; Brown et al. 2013). The methodology of the Focus Group such as the selection of participants and types of activities are described in more detail in Section 4.5.3.1.

4.5 Research Methods

This research utilises the combination of a qualitative case study approach (Stake 2000; Yin 2003) with systems methodology (Sterman 2000). Both were used to conduct a holistic examination of the factors contributing to EIPEs. Such approaches are the most appropriate for this research, where the emphasis is on examining and interpreting the complex organisational behaviours. Selected EIPEs were analysed using the case study method due to their case-based nature and the amount of textual data involved (Takizawa 2000; Harrison and Legendre 2003; Whyte 2006). Stake (2000) classifies case studies as either intrinsic case studies, where the case is of primary interest or instrumental case studies, where the case is of secondary interest and is merely used to gain a general understanding of a phenomenon. In this research, the selected

instrumental case studies are used to facilitate a better understanding of the systemic causes of EIPEs. The works of Goh et al. (2010), Hopkins (1999) and Hynes and Prasad (1997) are some examples of instrumental case studies on industrial pollution events.

One of the major strengths of the qualitative case study method is its flexibility in integrating several information sources, which allows for the emergence of new inferences. Other benefits include the acquisition of a large amount of contextual data, the facilitation of data analysis, the provision of a background context to events and the discovery of nuances in various organisational settings. Complementary to the qualitative case study method is the systemic analysis of the dynamic interconnections in complex systems, which provides valuable insights into the interrelationships of factors contributing to EIPEs (Forrester 1994b).

Instead of achieving statistical generalisation to a population, Flyvbjerg (2006) and Yin (2003) suggest the case study as a strategy to achieve analytical generalisation to a theory. Like experiments, case studies are not meant to achieve representation of a population, but each case study can be seen as an experiment to test a pre-conceived theory, or 'theory testing,' and can allow modification of the theory, or 'theory building' (Layder 1993). Besides the generation of theory, other types of non-statistical generalisation include concept development, implications highlighting and insight generation (Walsham 1995). Such an approach is especially applicable in studies of EIPEs, because these incidents are relatively rare and each case will involve a significant amount of textual data, which makes detailed analysis of a large number of cases impractical.

Rather than attempting to generalise findings from case studies, the comparison of multiple cases (Miles and Huberman 1994; Miles, Huberman, and Saldana 2014), i.e. three purposively selected EIPEs, was conducted to provide more insights into the causes, both within each setting and across all three settings.

4.5.1 Part 1 - Background

4.5.1.1 Key Literature Review

This chapter examines the key components and characteristics of an organisational system. It looks at the complex nature of an organisation that is affected not only by its internal factors, but also its external factors of Political, Legal, Economic, Technological and Social (PLETS). Residing within the organisation is the HSEMS that organisations use to manage its HSE risks while carrying out its business activities. Organisational behaviours include complex interactions, failures of controls, conflicting interests and feedback loops, which cannot be easily explained using traditional incident causation models. Furthermore, the qualitative modelling approach used for this study is included in this literature review.

A review of the mainstream incident causation literature provided a theoretical base for this study and how it is related to the current body of knowledge. From the literature review, a plethora of conceptual models was categorised as "Sequential," "Epidemiological" or "Systemic," which also represented the progression in complexity of the causation models from an initially linear form to the recent more systemic approach. Within each category, characteristics and major themes of these causation models were identified. The strengths and weaknesses of these predominant models were discussed and summarised (see Table 2.1). More significantly, major themes such as the types of scope, contributing factors and their inter-relationships from the findings of the literature review emerged and formed the basis for establishing the key systemic factors.

Using the major themes found in the literature review, a classification scheme based on the principles found in the business environment survey PLETS and the HSEMS Standard was introduced (see Section 2.2 and Section 2.3). The business assessment tool and management system standard were selected because they reflected the research objectives and the context in which the case studies were examined. These were classified as the external and internal organisational factors, respectively (Figure 29). The application of this classification scheme on selected EIPEs during the process of data analysis helped to facilitate the coding of relevant data.

4.5.1.2 Definition of an EIPE

This research consists of multiple case studies, where each case study uses a common method to examine complex systemic factors contributing to its EIPE (see Appendix A). To increase the reliability of the findings, three well-documented EIPEs – Esperance Lead Pollution in Australia, Love Canal Disaster in the US and Minamata Disease in Japan - were selected to enable subsequent cross-case comparison and analysis (Department of Local Government and Regional Development 2007; Magellan Metals 2007). These EIPEs from different countries were selected to provide a platform for examination of key systemic factors across different geographic boundaries and national jurisdictions, while satisfying the selection criteria listed below (e.g., nature of exposure, impact of exposure). Another reason for their selection was the fact that these countries – the US, Japan and Australia - were among the largest economies with high resource use and impacts upon public health and the environment.

These cases were chosen based on the following sampling attributes as suggested by Miles and Huberman's (2007).

- Sources of pollution – The point source of emission could be traced to specific industrial activities, such as a manufacturing facility. In contrast, non-point sources involve pollution that is not possible to confine, such as household emissions. For instance, the human-to-human transmission of infectious disease or pandemic will not fall under this criterion.
- Nature of pollution – The EIPes involved protracted community and environmental exposures to harmful substances (e.g. toxic waste) from industrial sources due to the failure of controls to prevent them.
- Impact of pollution - The exposures had significant community impacts beyond the perimeter of the immediate industrial operations. At least two or more members of the public were exposed to harmful substances.
- Role of regulator and government agencies - Comprehensive investigation by the national regulatory framework had been undertaken, allowing the effectiveness of enforcement actions to be assessed.
- Role of organisation - Comprehensive investigation of management actions and other organisational factors (e.g. production over safety) would be possible.
- Role of community - Comprehensive investigation of community engagement would be possible and informal safety, health and environmental compliance pressures from the community were evident.

Unlike the three EIPes mentioned above, most of the high-profile, well-researched industrial disasters were caused by discrete occurrences, which involved the sudden release of uncontrolled energy sources resulting in

widespread damage. Examples of these incidents include the nuclear disasters at Three Mile Island in 1979 and Chernobyl in 1986; the explosions of Piper Alpha in 1988, Esso Longford in 1998, the Texas City Refinery in 2005 and BP Deep Horizon in 2010; and the large scale gas leaks at Seveso, Italy, in 1976 and at Bhopal in 1984.

4.5.2 Part II – EIPE Case Studies

4.5.2.1 Conceptual Framework for EIPEs

Findings from the literature review in Chapter 2 form the basis for a proposed conceptual framework to convey the fundamental principles and structure for an EIPE (see Figure 29). Rather than a mathematical model, this provides a platform for subsequent data organisation and case study analysis. The conceptual framework draws from across the disciplines of strategic business planning and HSE, by combining the key elements of an HSEMS and a macro business environment assessment. For this conceptual framework, the internationally recognised Standard of Occupational Health and Safety Assessment Series 18000 and variation of the PLETS business survey tool were used (Aguilar 1967; British Standards Institution 2007).

4.5.2.2 Data Organisation

Different levels of data analysis were applied to the selected EIPEs (Bryman 2012). The literature was reviewed for major themes, unusual issues and events. They included organisational behaviour, government policies, historical background and other obvious themes unique to each case study.

Subsequently, data was re-examined and broken down into more manageable components. Key words and phrases were highlighted and grouped into categories (Corbin and Strauss 2007). Data was categorised using the conceptual framework, which included external organisational factors (political,

legal, economic, technological and social) and internal organisational factors (policy/planning, implementation, checking/review).

To assist with the efficient management of a large database such as the parliamentary inquiry, specialised qualitative research software, NVivo version 9 (QSR, 2010), was used. However, for data such as books and documents in formats that could not be easily imported into NVivo without any loss in translation (e.g. typeface unrecognised by the image recognition feature of the software), coding had to be done manually or without the assistance of computer software. While such software might be useful in marking and coding data more efficiently, it could not determine meaningful themes and categories or interpret the data. Therefore, the researcher still had to determine the type of data to be included in the more appropriate categories.

4.5.2.3 System Tools

To view organisations and their external environments as systems made up of interacting parts, new tools were needed to explore these complex relationships. Hence, analysis of the data was further enhanced with the introduction of a System Dynamics tool such as CLDs and SFDs into this instrumental case study approach (Kim 1992; Forrester 2003). To provide further insights into the complex causal behaviours, various CLDs for both the external and internal organisational factors of each selected EIPE were developed. The cross-functional and strategic influences among the various factors were captured in easy-to-understand reinforcing and/or balancing feedback loops, including time lapses, to emphasise the circular and time-dependent nature of such complex relationships. Where applicable, generic causal loop models, also known as system archetypes, were used to depict common patterns of behaviour underlying complex systems (Marais, Saleh, and Leveson 2006).

4.5.2.4 Cross-Case Comparisons

The research objectives are best addressed through a compare-and-contrast approach. To enable the comparison of multiple cases (Stake 2005), in search of similarities and differences, cross-case analysis of the coded data and CLDs was conducted on these EIPEs. Each of the external (political, legal, economic, technological and social) and internal (policy, planning, implementation and checking/review) organisational factors was compared across the three selected EIPEs. Data was compiled in tables and diagrams to promote understanding of the dynamics, trends, patterns and inter-related factors (see Chapter 9). This cross-case analysis contributed to the identification of differences and commonalities found in both the external and internal systemic factors for the EIPEs. Also, a value judgment was included to determine the signification of these factors contributing to the EIPE. Findings from this contrast and comparison provided a platform for the eventual development of a qualitative model (Eisenhardt 1989b).

4.5.3 Part III – EIPE Evaluation and Preventive Strategies Development

EIPEs do not happen in isolation from a complex organisational system; changes in one part of the system impact on other parts of that system. Therefore, causal models need to reflect inter-relational and non-linear causation over time (Benner Jr 1984). Due to human constraints in understanding the underlying structures and dynamic behaviours of such complex systems, development of qualitative models is necessary to overcome limitations in mental models. Nevertheless, causal models can sometimes become too complicated, to the extent that they lose a more holistic perspective. Ideally, the level of complexity for these qualitative models should not reach the point of diminishing returns in understanding complex systems, as represented by the dashed line in Figure 21 (Roberts et al. 1983).

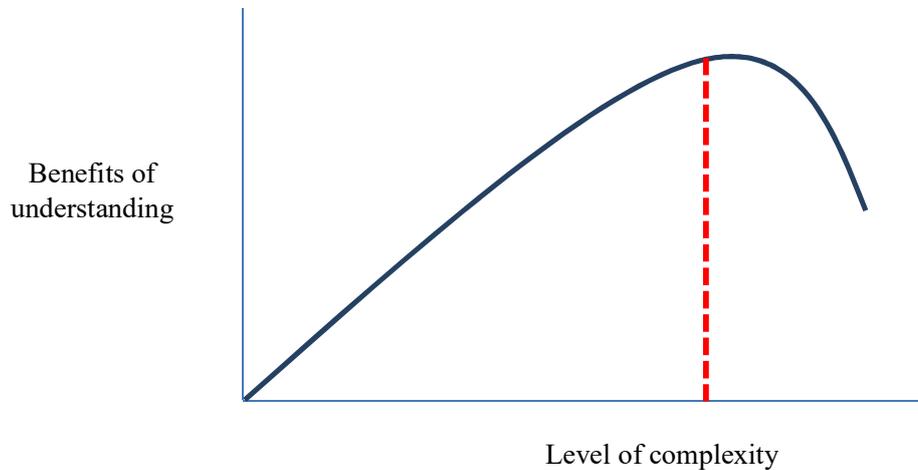


Figure 21: Relationship between Complexity and Understanding (adapted from Tainter 1988)

Most of the information needed for the development of a causal model is derived qualitatively, or is non-numerical in nature, and it is this main source of information that facilitates this modelling process (Forrester 1994a). Development of the qualitative model is an essential means by which the dynamics of the problem can be represented and from which insights can be generated. For policy-makers, the qualitative model helps to elicit the interdependency and latency of organisational factors, and to raise awareness of the consequences of policy decisions. More importantly, qualitative modelling may provide stakeholders with more confidence to support certain policy directions (Desthieux, Joerin, and Lebreton 2010).

Since the emphasis is on both learning, or 'modelling as learning' (Lane 1994), and the generation of insights into the non-linear behaviour produced by the complex systems, the value of adding quantified modelling to qualitative analysis may be limited. Therefore, instead of pursuing a mathematical simulation of a quantitative model, it is more beneficial to gain non-quantifiable insight from a Focus Group of experts in the field of EIPes (Kitzinger and Barbour 2001).

4.5.3.1 Focus Group Evaluation

The methodology and format of the Focus Group is explained in more detail in this section.

A Focus Group of experts was led in an open discussion by a skilled moderator (Morgan 1997). Here the term 'expert' refers to industry, academic or government professional who has involvement in the area of public health or industrial planning, development and operation. The Focus Group used here was an adaptation of the collaborative modelling approach to better understanding complex systems (Newell and Proust 2012; Brown et al. 2013).

To support the research aim (see Section 1.3), the following set of objectives for the Focus Groups were established:

- Identify key contributing factors linked to EIPE.
- Provide insight into the interaction between these contributing factors.
- Discuss possible strategies that can prevent the occurrence of EIPE and improve management of EIPE.

In order to maximise participation and allow each participant the opportunity to engage in rich discussion, a total of 8 experts from the industry association, government agencies and academic institutions were recruited (see Appendix H). Some of the targeted experts for recruitment were not able to participate in the Focus Group, because of work commitment or sensitivity to information that could have any references to the organisations they worked for.

A suitable location for carrying out the Focus Group activities was generously offered by one of the government departments. Other logistical requirements such as drinks, snacks, stationery, projector, activity plan and PowerPoint presentation were organised with the help of the facility provider.

A pre-reading information sheet on the purpose of the Focus Group and background information about EIPE was sent to the participants two weeks before they were involved in the Focus Group activities (see Appendix E). One week before the Focus Group activities, phone calls were made and emails sent to remind the recruited experts.

A set of four activities lasting for about half a day were designed to meet the above-mentioned objectives (see Appendix F). The duration of the Focus Group activities took into consideration the availability of time from professionals who had to return to their workplaces on that same day.

The research author facilitated the activities, which progressed from the development of individual ideas to paired and group insights of EIPE. Instructions for each activity were clearly explained to all the participants by the facilitator. Also, the same instructions were presented on the screen for the duration of the respective activities. During the Focus Group activities, the facilitator was available for questions and to provide necessary assistance in a way that would not influence the individual or group contributions. These discussions were captured using visualisation tools such as the individual influence and pair-blended diagrams (Newell and Proust 2012; Brown et al. 2013) (see Section 10.4).

The first activity (Exercise 1, Appendix F) was an individual effort of visualising an EIPE using influence diagram without feedback loops. After four pairs of experts had completed their pair-blended diagrams (Exercise 2, Appendix F), they were merged into two groups of fours. Each group of four experts then identified the top three external contributing factors and top three internal contributing factors, which were determined with point allocation for each factor (Exercise 3, Appendix F). These top factors were calculated and tabulated for further group discussion about possible strategies for EIPE prevention (Exercise 4, Appendix F). Furthermore, analysis of data from the Focus Group also

facilitated the comparison of findings from the case studies, which were discussed in more detail in Chapter 10.

4.5.3.2 Archetypes and Qualitative Models

Qualitative models are helpful in allowing us to visualise the interdependent relationships and circular nature of causal factors that exist in complex EIPes. These models consist of a combination of reinforcing and balancing loops, including the use of system archetypes to depict common patterns of behaviour underlying complex systems (Marais, Saleh, and Leveson 2006). Furthermore, these models can capture the dominant structure and time-delayed relationships among factors that shape the systemic behaviours, not only within an organisation, but also interacting externally with it. The common archetypes are described in more detail in Section 5.3.4.

The traditional formulation of models has largely been associated with creating mathematical models that eventually produce numerical results. However, as mentioned in the justification for the qualitative modelling (Section 2.7), it is not the intention of this study to convert the qualitative models into a computer simulation model, since precise inter-relationships among the intangible factors (e.g. HSE commitment or Safety Culture) in the system to be modelled may be difficult or impossible to determine. Also, the accumulated errors in attempts to quantify the contributing factors may become too gross to achieve any meaningful interpretation and application of the models.

4.5.3.3 Development of Strategies

Combining data from the case studies and the Focus Group, more comprehensive and holistic strategies for the prevention of EIPes were developed. Additionally, leverage points provided opportunities for stakeholders, where changes could be made to systemic behaviours that could mitigate the occurrences of EIPes (Meadows 1999).

Supporting these strategies for prevention of EIPE, a business planning guide was recommended to facilitate organisational discussion of possible HSE implications arising from certain business decisions and strategies (Table 12.1).

4.6 Conclusions

This chapter outlined a combined method of instrumental case studies, a systems approach and a Focus Group to collect and analyse data. Furthermore, the overall design and methods relate to the specific objectives addressed in the thesis.

The following chapter examines both the characteristics of an organisational system and elements within an HSE Management System, which provides the conceptual framework for examining the contributing factors to EIPEs.

Chapter 5

CONCEPTUAL FRAMEWORK FOR AN EIPE

5.1 Introduction

From the review of the components and characteristics of an organisational system, elements of an HSEMS, qualitative modelling of a complex system and existing incident causation research in Chapter 2, a conceptual framework is proposed for EIPEs. This has been done to facilitate a better understanding of the dynamics – connections and relations - in a complex system, rather than focusing on the discrete aspects of the incidents. The conceptual framework is comprised of key ideas, which combine the features found in a typical system for managing HSE and the interactive dynamics that exist among various organisational factors. Also, it draws from interdisciplinary fields and the knowledge of systems theory, the HSE Management System and macro business environment assessment. For this study, the internationally recognised Occupational Health and Safety Assessment Series 18000 was used to represent the HSEMS (OHSAS Project Group 2007). An example of a system is an organisation where various business units or functions interact, both internally and externally, with its environment. Therefore, to understand the multi-factorial causation of incidents, there is a need to first understand how these interactions and HSE risks are managed in a complex system.

Based on the attributes listed in Chapter 4, the selected EIPE case studies had sources of pollution that could be traced to specific industrial activities, which involved the protracted community and environmental exposures to harmful substances. These hazardous exposures had significant community impacts beyond the perimeter of the immediate industrial operations. Additionally,

organisations, government agencies and community play important roles in contributing to the EIPE.

In examining these EIPE cases in the subsequent chapters, they serve to illuminate the causes of these incidents within the larger context of the behavioural patterns found within complex systems. It is not the intention of this study to extensively cover the area of organisational science and its theories, such as Classical Organisation, Neoclassical Organisation, Human Resource, Organisations and Environments, Organisational Culture and Change, Power and Politics of Organisations, Modern Structural Organisation and Organisational Economics, which are already well-researched (Shafritz, Ott, and Jang 2011). However, because understanding of the industrial incidents will require some knowledge of the organisational system and behaviours, some pertinent articles in these areas will be highlighted. Beyond the organisational dynamics, the framework does not attempt to focus on individual motivations and behaviours.

5.2 Organisational System

An organisation (Section 2.2) is a collective system of its inter-related functional units or components being mobilised to attain specific business objectives (Forrester 1994b; Sterman 2000; Senge 2006). Therefore, various business units and functions need to be purposefully structured and efficiently organised, in order to be productive and to remain competitive in the marketplace.

Organisational system reflects the IPO model (see Figure 3) (Curry, Flett, and Hollingsworth 2006) where resources (Lengnick-Hall et al. 2009) are sourced and organised, before they are transformed (Groover 2010; Mendling and Reijers 2013) into products and services required by the customers. Through customer and market feedback, organisations adjust their management process and input to continually improve their products or services (Kiran 2017). These

components within an organisation interact with external PLETS factors (Aguilar 1967), which could impact the effectiveness of organisations achieving their goals (Keim and Hillman 2008; Marsden, Tran, and Marsden 2012; Avidar 2016; Hawksworth, Audino, and Clarry 2017; Silva, Styles, and Lages 2017). By adapting this business survey tool of PLETS for identifying these external forces impacting an organisational system (Cadle, Paul, and Turner 2010), it can provide a holistic view of the underlying behavioural forces beyond the immediate causes of industrial incidents (Britkov and Sergeev 1998).

5.3 Using SD tools to Represent Organisational System

Embedded in complex systems are circular chains of cause-and-effect forming feedback loops (Section 2.4.4), which can be difficult to visualise using conventional modelling tools. On the other hand, System Dynamics is an effective method for modelling complex interactions and exposing the underlying organisational behaviours (Marais, Saleh, and Leveson 2006). CLD is a primary tool used in System Dynamics to represent the feedback structure and dynamic behaviours. Such unique features of the CLD make it an ideal tool for analysing causal factors contributing to EIPEs. Otherwise, the lack of an explicit awareness of the underlying systemic behaviour can impede the formulation of effective strategies for EIPE prevention.

5.3.1 Components of a Causal Loop Diagram (CLD)

A CLD visually represents the causal relationships between the components in a system. Basic components of a CLD consist of the variables (contributing factors), causality (directional arrows), polarity (“+” or “-”) and feedback loop(s) (balancing and/or reinforcing). These are described in more detail in subsequent sections. The selection, organisation and visualisation of these components can affect the way readers interpret the CLD. There is no one “right” way of presenting a CLD, but there are good practices in the development of a CLD in

order to minimise possible confusion in its interpretation. Following are some suggestions for constructing a CLD (Kim 1992; Sterman 2000).

As much as possible, when selecting the variables in a CLD, a noun should be used, because using verbs or action phrases could affect the application of the polarity (Kim 1992). For instance, use “population” and not “population growth.” This way, the numerical increase “+” or decrease “-” of the noun (population) is represented by the causality links and not on the variable itself. The mechanics of the polarity is explained in the latter part of this section. However, for the purpose of explaining the characteristics of certain archetypes in Section 5.3.4, variables such as “unintended consequences” (Figure 26) and “growing action” (Figure 27), this naming convention is not followed. To apply the respective archetypes, examples of the actual variables could be “number of crimes” (unintended consequences) and “addiction” (growing action).

It is important to recognise that not all variables are easily quantifiable with a narrow definition. For instance, representing qualities of contributing factors such as “management commitment” or “safety culture” is not always precise; especially, when there is no universal agreement of their definitions among academia and industry practitioners (Baram and Schoebel 2007; Díaz-Cabrera, Hernández-Fernaud, and Isla-Díaz 2007; Edwards, Davey, and Armstrong 2013a).

The link between the two variables such as “birth” and “population” represents the cause and effect or causal relationship (Figure 22). Sometimes, the link between variables may not be as explicit and an intermediate variable may need to be included (Kim 1992). For instance, if a loop (Figure 23) is only shown with the variables “cold” and “heat” without the other intermediary invariables - “thermostat kicks-in” or “thermostat cuts-off,” then it would be harder to interpret the balancing loop.

Another good practice of the CLD development is to label the polarity of every link in a CLD. A causal link from one factor to another is positive or '+' if the cause increases, so that the effect increases as well (Sterman 2000). Polarity may also be represented with an "s" for increase in the same direction (Kim 2000; Cooke 2003). Applying this definition to Figure 22, this shows that if the value of 'birth' increases, then the 'population' size increases in the same direction.

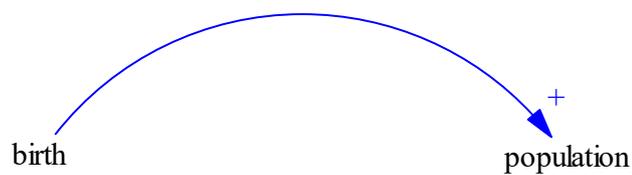


Figure 22: Positive Link for Birth and Population Relationship

In contrast, a causal link from one factor to another is negative or '-' if the cause increases, then the outcome will be affected in the opposite direction (Sterman 2000). Polarity may also be represented with an "o" for decrease in the opposite direction (Kim 2000; Cooke 2003). Applying this definition to Figure 23, this shows that if the value of 'death' increases, then the 'population' decreases or moves in the opposite direction.

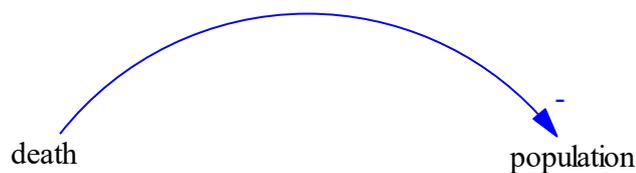


Figure 23: Negative Link for Death and Population Relationship

5.3.2 Reinforcing and Balancing Loops

At the heart of System Dynamics is the concept of feedback (Sterman 2000, p. 137). Common feedback patterns within organisational systems consist of either multiple reinforcing loops, or balancing loops, or a combination of both.

A reinforcing loop, also known as a positive loop, promotes or reinforces change with even more change (Proust and Newell 2006). For instance, births add to the population. In Figure 24, the arrows are used to show causation between birth rate and population. The factor at the beginning of the arrow causes a change in the factor at the end of the arrow. Thus, a growing population creates more births, which adds even more to the population growth. Thus, this reciprocal cycle of cause and effect becomes a loop that feeds on itself.

On the contrary, an increase in the death rate will cause a decrease in contribution to population growth. This balancing loop, also known as a negative loop, seeks to achieve a goal (Proust and Newell 2006). In this case, a goal can be maintaining a healthy national economic growth by ensuring there is a healthy rate of population growth.

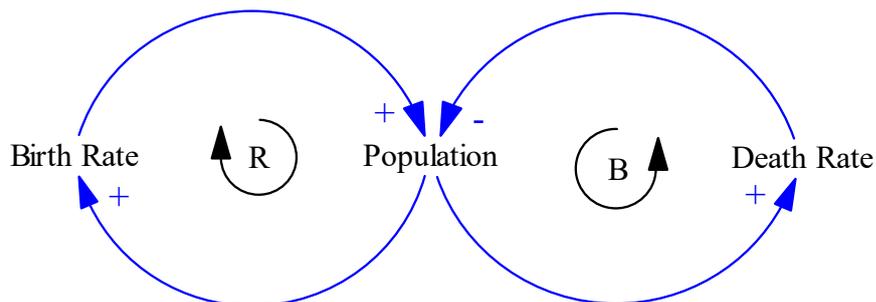


Figure 24: Reinforcing and Balancing Loop for Population adapted from (Sterman 2000, p. 138)

5.3.4 Common Archetypes

System archetypes are common themes of dynamic behaviours observed in systems (Kim 2000; Braun 2002; Wolstenholme 2003; Senge 2006). Essentially, these common patterns of behaviours can be the warning signs for the development of an EIPE. Although they offer useful insight for understanding the underlying feedback structure of an organisational system, they are usually not sufficient in themselves to be considered as models. Nevertheless, system archetypes serve as basic platforms upon which more comprehensive models can be further developed (Marais, Saleh, and Leveson 2006). Moreover, archetypes facilitate the consideration of not only the anticipated outcomes from a contributing factor, but they also explore possible unintended consequences, which is another good practice for a CLD development (Richardson and Pugh 1981; Kim 1992). To better understand the characteristics of these generic feedback structures, several studies have contributed to the classification and refinement of system archetypes (Wolstenholme 1990, 1993; Wolstenholme 2003; Marais, Saleh, and Leveson 2006; Senge 2006). This study illustrates examples of common system archetypes that can be used in the analysis of EIPE cases.

“Shifting the Burden” is an archetype (Figure 25) that depicts the tendency to address a problem symptom with a short-term or symptomatic solution (B1, Figure 25) rather than with a long-term or fundamental solution (B2, Figure 25) (Kim and Lannon 1997; Braun 2002). The hash line for the fundamental solution indicates a greater time commitment (time lag) for planning and mobilising the resources to address the problem. The symptomatic solution produces short-term results that reduce the need to develop a more sustainable solution. Unfortunately, when the focus is on developing a symptomatic solution, then it produces an undesirable side-effect (R1, Figure 25) causing the underlying issue affecting the system behaviour to get worse.

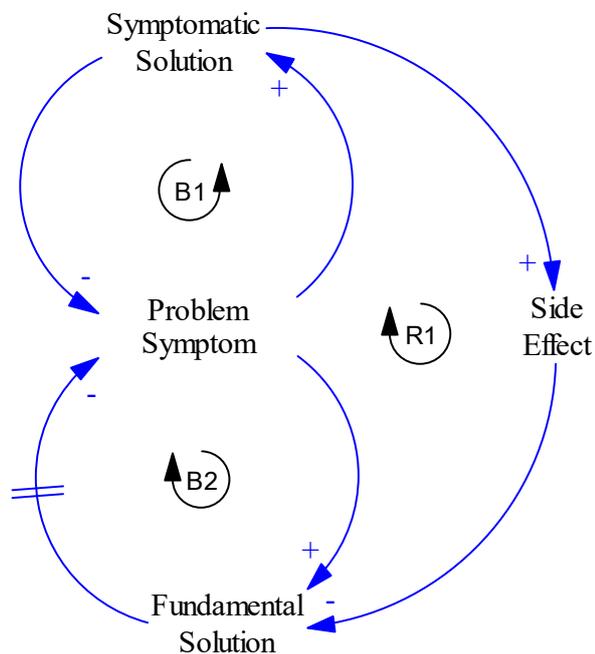


Figure 25: ‘Shifting the Burden’ Archetype (Braun 2002, p. 4)

Bearing a strong resemblance to “Shifting the Burden” is the archetype called “Fixes that Fail” (Figure 26) (Kim and Lannon 1997; Braun 2002). While the focus is still on fixing the problem symptom (B1, Figure 26), the unintended consequence of not addressing the underlying issues exacerbates the initial problem (R1, Figure 26). Initially, the successful results from the fixes may encourage the continued focus on temporary solutions. However, the accumulation of the unintended consequences will reach a point where they can no longer be ignored, i.e. the reinforcing loop will get stronger and the balancing loop will become weaker. The above two archetypes differentiates both short and long term consequences with separate loops, which is another good guiding principle to follow when developing CLD (Richardson and Pugh 1981; Kim 1992).

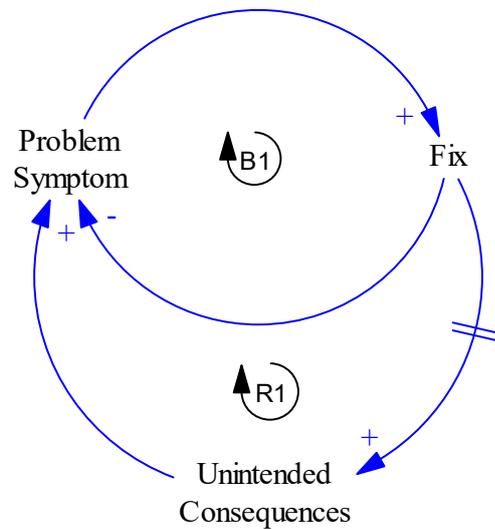


Figure 26: ‘Fixes that Fail’ Archetype (Braun 2002, p. 14)

Figure 27 is another archetype known as “Growth and Underinvestment,” which illustrates the interaction between cause and effect on growth and underinvestment (Kim and Lannon 1997; Braun 2002).. Due to the growing action that is generated from the current demand (R1, Figure 27), there is a need to invest in additional capacity (B2, Figure 27) to maintain current performance (B1, Figure 27). Otherwise, the lack of capacity expansion, in light of the growing demand and action, can lead to a decrease in performance. Such decrease in performance can impact business productivity and an organisation’s ability to meet the demand of customers.

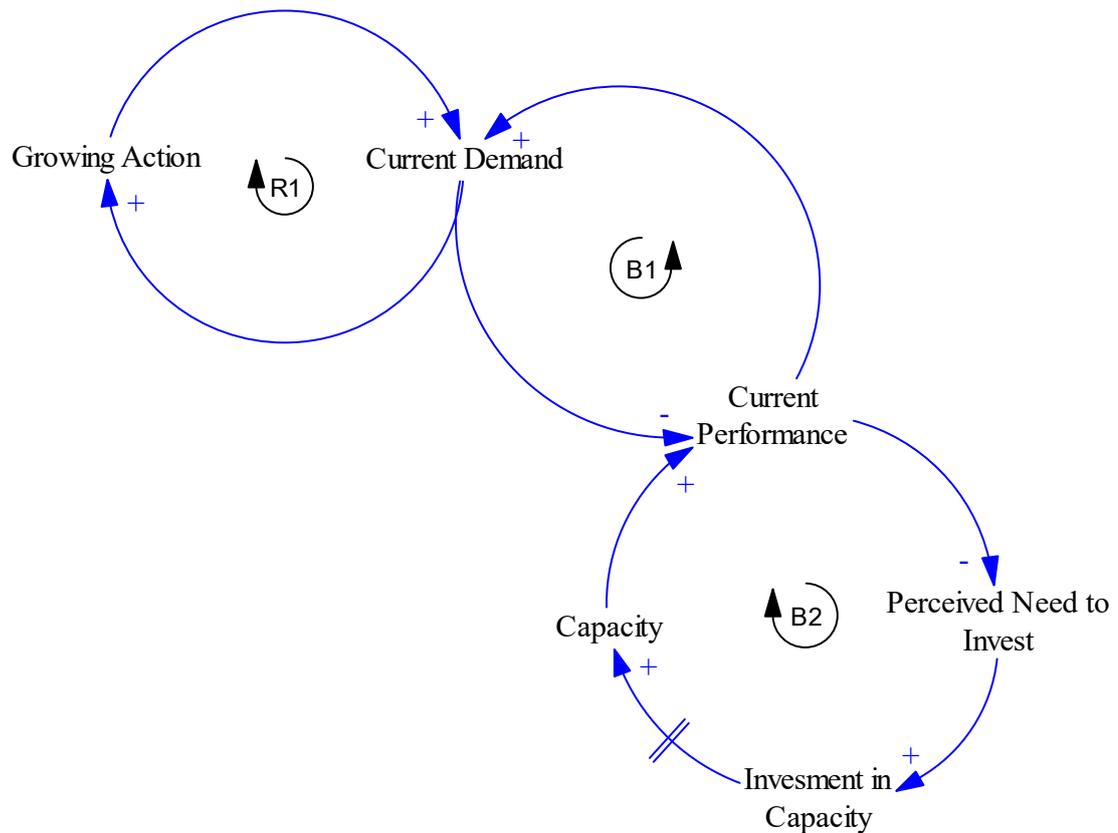


Figure 27: 'Growth and Underinvestment' Archetype (Braun 2002, p. 16)

Even in complex systems, there are identifiable recurring themes. These recurring themes, or patterns of feedback structures, are captured in these system archetypes, which help to simplify and explain the dynamic behaviours. Different system archetypes are sometimes linked together to provide a more comprehensive view of the underlying systemic behaviour in an interconnected organisation. In this way, archetypes facilitate the understanding of complex mental models, which represent an approximation to the real world situation. Instead of using limited human cognition to understand detailed complexity, the real value of SD tools is in their ability to capture the essence of dynamic complexity (Senge 2006).

Since the ability to understand the total dynamic behaviour of a complex system becomes weaker as more details are added to CLDs and SD models, it is important that SD tools are used in a way to add value to the understanding of dynamic behaviour without creating more confusion. To provide visual clarity that aid in the interpretation of CLD, all the above-mentioned archetypes are kept as simple as possible by ensuring that the causal links do not cross or overlap one another, which is another hallmark of a good CLD (Richardson and Pugh 1981; Kim 1992).

5.3.5 Stock and Flow Diagrams (SFD)

Stocks and flows are basic building blocks of a dynamic system model, which help to make the stock and flow structure in a CLD more explicit (Sterman 2000, p. 203). Dynamic behaviour of a system occurs when flows accumulate in stocks. A stock in the shape of a rectangle can be a collection of material or non-material things. A flow, represented by a pipe, brings those material or non-material things out of or into stock. A valve controls the flow of material or non-material. A cloud represents either the source or sump for the flow, which is not constrained by its capacity.

For instance, if the flow is 'bank interest' and the stock is 'savings,' then the stock level or saving balance is essentially the accumulation of interest earned on an initial balance over a period time (Figure 28).

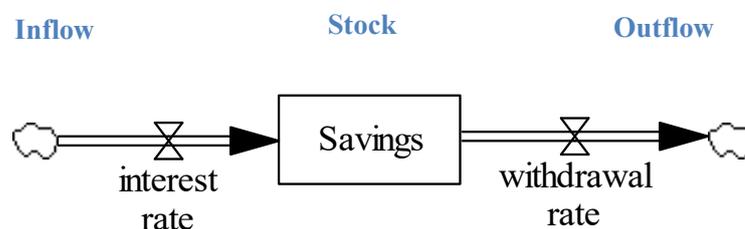


Figure 28: Stock and Flow of a Savings Account adapted from (Sterman 2000, p. 193)

There is no outflow when there is no withdrawal made on the savings account. If the rate of withdrawal is faster than the rate of interest earned, then the level of savings will drop, and vice versa. Understandably, the real world environment is more complex than the represented simple SFD.

5.4 Health Safety and Environmental Management System

Complementing the organisational system is the HSEMS (Section 2.3), where emphasis in the areas of health, safety and environment management should be carried out in a systematic and organised approach (International Labour Organisation 2001b; American National Standards Institute 2005; British Standards Institution 2007). HSEME is compatible to the understanding of system where Policy, Planning, Implementation and Operation, Checking and Management Review interact and response internal and external changes to the organisation system (Borys et al. 2012).

Similar to any guidelines, these well-established frameworks are more effective when correctly applied and integrated into the overall organisational culture and management system (Gallagher, Underhill, and Rimmer 2001). For instance, they are not intended to be an end in themselves, where organisations may incorrectly use specific Standards as a one-size-fits-all prescriptive checklist, regardless of their different operating environment. Studies have shown that different organisational factors affect the effectiveness of the HSEMS application (Nordlöf et al. 2017).

Contrary to certain industry mindset, OHS and production objectives should not be mutually exclusive and studies have shown that it is possible to create both a safe and productive workplace (Pagell et al. 2014). Also, other research findings have shown that HSEMS can enhance organisational HSE performance (Fernández-Muñiz, Montes-Peón, and Vázquez-Ordás 2007; Purse, Dawson,

and Dorrian 2010) and improve business performance (Fernández-Muñiz, Montes-Peón, and Vázquez-Ordás 2009).

5.5 Integrated PLETS and HSEMS Framework

Underpinned by the international push for a systematic approach to HSE (European Union 1989; International Labour Organisation 2003), the application of systems models to HSE (International Labour Organisation 2001a) has been actively pursued by businesses, governments and global companies as an effective strategy to harmonise HSE and business requirements (EU-OHSA 2010). Reinforcing the need for the effective implementation of an HSEMS, the World Health Organisation (WHO)(2010) proposed that safety and health issues be viewed as part of the larger environment beyond the physical workplace, with collaborative engagement between management and workers, and organisational core principles of ethics and values.

Despite these HSEMS and models being used to manage safety and health, integration of HSE within the holistic business management approach has been limited (Zanko and Dawson 2012). For instance, macro business factors include changing business contexts, societal developments, legislative requirements, technological advancements and other external forces that can have lasting implications for HSE (Leamon 2001). Thus, an effective HSEMS cannot be isolated from the internal business management framework or the external organisational context.

Understanding how HSE is managed within such a systemic approach can provide valuable insights into the underlying factors contributing to industrial incidents. Therefore, to analyse the EIPE cases, this study proposes a conceptual framework that combines the systems approach, PDCA management principles and the macro business assessment criteria. Shown in

the same figure, the HSEMS based on the Standards OHSAS 18001:2007 is embedded within the macro business environment of PLETS (Figure 29).

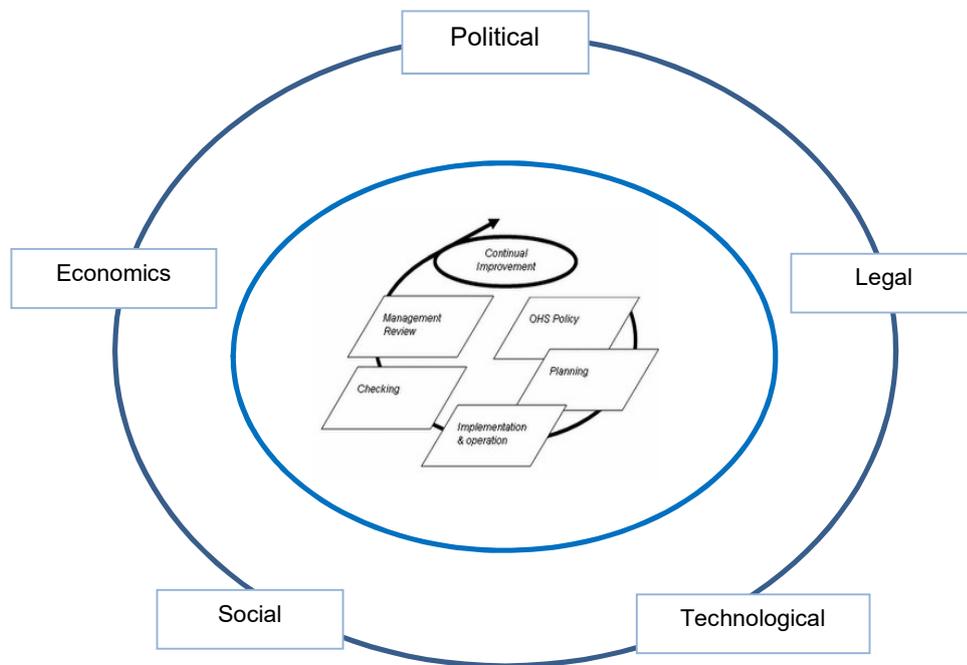


Figure 29: Conceptual Framework for Integration of an HSEMS and PLETS

Organisational factors are connected to the organisational activities, where the external PLETS factors are integrated into the business strategies and planning, and HSEMS is integrated within the operations of the organisation. Essentially, the strategies and planning provide a blueprint, which enables organisations to execute their operations (Mankins and Steele 2005; Guillén and García-Canal 2012). The outcome of the operation in turn provides critical feedback for organisational review against predetermined strategic goals and to make planning adjustments, if necessary (Martin 2010) (Figure 30). Additionally, these inter-relationships and interactions are influenced by the characteristics of the organisational system (Neilson, Martin, and Powers 2008; Sull, Homkes, and Sull 2015).

By examining the current operational performance (e.g. percent increase in production volume) of the business strategy (e.g. expansion of manufacturing capacity), and then measuring that against an established set of performance parameters and goals (to achieve 30% output increase per production shift), assessment can reveal the effectiveness or impact of the strategy-operation alignment and any opportunities for improvement. Diligent collection of HSE data, including both lagging and leading indicators can also reveal if health and safety performance has been compromised with changes in the organisational strategies. However, due a combination of factors such as a lack of dedicated personnel maintaining HSE specific performance indicators, the generally non-enforceable nature of carrying out such administrative activities and/or sensitive nature of such data with reputational implications for any organisations, access to relevant HSE data is not always possible to conduct such analysis for EIPE.

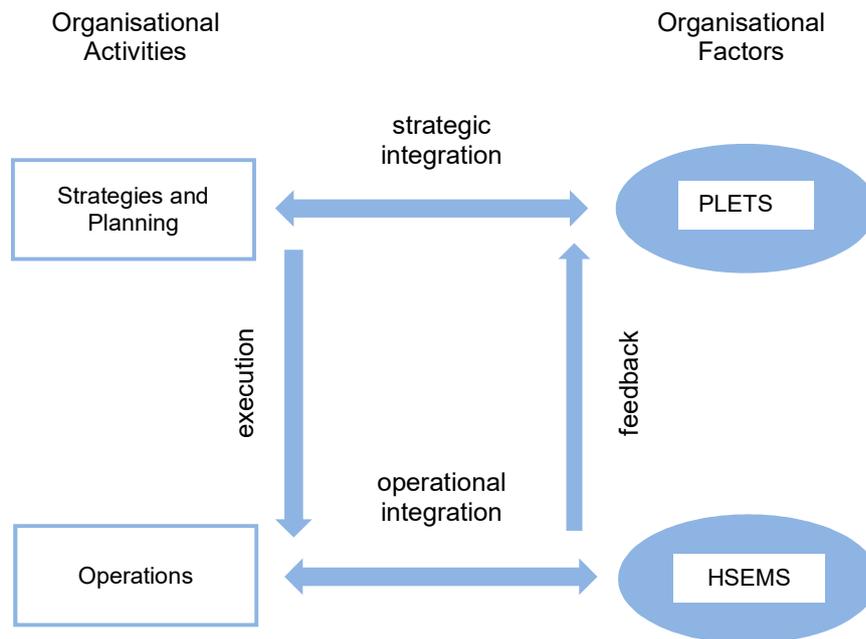


Figure 30: Interaction between organisational activities and factors

5.6 Conclusions

Any effective organisation needs to have a purpose for its existence, and that collective goal can only be achieved within a functioning system (Forrester 1994b; Sterman 2000; Senge 2006). In the process of achieving a corporate goal, undesirable incidents with significant environmental health consequences can occur. To advance our understanding beyond the immediate cause and effect of these industrial events, it is no longer sufficient to examine incident causation solely from an internal organisational perspective (Marais, Saleh, and Leveson 2006). The increasingly dynamic environments in which most organisations are operating, and the growing complexity of the risks that societies face, require an appreciation for the broader system beyond the internal organisational structure and behaviour. This external organisational perspective looks at political, legal, economic, technological and social factors that are not as easily controlled as those found within the organisation itself. Like the internal organisational factors, such as policy, planning, implementation and operation, checking and management review, the external PLETS factors are just as capable of introducing vulnerabilities into a complex organisational system (Aguilar 1967).

Recognition of the key attributes - complexity and interactivity (Sterman 2000) - of a complex system, which is made up of a web of feedback loops, is the prerequisite for the development of a conceptual framework for EIPes. Therefore, taking all these into consideration, the conceptual framework (see Figure 29) and SD tools such as CLD and SFD used in this thesis provide a systems approach to examining the inter-relationships of contributing factors to industrial incidents.

This conceptual framework overcomes the limitations of the sequential and epidemiological causation models highlighted in Chapter 2. Among the main limitations are the direct and linear causal relationships that do not take into

account the feedback and cyclical nature of a complex system. In contrast to the proposed model, both the sequential and epidemiological causation models do not adequately represent the wider interactions with the external macro business environment. Instead of narrowly focusing on human errors and/or plant and equipment defects, the systems approach moves away from the common 'finger-pointing' exercise in any incident investigation and, instead, examines the underlying systemic causes. Moreover, the continual improvement management framework that has been widely used to manage organisational HSE risks is incorporated into the conceptual framework as well.

The following three chapters apply the conceptual framework to three purposefully selected EIPE cases; namely Love Canal, Minamata Disease and Esperance Pollution. Data from the three cases is organised into internal and external contributing factors and SD tools are used to better explain the systemic behaviours in each case study.

Chapter 6

CASE STUDY – LOVE CANAL DISASTER

6.1 Introduction

Building on the conceptual framework that was proposed in the previous chapter, a series of purposefully selected case studies were examined in this and subsequent chapters. A consistent approach was used to examine both the external and internal systemic factors that contributed to the EIPEs. The findings of this Love Canal case study presented a higher level of systemic framework for the comparison and analysis of factors for the other two case studies.

Part of the examination into the contributing factors for this EIPE required the identification of the roles and functions played by key stakeholders, such as government regulatory agencies, the School Board and the Hooker Chemical and Plastics Corporation. Also, the interactive behaviour of the various causal factors was analysed using CLDs. By taking into account the feedback loops and time lapses in the dynamic system of Love Canal, CLDs provided invaluable insights into the complexity and inter-relationships that existed in this case.

“Described as an environmental time bomb gone off, Love Canal stands as testimony to the ignorance, lack of vision and proper laws of decades past which allowed the indiscriminate disposal of such toxic materials” (Herdman 1978, p.3). It was one of the most high-profile industrial disasters in American history that eventually paved the way for more stringent legislative requirements to prevent similar industrial incidents (Dickson 1982). Unlike most IPEs where the HSE impacts were due to the sudden release of energy, such as explosion or fire, or a combination of both, Love Canal consisted of an accumulation of disposed hazardous waste that would eventually result in serious health and environmental consequences (EPA 2007b, p.1).

Several studies have been conducted on IPEs to understand their causes and how they could have been prevented (Bowonder and Linstone 1987; Bertazzi 1991; Browning 1993; Perrow 1999; Chernobyl Forum 2003-2005; Bozeman 2011). However, there have been limited studies of EIPEs where there were protracted community and environmental exposures to harmful substances or harmful energy levels from industrial sources. Most studies about Love Canal have focused on its epidemiological or post-event environmental and health impacts (Herdman 1978; Online Ethics Center for Engineering 2006; Donaldson 2008; Gensburg et al. 2008). By using a systemic approach to examining the complex behaviours of key stakeholders in the Love Canal case, this study aims to provide a better understanding of the dynamic causes leading to the Love Canal disaster.

6.2 Case Overview

In 1892, an entrepreneur - William T. Love - planned to build a model industrial city in New York, which would be powered by hydroelectric dams on an 11km canal between the upper and lower Niagara Rivers. Unfortunately, the ambitious plan fell through within a year of its inception, after only one kilometre of a long canal pit had been built. By 1978, the unfinished canal was situated within the Love Canal site and surrounded by residential areas (see Figure 31).

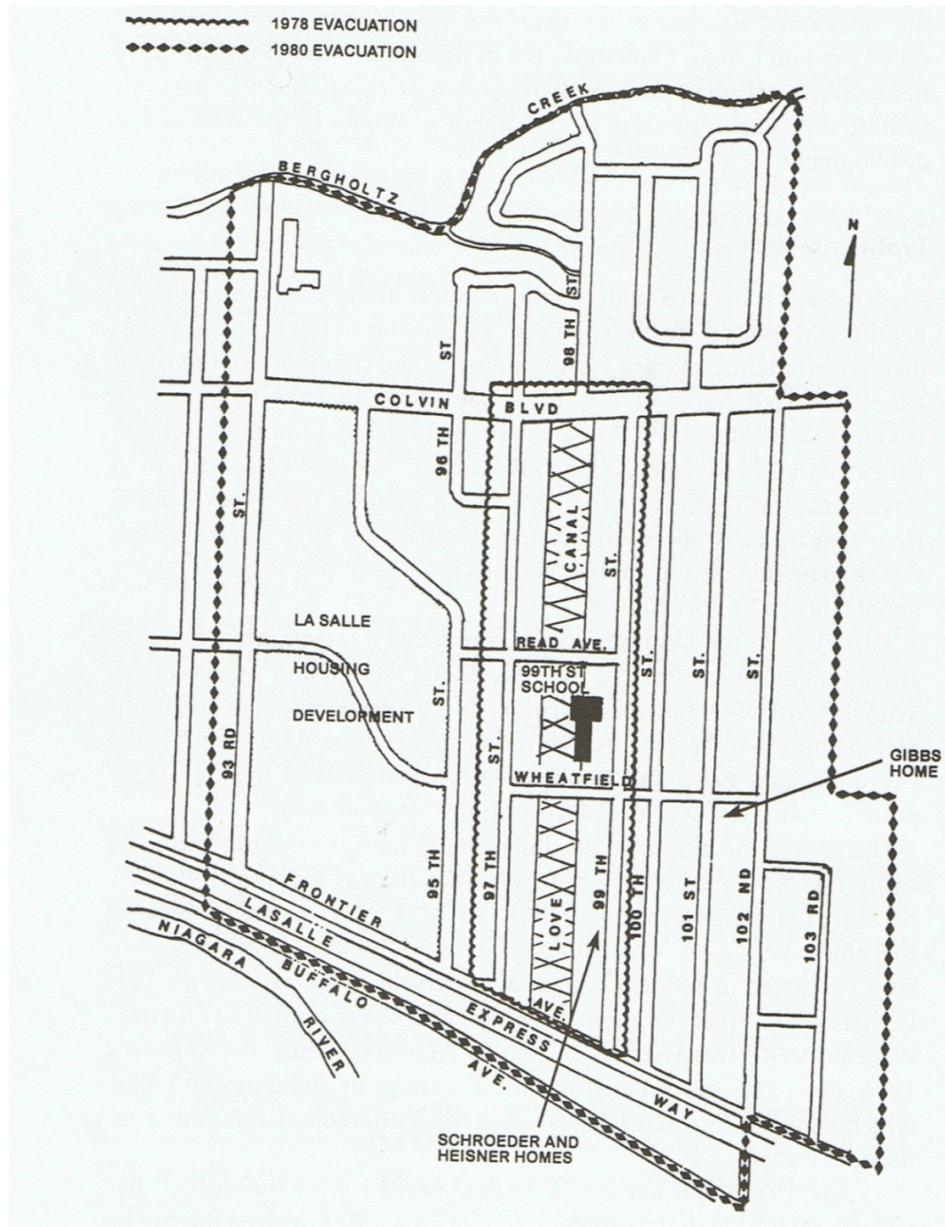


Figure 31: Map of Love Canal's Surrounding Area (adapted from DOH 1988)

For a few decades, the pit was a local recreation area for activities such as swimming, fishing, trapping and skating. Through a public auction in 1920, the City of Niagara Falls purchased this pit for the purpose of disposing of chemical waste for the municipal and chemical companies, which continued for more than 20 years. As early as April 1942, Hooker Chemical and Plastics Corporation

(Hooker Chemical), a subsidiary of Occidental Chemical Corporation (OCC), obtained an approval from Niagara Power Development Corporation (NPDC) to dispose of its chemical wastes. Among the toxic wastes were arsenic trichloride and thionyl chloride, used to make war gases (Hernan 1994). This disposal practice continued when Hooker Chemical acquired the land for their chemical waste disposal in 1947. By 1952, the company had buried almost 22,000 tons of pollutants.

Due to the urgent need for classroom space, the Niagara Falls Board of Education (School Board) purchased the same land for a new school to be built in May 1953. The surface of the Love Canal was covered with clay and dirt, and declared safe by the company before selling the land to the School Board. Not only was the land sold for the suspicious amount of a single dollar, but the company had also indemnified itself from any liability for the side-effects of chemical exposure. By 1955, hundreds of children were attending the school and hundreds of homes were being built in the surrounding areas. In 1958, a second school was opened six blocks from the first school.

During the construction of the sewer beds, water lines and an expressway, the barrier used to contain the chemicals was punctured. Residents and local officials were unaware of the serious health impact of such chemical exposure; thus, no actions were taken when incidents of chemical burns were first reported. However, the event took a turn for the worst in 1975 and 1976 when severe weather conditions caused a substantial amount of chemical waste to flow to the surface from the pit. More than 400 types of chemicals, including some known to be carcinogenic (e.g. benzene, dioxin, arsenic trichloride, thionyl chloride), were found in the air, water and soil, and they had contaminated the entire neighbourhood.

In the years that followed, health consequences of the exposure to those chemicals manifested in the form of abnormal rates of stillborn births, miscarriages, birth defects and prolonged illnesses. In 1978, the area around the Love Canal was declared as a serious threat to HSE (Herdman 1978). The school built on the contaminated land was closed, the land was quarantined and hundreds of families were evacuated. In August 1978, President Jimmy Carter declared the site as a federal emergency area and the Federal Disaster Assistance Agency (FDAA) was called in to help with the relief effort. Eventually, more than 1,000 families had to be evacuated. The health impact did not stop then; a National Environmental Protection Agency (NEPA) study revealed more cases of residents with chromosomal damage and unhealthy babies being born.

In December 1979, the US government filed suits against Hooker Chemical and its parent corporation, Occidental Petroleum Corporation (OPC). The suits totalling USD117.58 million sought to compensate for the clean-up cost of the chemical waste disposal sites, which were in breach of the Resource Conservation and Recovery Act, the Clean Water Act, the Safe Drinking Water Act, the Refuse Act and the common law of nuisance (EPA 1979). Although Judge Curtin, in his landmark ruling in 1994, found Hooker Chemical to be negligent for its handling of the hazardous chemicals, he did not accede to the request from the government to make OPC pay for damages amounting to USD250 million. Regardless, his rulings cost OPC more than USD233 million to settle other cases brought forth by the government.

The events of Love Canal triggered the enactment of the Comprehensive, Environmental Response, Compensation, and Liability Act (CERCLA) 1980 or the 'Superfund' law, which was used by Judge Curtin to apply its liability provision retroactively against Hooker Chemical (Mazur 1998). The 'Superfund' law was a federal programme launched to identify and clean up the worst hazardous chemical disposal sites in the US. As part of the settlement, Hooker Chemical were asked to pay a total of USD227 million to cover the New York

State and federal government's clean-up costs (Hernan 2010). In 1983, a lawsuit filed by 1,328 residents was settled for USD20 million dollars with OCC, a subsidiary of OPC (Clapp 2008). Later studies showed that more than 200 chemical compounds had been analysed, of which 12 were known carcinogens (Brown 1980). The key events during the period from 1892 to 1994 are represented in the timeline in Figure 32.

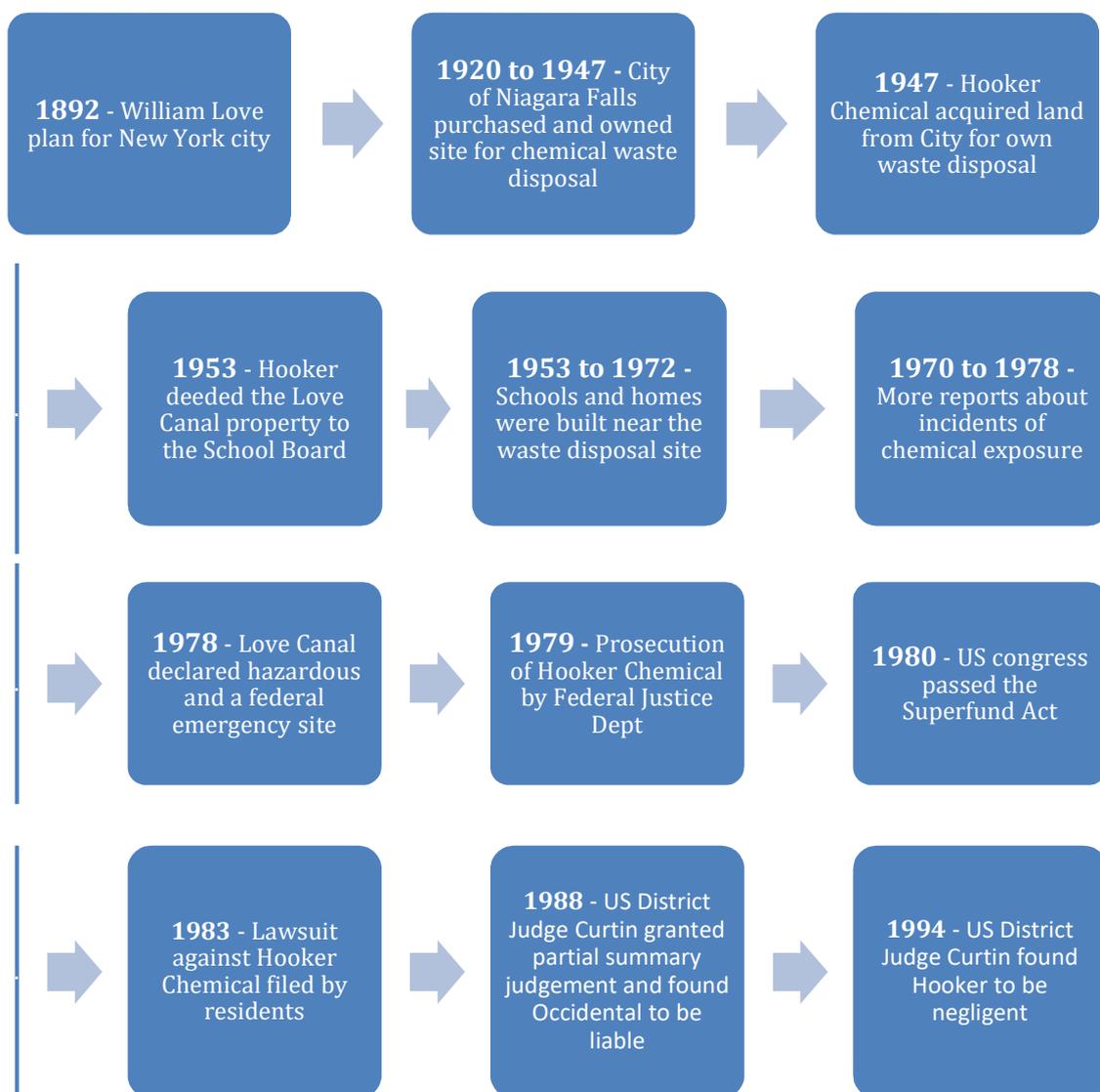


Figure 32: Sequence of Key Events in Love Canal Disaster

6.3 External Organisational Factors

The external organisational factors examined were those macro business forces – political, legal, economic, technological and social – that influenced the organisations’ decision-making and the implementation of strategies to achieve their objectives. Organisations would usually have lesser control over these external factors, compared to the same internal organisational factors. In order to better understand the underlying structural behaviour of the system, it was necessary to carry out systemic analysis of the organisations from a broader perspective beyond its internal context. Characteristics of the EIPE such as possible conflict of interests or tension between government, industry and society and their complex interaction are represented by SD tools.

6.3.1 Political

Policies at the national level had tremendous impact in shaping the operational direction at the industrial and organisational levels. The CLD in Figure 33 depicts how public policies could drive industry growth at the expense of public health protection. The system archetype “Limits to Growth” (Meadows et al. 1972; Braun 2002) was selected to explain such a dynamic relationship. This archetype consists of a reinforcing loop (see loop R2, Figure 33a) and a balancing loop (see loop B1, Figure 33a). Additionally, the SFD (Figure 33b) shows that the rate of industry growth and the rate of exposure to industrial activities impact upon the waste level and the number of health related incidents, respectively.

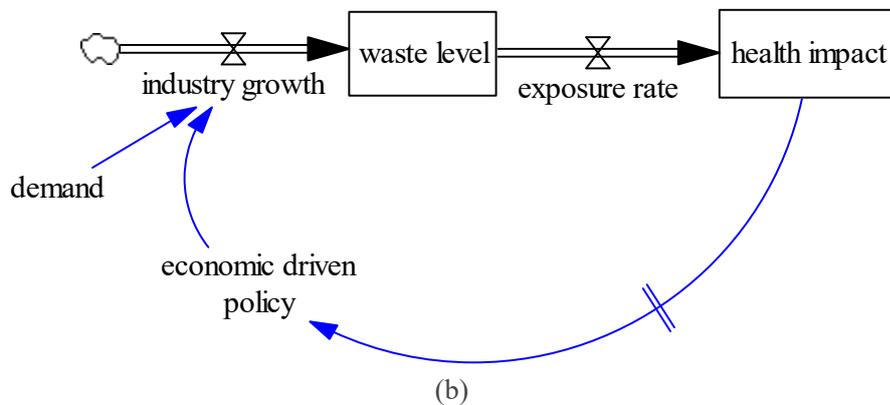
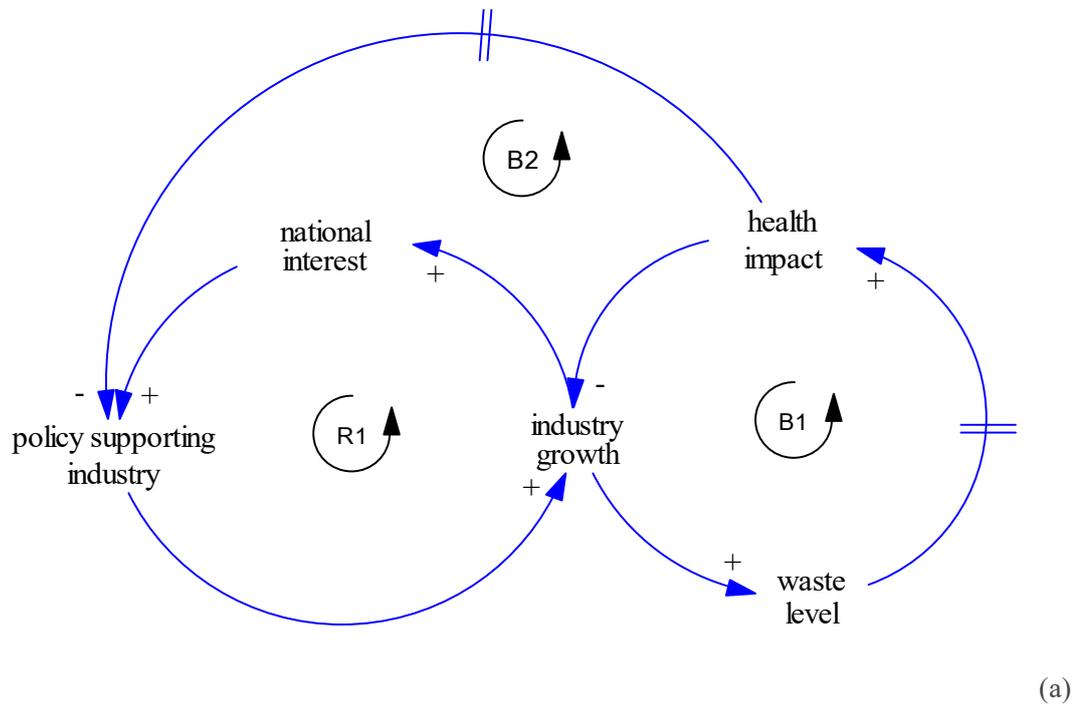


Figure 33: Love Canal's Political Factors

The R1 reinforcing loop (Figure 33) represents a vicious cycle of accelerating growth and expansion. During the Love Canal period, public policies in the US were driven by national interests. Due to World War II taking place, industries such as Hooker Chemical were encouraged to support the demand created by the military's involvement in the global conflict, to the extent that pollutants generated from the manufacturing activities were overlooked as long as they participated in defence-related contracts (Colten and Skinner 1996). Depending

on the political connection that one possessed in the City of Niagara Falls (e.g. William T. Love), an industrial project could receive strong political endorsement. Love's well-heeled political connections allowed him to marshal enough support from the State Senate and Assembly to endorse his model town development. Governor Roswell Flower signed the legislation granting Love's company authority to divert water from the upper Niagara River to support his power generation project. With the state's endorsement and approval of the project, manufacturers and factories were lining up for the opportunity to operate their businesses at the town site (Herdman 1978). Such favourable, nationally driven policy allowed the chemical industry to grow at a rapid rate and to contribute to the global war machinery.

However, the continued growth, or reinforcing loop (see R1, Figure 33a), encountered a slowing process known as the balancing loop (see B1, Figure 33a). Due to the expanding manufacturing activities, more industrial waste products were accumulated. Organisations could only expand as fast as they could find enough space to dispose of these hazardous chemicals, which contributed to the long-term health impacts. The negative health impacts caused a loss of productivity and the backlash from the public tempered further investment in industrial growth. Also, the health impacts would eventually result in the review of the policy, but such a reactionary measure would take a long time and only after serious health issues had occurred (see B1, Figure 33a). Therefore, the delay in policy intervention would not prevent the Love Canal disaster. In fact, it was many decades after Hooker had begun disposing of its wastes in the Love Canal that the Comprehensive, Environmental Response, Compensation, and Liability Act (CERCLA) 1980 was finally enacted.

6.3.2 Legal

Since the legislation was a reflection of the societal norms and expectations, government authorities at the federal and state levels played important roles in the ongoing reform and enhancement of the legislation they administered, which contributed to the elimination or minimisation of any health risk exposure. The CLD in Figure 34 shows the interaction among these factors in a balancing loop (B3). Each of these influencing factors is explained in more detail below.

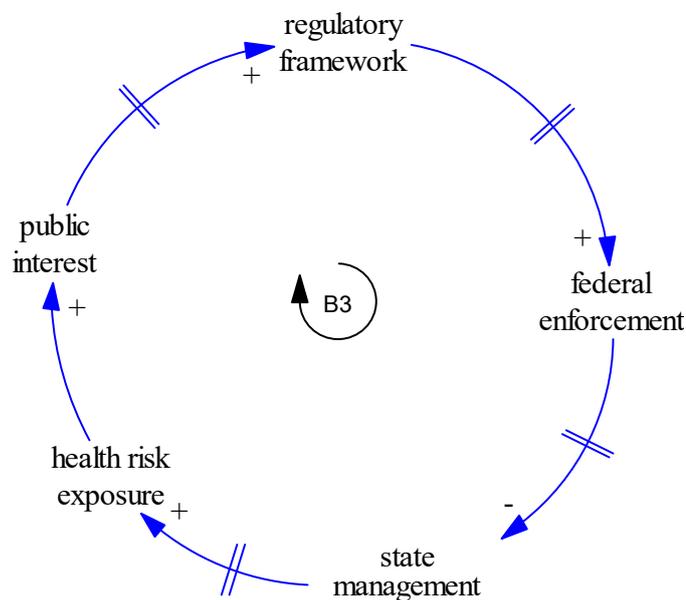


Figure 34: Love Canal's Legal Factors

6.3.4.1 Regulatory Framework

Prior to 1976 and reports of Polychlorinated Biphenyls (PCB) contamination and the industrial disaster in Seveso (the explosion of a chemical plant in Italy), there was scant coverage of chemical pollution in the news (Mazur 1998, p. 121 - 141). Due to the lack of public interest and government funding, there was lesser focus on land disposal of toxic wastes compared to that of air and water

pollution. Hence, government regulations on landfill disposal practices were not as up-to-date.

It was not until the Clean Water Act and Clean Air Act (EPA 2017a, 2017b) were enacted in 1972 and 1970 that people started to take interest (see delay sign 'II' for influence between 'Public interest' and 'Regulatory framework,' Figure 34) in the need to protect the environment (Columbia Law School 2012). Even then, the Solid Waste Disposal Act that was passed in 1965 did not provide for any federal regulatory or enforcement authority. New York State passed similar legislation in the following year, but there were inadequate resources at all government levels to support regulatory compliance. At the court case - United States v. Hooker Chemicals & Plastics Corp., experts testified that Hooker had often exceeded the requirements of the statute when carrying out its waste disposal activities. (U.S. District Court (NY) 1994, Section VI, p.1050).

6.3.4.2 Federal Enforcement

The US Environmental Policy Act (USEPA) was only established in 1970 (see delay sign 'II' for influence between 'Regulatory framework' and 'Federal enforcement,' Figure 34) and there was no prior experience in dealing with this kind of disaster, as witnessed in the case of the Love Canal (USEPA 2012). Before the establishment of the National Environment Protection Agency (NEPA), the protection of air and water supplies was mainly left to each state, and there was nothing said about solid waste. In fact in the 1950s, the Manufacturing Chemists' Association (MCA) favoured such state level management, and argued against any intervention from the federal government, which was seen as interfering with the operations of the organisations (U.S. Senate 1936, 1955).

To avoid burdens on public facilities, large industrial plants were indirectly encouraged to dispose of their wastes on company properties (U.S. District Court (NY) 1994). In 1976, the enactment of the Resource Conservation and Recovery Act (RCRA) classified solid wastes as 'hazardous' and limited the option of land disposal, but the law still depended on individual state agencies to enforce it. During that period, it was common for companies to dispose of their waste without much consideration for long-term health and environmental impacts (Engelhaupt 2008). Also, there was no distinction between household and industrial wastes, which could be dumped in the same municipal waste disposal site (Curtin 1994). Except for disposing of chemicals into water supplies, the practice of disposal of industrial wastes in landfills was lawful until the USEPA introduction of the RCRA in 1976 (Zuesse 1981).

In a survey conducted by ABC News in 1980, the perceived lack of federal and state government enforcement was given as one of the main reasons behind the Love Canal disaster. Any legislative enforcement was limited, and lax court rulings sent the wrong message that unsafe actions taken by manufacturers, especially those involved in defence related work, were tolerated. Attention was only given to hazardous substances that may endanger public health or the environment under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) enacted in December 1980. For the first time, this law provided broad federal authority to respond directly to the release of hazardous substances or threats of potential exposure to hazardous substances (see delay sign 'II' for influence between 'Federal enforcement' and 'State management,' Figure 34).

6.3.4.3 State Management

Generally, corporate security or concern about protecting manufacturing secrets became an obstacle for government to carry out inspections of waste management practices, although that was not particularly evident from the Love Canal case study.

In 1973, the Niagara County Health Department (NCHD) investigated resident complaints about an odour emitting from the Love Canal. In the following years, the NCHD attempted to contact owners of affected properties to adequately cover the exposed land. In August 1976, the NCHD approached Hooker Chemical to analyse a sample that turned out to be compounds of aliphatic acid (Curtin 1994).

The New York State Department of Environmental Conservation (NYSDEC) first visited the Love Canal in September 1976, while investigating the suspected discharge of Mirex (a chlorinated hydrocarbon insecticide) by Hooker Chemical. Samples from the basement sump and sewer system were collected for Mirex/PCB (Polychlorinated Biphenyls) analysis. The result of the analysis prompted the NYSDEC to urge the City of Niagara Falls to hire a consultant. The role of the consultant was to conduct a hydrogeological study and to develop a pollution abatement plan. Subsequently, the environmental study conducted by the consultant, the Calspar Corporation of Buffalo, was submitted to the NYSDEC for review, in September 1977.

In early 1978, the NYSDEC and New York State Department of Health (NYSDOH), with the help of NEPA, conducted an intensive survey of the groundwater pollution and air samples. Analysis of these samples collected from homes, yards and throughout the Love Canal neighbourhood revealed the presence of organic compounds. These results concerned the authorities enough for the State Commissioners of Health and Environmental Conservation to visit the Love Canal site to gain a better understanding of the situation (NYDOH 1981).

In April 1978, officials from the NYSDOH, NYSDEC and NEPA began reviewing test data and started to organise a concerted remedial plan. For the next few months, not only did the NYSDOH and NYSDEC intensify their environmental monitoring efforts, they also increased their delivery of education to residents on

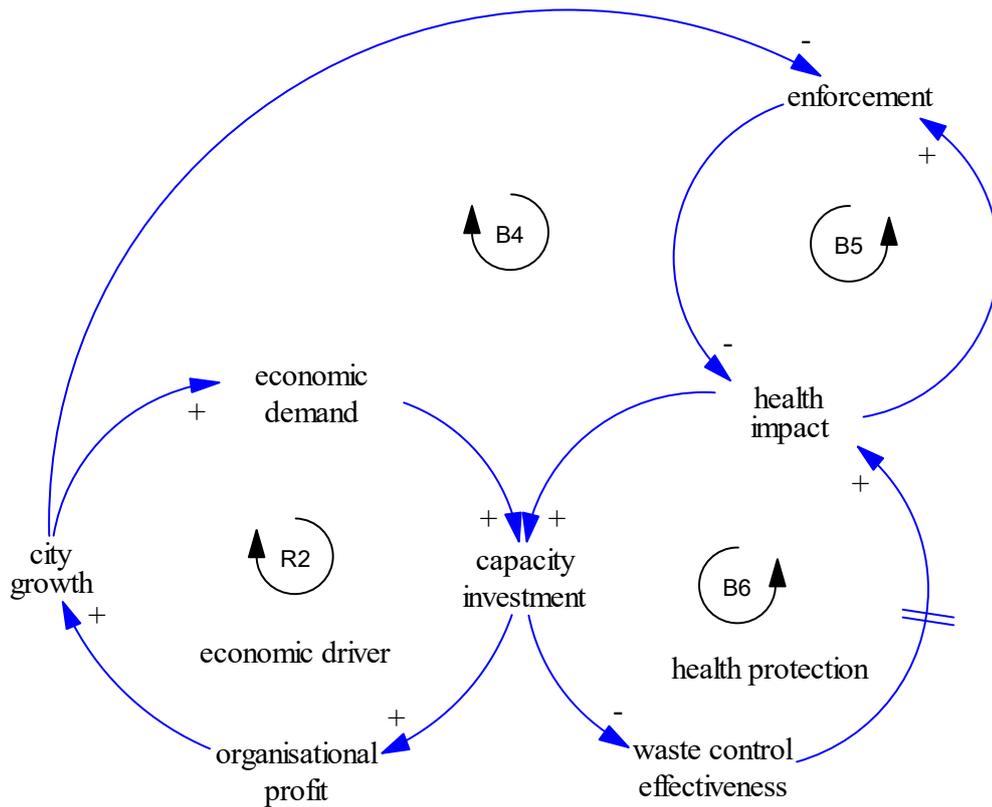
the potential health impacts from chemical exposure. The NYSDOH began collecting blood samples and conducting a survey of the residents as part of the investigation into the high rates of birth defects and miscarriages. A series of state- and federal-sponsored studies, including a grass root-initiated study were conducted between 1978 and the 1980s (Online Ethics Center for Engineering 2006).

6.3.4.4 Health Risk Exposure

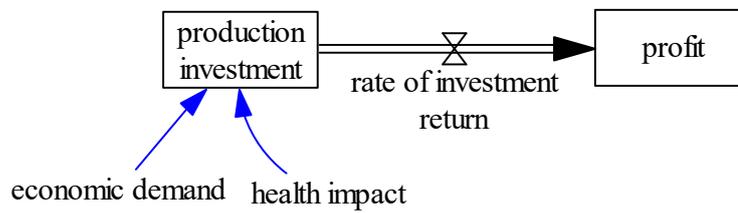
From the case study, it could be seen that the public's exposure to health risk was influenced by the state management of industrial activities in New York. Concentrated investigative activities were carried out by the county, state and federal agencies only a couple of years before the declaration of the Love Canal as a federal emergency area. This suggested a lack of proactive, compliance monitoring of the waste disposal activities and well-planned strategies that could have minimised the long-term exposure to health risks, or even prevented the Love Canal disaster. It had taken more than 20 years after the final waste disposal activity in 1953, before residents started to experience symptoms of the chemical exposure (see delay sign 'II' for causal link between 'State management' and 'Health risk exposure,' Figure 34). The health impact created more awareness among the residents to eventually put pressure on the government to review the adequacy of the existing legislative requirements to protect public health. However, the federal legislative process was complicated and the path for a bill to be deliberated in the congress and eventually enacted would take a considerable amount of time (see delay sign 'II' for influence between 'Public interest' and 'Regulatory framework,' Figure 34). All these delays between most of the influencing factors in this CLD made this a weak balancing loop (B3, Figure 34). Also, these cumulative time lapses made it difficult to visualise the causal relationships in this CLD.

6.3.3 Economic

An underlying systemic factor contributing to this EIPE was the integration of the American economy into the war effort (Dickson 1982; Romer 1986). The close cooperation between the government and businesses was evident from the establishment of the War Production Board in 1942, with the primary purpose of harnessing industrial capabilities and resources to meet war needs (Brown 1979a). These macro-economic factors that influenced the development of the Love Canal disaster are represented by one reinforcing loop (R2) and three balancing loops (B4), (B5) and (B6) in Figure 35a. Also, the level of profit gained from the sale of industrial chemicals was dependent upon the return on investment made from increasing the production capacity (Figure 35b).



(a)



(b)

Figure 35: Love Canal's Economic Factors

6.3.3.1 Economic Driver

To support the war machinery, the US government pressured the chemical industry to increase its production and products, which created an urgent demand for investment in more production plants. With the abundant supply of hydroelectric power, salt and skilled labour, the Love Canal became an attractive location for Hooker to build its manufacturing plant.

Hooker Chemical was one of the major beneficiaries of the World War II-driven economy. Founded in 1905, Hooker started out manufacturing bleach and caustic soda. It would later invest in the production of other organic and inorganic chemicals to meet the increasing demand of the government and defence contractors. This investment in production capability reaped substantial organisational profit for Hooker (Figure 35b). According to estimates given by employees of Hooker, Jay Cull and Leonard Bryant, annual sales of the various products went from USD7.1 million in 1940 to USD38.7 million in 1958, and reached USD450 million by 1970 (Curtin 1994).

Strong growth from organisations like Hooker had filtered into the economies of the State of New York and City of Niagara Falls. It was not long before more amenities and better infrastructures were needed to support the burgeoning manufacturing industry. More schools were constructed to meet a growing

population that was seeking better employment opportunities. Following the construction of the 99th Street Elementary School on Love Canal grounds, many homes were sold between the 1960s and 70s. By 1978, average house prices had increased by more than 50% of their original value. This prosperity of the city reinforced the economic demand. The high value of houses was supported by working class people earning a good income from the demand for skilled labour within the manufacturing industries (Hay 2009a). As a result, the prosperity enjoyed by the city and state, in turn, contributed to the Gross Domestic Product (GDP) growth of the national economy. This became a positive cycle of growth, as represented by the reinforcing loop (R3, Figure 35a).

6.3.3.2 Health Protection

Wartime pressures placed high demands on productivity and diverted resources away from adequate attention to waste treatment, at a time when the organic chemical industry flourished and created toxic wastes in both quantities and toxicity that had risen to unprecedented levels. Although the legislative framework might not be as comprehensive as it could have been, it could be more costly (Guyton 1999) for organisations to persist with unfettered production growth without consideration for its long term health and safety impacts. As shown in Figure 35a, the economic driver (R3) was influenced by the need to protect the health of the residents (B5).

A survey conducted by the Manufacturing Chemists' Association revealed that only 20% of its members installed any waste treatment equipment (MCA 1938). There remained a pervasive culture of using waste burial as the primary means of exposure control while Hooker was operating in the Love Canal site. Thus, with increasing waste disposal without corresponding investment in better waste control, the accumulated exposure to chemicals eventually led to more adverse health impacts. As mentioned earlier, there was a significant time lag before symptoms of exposure to toxic chemicals were visible (see delay sign 'II' for causal link between 'Waste control' and 'Health impact,' Figure 35a). The

consequences of such health impacts included the losses of productivity, skilled labour and company reputation, not to mention increased liability such as law suits and legislative penalties. Hence, undesirable health impacts negatively influenced future investment in production.

6.3.3.3 Enforcement

The extent of health impacts from the manufacturing activities was partly influenced by the effectiveness of the enforcement by the city authorities. Feedback from adverse health impacts should lead to stronger enforcement, which would then reduce the adverse health impacts. This interactive relationship is represented by a balancing loop (see B5, Figure 35a). However, it was suggested that one of the reasons for the City's reactive approach to addressing reports or enforcement of health issues was its close economic ties to the manufacturing industry (Brown 1979b). (see balancing loop B3, Figure 35a). After all, Hooker Chemical provided employment to about three thousand workers and much needed revenue to the City. Additionally, the City of Niagara did not want to jeopardise Hooker Chemical's plan to build a USD17 million headquarters in Niagara Falls (Brown 1980).

6.3.4 Technological

Breakthrough technology played an important role in the creation of the Love Canal disaster. With the invention of Tesla's alternating current that enabled electricity to be transmitted over long distances, industry no longer had to be located near the source of electrical power. As a result, Love's plan to construct a hydroelectric dam became obsolete due to a better and more economical solution. The partially constructed canal that was to provide the hydroelectric power to the proposed model city was abandoned and subsequently used as a waste disposal site. Other technological factors that influenced the development of the Love Canal disaster included the advancement of industry knowledge about chemical properties, better controls for waste management and

improvements in health monitoring techniques (Colten and Skinner 1996, p. 46-68).

As shown in Figure 36, industry knowledge could be gained through either scientific studies or sharing of information among players within the industry. For instance, the MCA organised a pollution abatement committee in the 1930s to share waste treatment technologies within the industry, though it was not common practice due to corporate security in regard to manufacturing processes. The CLD in this figure consists of: (i) a balancing loop (B7, Figure 36) where increased knowledge would bring about better control strategies to reduce health impacts; and (ii) a balancing loop (B8, Figure 36) where a learning culture within the industry would contribute to the existing understanding of waste chemicals and their controls.

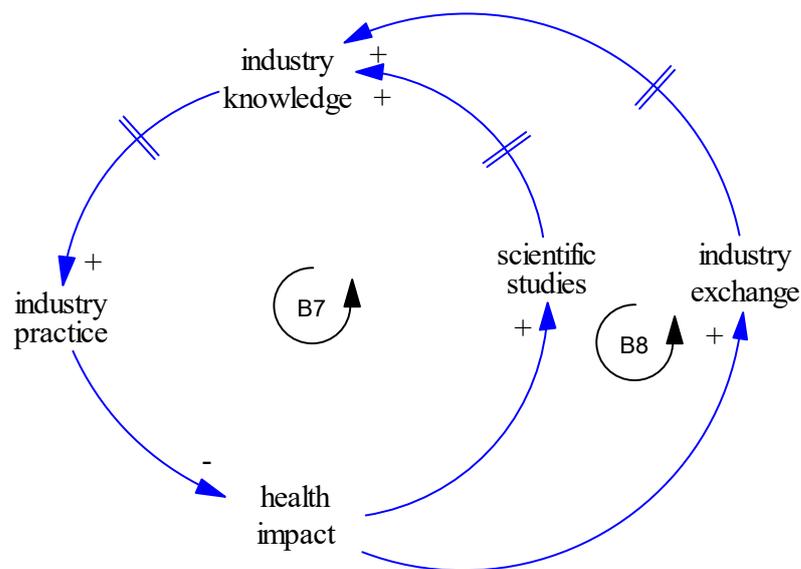


Figure 36: Love Canal's Technological Factors

Until 1980, research into stratigraphy and established methodologies of soil testing in the 1940s had been limited; therefore, there was a lack of industry knowledge about certain chemicals that could migrate through fractures in clay soils (Curtin 1994). Hooker Chemical's understanding during the 1940s and

1950s was that clay soils were impermeable, while silts and sands were permeable. According to the knowledge at that time, the chemical industry and government had no reasons to believe that industrial wastes which were buried in undisturbed clay soils would result in exposure that could cause health problems (LeGrande 1990).

Waste management and control involved complex technical knowledge that required the bridging of multi-disciplinary specialities and expertise (Colten and Skinner 1996). During the time of Love Canal, installation of waste treatment equipment was lagging behind the available technology. There were more effective and complete treatments than waste burial, but their prohibitive costs were often an impediment for more pervasive usage. Moreover, it was neither the industry practice nor the government's requirements to engage engineers, geologists, toxicologists and other scientists for site assessment, planning, design and operation. Nevertheless, as more sophisticated scientific detection techniques were made available, awareness of the full potential health threats from the hazardous substances began to increase, and that eventually resulted in better industry practices to mitigate the health impacts of chemical exposure (Dickson 1982). Nonetheless, it would take years, if not decades, before there was a transfer of knowledge from either scientific studies or industry sharing (e.g. MCA) that could be translated into practical standards and effective applications within the industry (see delay sign 'II' for causal link between 'Scientific studies,' 'Industry knowledge' and 'Industry practice,' Figure 36).

Instead of sharing the latest technology or innovation in waste treatment and control, organisations were not always generous with their findings and experience. With substantial investment poured into corporate research, companies wanted to make enough profits to cover their cost of invention and possible failures (U.S. Congress 1990, p.214) To maintain a competitive advantage, companies would not openly share information about waste disposal technologies with other manufacturers in their own industry. Instead, companies

like Hooker Chemical would dispose of its wastes on properties that they owned, rather than risk the chance of competitors acquiring the chemical compounds from municipal waste dumps or sites that they did not have control of (Colten and Skinner 1996, pp.135, 146). Hence, the limited industry exchange is represented by a reinforcing loop (see R4, Figure 36). Otherwise, such sharing of information among the manufacturers could have contributed to better industry knowledge, and the development of better industry practice, to minimise the health impacts from chemical exposure.

Rather than a search for truth, scientific studies could be used as political tools to endorse the position of a certain party or lobby group. When the seriousness of the Love Canal problem required national intervention, scientists were engaged to determine the impact upon public health caused by chemical exposure. Controversies surrounded the different studies conducted by the government agencies (e.g. NEPA's chromosome study in 1980) and community interest groups (e.g. Swale Theory in 1978, Dr Paigen's study in 1980) with competing interests. Far from being objective and reliable sources, findings from these studies were used to manipulate and justify certain policy decisions (Mazur 1998).

6.3.5 Social

EIPes became more than just health or environmental issues; there were wider social implications, with the potential to destroy homes and communities, as seen in the Love Canal case. The tension between meeting the needs of a growing society and recognising the health implications of the industry's expansion and infrastructure development was well documented (Costa and Steckel 1997; Freudenberg, Galea, and Vlahov 2006; Frumkin 2006).

The cheap and abundant source of hydroelectric energy powered by the massive Niagara Gorge attracted investment from industries such as chemical and steel manufacturing (see Figure 37). Consequently, immigrants from Europe contributed to the population boom in the city. In 1970, Niagara Falls had a population of almost 86,000 with 9 major chemical producers employing more than 5,000 people in the county. There were almost 100 homes with around 350 residents living close to the canal. About 400 students were enrolled in an elementary school that was built in 1954 (NYDOH 1981). Hence, the post-war baby boom had put pressure on the School Board to build more schools to cater for the needs of a growing population. Armed with a tight budget to source new school sites, the School Board took interest in the low-priced land surrounding the Love Canal waste disposal site. This pressure of urbanisation and industrialisation experienced by the city, where it was constantly trying to catch up with the increasing societal needs, is reflected in the reinforcing loop R5 (see Figure 38a). That is, infrastructure investment was driven by the increase in population (Figure 38b).



Figure 37: Industries Along the Niagara Gorge and River Around 1890s (Niagara County 2008)

Since most industrial plants were located away from residential areas, community interest and awareness about the hazards of chemical waste disposal on land had been rather low in the 1940s and 50s. As long as waste disposal was carried out away from public view, it rarely attracted any attention from the regulators. As long as radioactive and toxic chemicals were dumped in covered earth, they were not considered to present long-term health or environmental problems (Curtin 1994). People had always thought that illness could only be caused by direct contact or ingestion. Low-level exposure to chemicals was an unknown entity until much later. Public interest in industrial contamination only gained traction around 1976, when major stories about PCB contamination broke, and reports of the explosion in Seveso, Italy, publicised the dispersion of toxic dioxin to nearby residents. This coincided with the increasing complaints by residents about chemical invasion into their homes (Mazur 1998).

This significant time lapse from the time when Hooker started disposing of the toxic waste in 1942 is noted with the delay sign 'II' on the causal link between 'Health impact' and 'Societal awareness' (B9, Figure 38a). Acknowledgement of possible health problems only came in 1977 and 78 when government agencies started to investigate complaints about chemical exposure. Further scientific studies resulted in better understanding of the extent of contamination and morbidity.

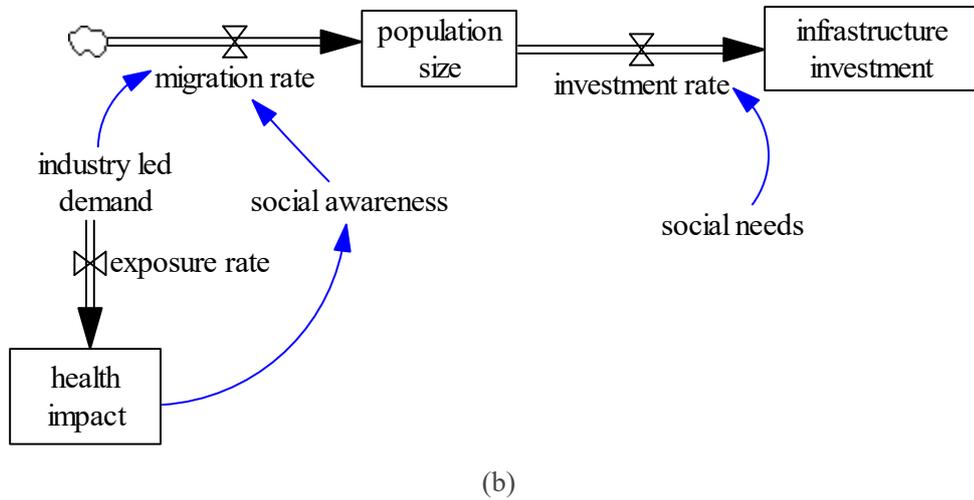
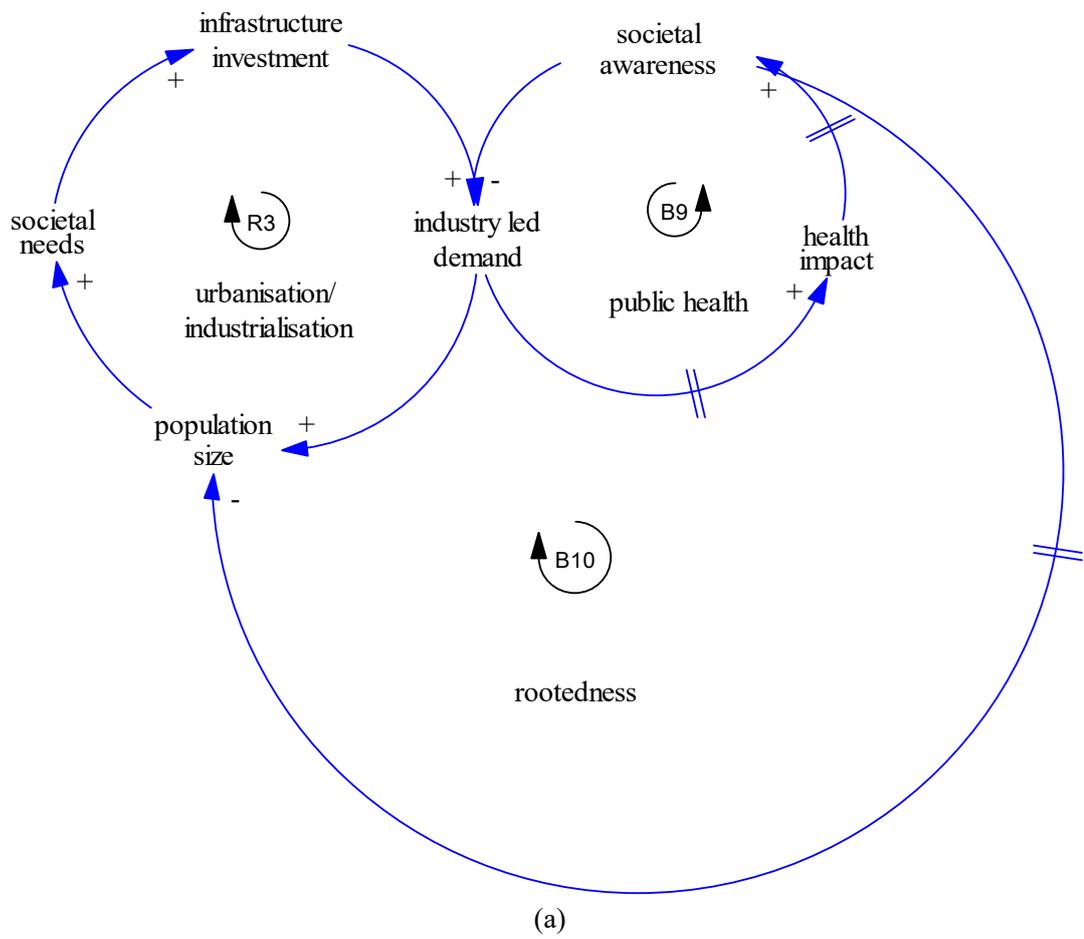


Figure 38: Love Canal's Social Factors

Societal awareness increased with the subsequent involvement of residents of the Love Canal, and persistent news coverage eventually attracted the attention of the government agencies. The Niagara Gazette covered the Love Canal stories for more than two years before they became national headlines. Other papers like the Buffalo Evening News and the New York Times also published several articles relating to the Love Canal (Ploughman 1995). After the Love Canal was declared a disaster area, requiring evacuation of families, grass root organisations such as the Love Canal Homeowners Association (LCHA) and the Ecumenical Task Force of the Niagara Frontier (ETF or Task Force) helped to organise the relief efforts for the disaster (Hay 2009b).

From the above, it appeared that the “urbanisation/industrialisation” reinforcing loop (R3, Figure 38a) was counteracted by the public-health balancing loop (B9, Figure 38a), albeit at a much weaker strength and moving at too a slow a pace to be causing any substantial impact upon the more dominant urbanisation and industrialisation cycle. Due to the increasing societal awareness of the Love Canal disaster, families were no longer interested in setting up homes in a hazardous environment, so the population size decreased. In fact, after declaration of the Love Canal as a health emergency area, the government bought out hundreds of homes (Philips, Hung, and Bosela 2007). Therefore, the influence of the societal awareness on population size is reflected in the balancing loop “rootedness” (B10, Figure 38a) and the SFD (Figure 38b).

6.4 Internal Organisational Factors

Internal organisational factors refer to the HSE Management System or the way in which health and safety are managed within an organisation. These internal factors include policy, planning, implementation and checking (monitoring and evaluation) are part of the operational activities driven by PLETS-informed business strategies. Much of the evidence for this case was drawn from the analysis of the seven-day trial – US vs. Hooker Chemicals & Plastics Corp. 850

F. Supp. 933 (1994) - by Judge John Curtin. Both pre-transfer and post-transfer events of the Love Canal disposal site will be discussed (U.S. District Court (NY) 1994). Pre-transfer refers to events before Hooker deeded the Love Canal site to the Niagara Falls Board of Education in 1953. After the transfer of the disposal site, or post-transfer events, the City of Niagara Falls, New York State Department of Transportation (NYSDOT), and private housing developers disrupted the waste disposal site through various construction activities.

6.4.1 Policy

Based on the available evidence, there was little information to determine how Hooker Chemical and the School Board defined their organisational HSE policies. Neither was there any way of establishing the content of the policies to help understand the kind of commitment Hooker Chemical made to prevent injury and ill health in the workplace. However, the board's and top management's decisions provided some basis for the type of policies that were put in place. For instance, Hooker Chemical might not have an explicit policy against the sale of the waste disposal site, but its actions in the negotiation process demonstrated a certain level of desire not to allow any misuse of the land. The site was deeded to the School Board with the understanding that it would only be used for school and park construction, and not for private property development, as was later discovered. Understandably, whatever policies were in place did not necessarily mean adherence to them at all times (U.S. District Court (NY) 1994, pp.1020-1031).

From the planning perspective, there was some evidence to suggest that the School Board, made up entirely of volunteer directors, lacked the necessary expertise and experience to exercise due diligence in HSE matters. If the School Board had any kind of written policy to express its commitment to HSE, then its approach to acquiring the Love Canal site certainly did not demonstrate that commitment (Mazur 1998, p. 38).

6.4.2 Planning

6.4.2.1 Hooker Chemical

Among the common reasons for corporate planning within the chemical industry were desires to avoid lawsuits for property damage or personal harm, to control insurance costs, to maintain a good public image and to prevent government interference with company operations. Such corporate concerns were reflected in Hooker's 1944 Annual Operations Report where it highlighted the potential future liabilities of burying chemical wastes. Years before that, Hooker already knew that exposure to chlorobenzenes, arsenic trichloride and trichlorophenol could cause a range of health impacts (Hernan 1994). Nonetheless, it was not clear how much of the warning was heeded, or lessons learned, as a contribution to the risk management planning process.

The extent to which Hooker Chemical developed, implemented and maintained a procedure for the identification of hazards, assessment of their risks and determination of the necessary controls could only be considered as haphazard. There was some evidence that Hooker Chemical took into account workers and residents who might access the waste disposal site (U.S. District Court (NY) 1994, p. 1008, 1025).

The policy and planning factors relating to Hooker Chemical are represented on the left portion of the CLD in Figure 39. In this CLD, a 'shifting-the-burden' archetype (Senge 2006) was used to explain the tension between two balancing loops (B11) and (B12) and the side-effect of the reinforcing loop (R4).

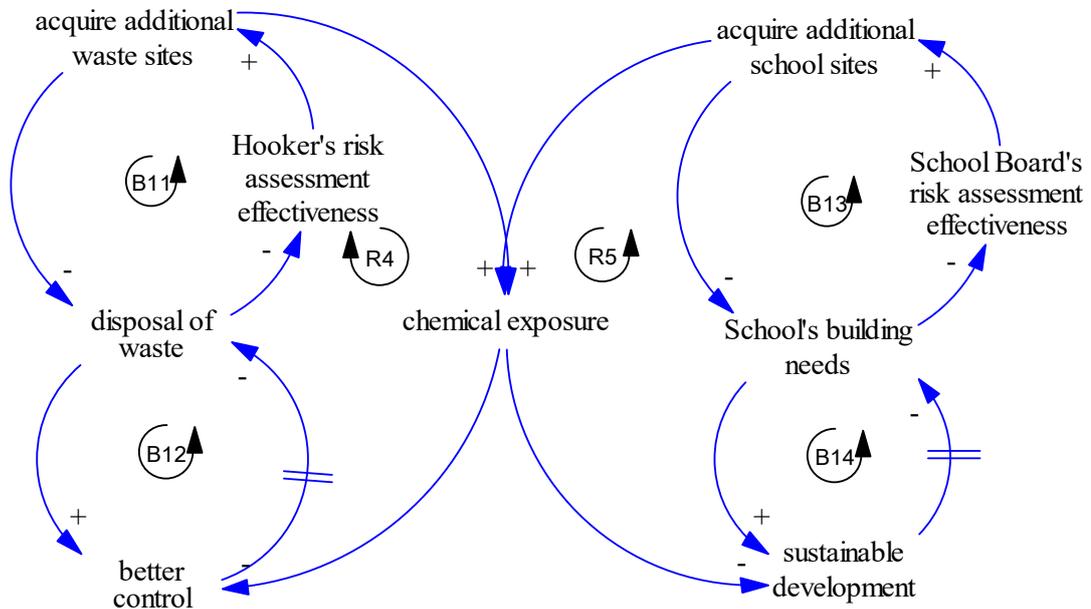


Figure 39: Love Canal's Planning Factors

With expanding business, Hooker Chemical started its feasibility study for use of the Love Canal as a waste disposal site, in 1942. It was eventually selected as an appropriate site because of the impermeable clay characteristic of the soil, and the sparse population in the area (Zuesse 1981). However, the outcome of this risk assessment was not based on all the available information made known to Hooker. Thirty years prior to the Love Canal disaster, staff at Hooker Chemical had foreseen a "potential future hazard" and a "quagmire at Love Canal which will be a potential source of lawsuits" (Glaberson 1990, p.1). Expert testimony at the US vs Hooker Chemical suit revealed that Hooker Chemical had recognised, through various literature and data sources, the toxicity of different chemicals manufactured or used, and the damages they could cause to human health (U.S. District Court (NY) 1994, p. 998, 1011). In fact, some of the workers did suffer from skin diseases caused by contact with chemicals (Curtin 1994). As shown in the balancing loop (B11, Figure 39) it appeared that an inadequate risk assessment justified the acquisition of the Love Canal site, which increased the availability of sites for waste disposal.

Not long after the acquisition of the Love Canal site, an internal memorandum (dated August 1946) from Hooker Chemical's lawyer, Ansley Wilcox, warned Hooker Chemical's president, Barlett, about the contamination of the site. Following the development of the city, similar concern was expressed in March 1952 by Hooker Chemical's executive vice president, Bjarne Klaussen, that it might be "advisable for us to discontinue using the Love Canal property for waste disposal ground...It is also rather clear to me that we should not sell the property in order to avoid any risks." However, with the threat of condemnation proceedings from the School Board, Klaussen would later change his mind by supporting the sale of the property as a means of reducing liability (Glaberson 1990, p.1). The deal did not receive the support of everyone. A former Hooker Chemical plant superintendent warned management that the property was not safe for any kind of development. He later testified, "...we knew, with what was there, the safe thing to do was keep it away from everybody forever" (Glaberson 1990, p.3).

Although the decision to acquire the Love Canal site might have temporarily relieved the pressure to increase the stock for disposal sites, it delayed the investment in better waste controls (e.g. effective waste incineration equipment), since the site conformed to the RCRA regulations at that time (Mazur 1998, p. 19). This approach of using a symptomatic solution (acquire waste site) to alleviate the problem (disposal of waste), and temporarily reducing the pressure to invest in a fundamental solution (better control) led to the side-effect of chemical exposure. The weak balancing loop (B11, Figure 39) represents what could have been an investment in better solutions to address the ever-increasing need for waste disposal. In the same loop, the delay sign on the causal relationship between 'Disposal of waste' and 'Better controls,' signifies the long-term impact of resolving such underlying problems (see Figure 39).

As the waste disposal site was becoming a liability, and coming to the end of its operational effectiveness, Hooker Chemical finally decided to sell the land to the School Board for the symbolic price of a dollar, in April 1953. To ensure that the buried chemicals were not disturbed, Klaussen suggested that a school and a sports field could be built on specific sections of the canal (U.S. District Court (NY) 1994, p. 1021). Also, Hooker Chemical included in the deed that it would not be held liable for injury or death to people who might come into contact with the industrial waste.

Despite the explicit disclaimer and the clear warning about the hazardous wastes, the School Board was not discouraged from procuring the property for its school construction (Denblanx 1953). However, Judge Curtin believed that Hooker Chemical could have provided the School Board with more information about the physical properties and toxicity of the buried chemicals. Also, Hooker Chemical did not carry out any assessment of the School Board's capacity to monitor and to maintain the chemical waste disposal site. Certainly, there was no suggestion to the School Board of the requirement for training that should be given to the staff and residents regarding the dangers of the chemicals in the area (Curtin 1994).

6.4.2.2 School Board

The School Board did not fare any better in their planning for hazard identification, risk assessment and determination of controls. In fact, it had already begun planning for the development of schools on the Love Canal site before seeking development approval from the Niagara Falls Planning Board in December 1952. The main reasons for the School Board's decision to acquire the Love Canal site were the urgent need to build more schools for a growing population and the lower than average land price around a relatively low density area at that time (Zuesse 1981). However, the School Board was made up of members who did not have the necessary knowledge and expertise to assess the suitability of the land for sale (U.S. District Court (NY) 1994, p. 1029).

Neither was there evidence of Hooker's attempt to ascertain whether they had the necessary resources and competency to manage the disposal site (U.S. District Court (NY) 1994, p. 1027).

Initially, Hooker Chemical was reluctant to sell its waste disposal site to the School Board because of safety concerns. However, faced with the threat of condemnation causing Hooker to be in a position where it could not reject the School Board's bid to procure the land, Hooker decided to sell the land to the School Board (Ives 1997). To ensure that the School Board had full knowledge of the property condition, Hooker Chemical had incorporated in its sales deed information about the presence of hazardous chemicals buried on the site (Denblanx 1953). Hooker Chemical was so concerned about potential misuse of the property by future owners that it proposed special provisions to restrict the use of the property for park development and nearby school construction only; should the property cease being used for the intended purpose, then the title would revert to Hooker Chemical. However, the School Board rejected the proposal and Hooker Chemical settled for a liability provision and warnings in the deed to all future title holders of the property (Zuesse 1981, p. 2). Despite a warning from the School Board's own attorney about possible liabilities that the board could be exposed to by accepting the deed, the School Board unanimously voted to acquire the land in May 1953. After the sale of the waste disposal site, Hooker Chemical made unsuccessful attempts to stop the sale of the site to external parties for private development of the property (Mazur 1998, p. 32).

Even after they acquired the property from Hooker Chemical, the School Board continued to rely on Hooker Chemical to provide the necessary expertise to assist in the management of chemical exposure issues (U.S. District Court (NY) 1994, p. 1029). This was due to the lack of competency within the School Board, which was made up of part-time volunteers. They exhibited little evidence of overseeing HSE other than to accept the recommendations of the Buildings and

Grounds Committee. The board probably did not consider the property to warrant special attention, because other schools situated near chemical waste disposal sites had no health related complaints (Mazur 1998, p. 38).

Despite information from the Chairman of the Building and Grounds Committee that the property should only be used for a school and park, and not for any other types of development, the board wanted to trade part of the Love Canal property to other developers in return for other properties and some profit (Zuesse 1981, p. 1). When Hooker Chemical discovered the School Board's intention, in 1957, its attorney warned the board that the buried chemicals made the property unsuitable for development with basements, water lines, sewers and other underground services (Zuesse 1981, p. 3). In spite of explicit warnings from Hooker Chemical on two separate occasions, the School Board auctioned a section of the land to a private developer in 1961. The deed had added an indemnity clause to protect the School Board from liability, because the School Board was aware of the hazardous condition of the land it had sold. Subsequent transfers of land ownership to other developers had not included the original full warnings and restrictive provisions from Hooker Chemical (Ives 1997).

From the above, it appeared that the School Board did not carry out adequate risk assessment of the Love Canal acquisition, despite warnings from Hooker Chemicals and its own attorney about the hazardous chemicals. There was little evidence of other long-term considerations, such as public health impacts from the acquisition of an industrial waste site, which were overshadowed by the more immediate concerns of space and budget. These policy and planning factors relating to the School Board are represented by the right portion of the CLD in Figure 39. The School Board shared the same 'shifting-the-burden' archetype (Senge 2006) as that of Hooker Chemical. Similarly, the dominant balancing loop (B13, Figure 39) was barely influenced by the absence of any sustainable development to address the lack of school facilities, as shown in balancing loop B14 (Figure 39). Meanwhile, the acquisition of the Love Canal

site for school construction created a higher risk of exposure to hazardous chemicals, which undermined the sustainable development of the city (see R5, Figure 39).

6.4.3 Implementation and Operation

6.4.3.1 Consultation and Communication

Other than operational communication within Hooker, consultation with other stakeholders such as engineers, geologists, and/or scientists for the siting, design or operation of the site was not an industry practice during that time (U.S. District Court (NY) 1994, p. 1049). Communication and consultation with the School Board before the site transfer was focused mainly on the terms and conditions of the sale. After the transfer, communication between Hooker Chemical and the School Board were reactively driven by reported incidents from the development of the site, rather than the proactive management of chemical risk exposure through internal audits or inspections (U.S. District Court (NY) 1994, p. 1028 - 1037). Consultation could take place after reported incidents of chemical exposure (see R6, Figure 40) without any immediate observable health impact (e.g. fire at disposal site, chemical leak) and/or after a health impact (e.g. chemical burns, developmental problems in children) from the exposure had been observed (R7, Figure 40).

In the early 1940s, Hooker Chemical, government agencies and other experts explored ways of preventing a serious skin disease called Chloracne. As a result, Hooker Chemical implemented a series of engineering controls and operating procedures, which reduced the incidences of Chloracne (U.S. District Court (NY) 1994) (B15, Figure 40). This health impact-driven consultation to achieve better operational controls against chemical exposure is represented in the reinforcing loop R7 (see Figure 40).

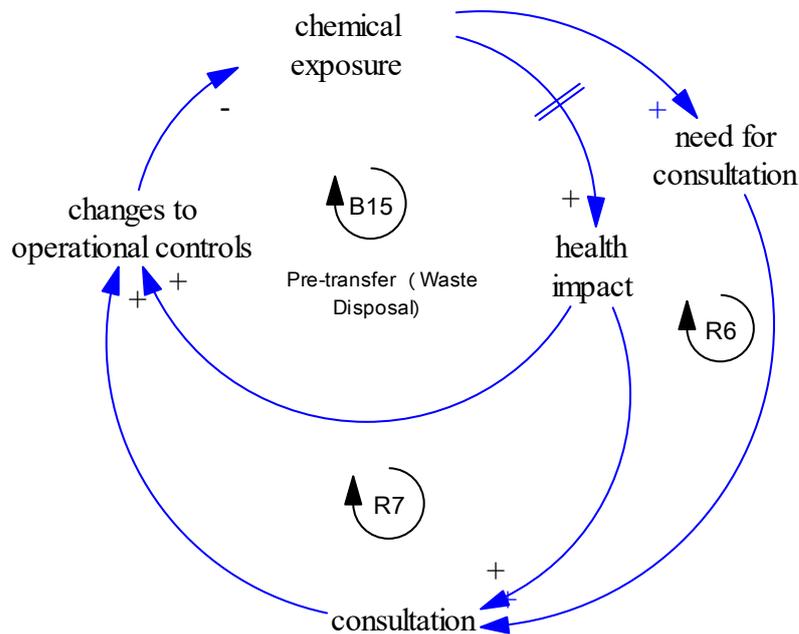


Figure 40: Love Canal's Pre-Transfer Waste Disposal

However, consultation and sharing of technical information did not always take place between Hooker Chemical and the School Board. For instance, German research on the toxicity of dioxin was reported to Hooker Chemical, but this same information was not communicated to the School Board (Hernan 1994). When the School Board decided to profit from part of the property for home construction, Hooker was not informed about this decision. When Hooker discovered the plan, it opposed such a transfer and reminded the School Board about the earlier warnings against improper use of the land (U.S. District Court (NY) 1994, p. 1031, 1032).

After the title deed had been transferred to the School Board, Hooker Chemical continued to render assistance to the School Board on its own initiative, which won the support and praise of local officials (Curtin 1994). Such advice proved to be necessary when contractors for the School Board did not have accurate information about the waste disposal sites. While constructing the schools in 1941, excavation activity hit chemical deposits that were not previously made

known to the contractors (Mazur 1998).

During the excavation of Wheatfield Ave by the City, between 1959 and 1962, drums of buried chemicals were disturbed (see Figure 41). Other than providing basic advice on ditch shoring and backfilling, Hooker Chemical did not warn the city workers of the necessary safety and health precautions to take (U.S. District Court (NY) 1994, p.1035). Furthermore, Judge Curtin (1994) felt that the City should also put in place more effective control measures to minimise chemical exposure.



Figure 41: Drums of Toxic Waste Removed from Love Canal Site (ETF 2009)

After acquiring the property from the School Board in 1968, state contractors came across chemical residues during the construction of the LaSalle Highway. Hooker Chemical advised the State Engineer that the flammable material should be covered to prevent possible ignition when dried (U.S. District Court (NY) 1994, p. 1035).

Analysis of samples in November 1976 confirmed that chemicals had been released from the Love Canal and had migrated to the city sewerage system. Consequently, Hooker Chemical, the School Board, the NYSDEC, the City and other interested parties got together to discuss ways to address the issue. Except for the State and NEPA, the rest of the stakeholders formed the Love

Canal Study Group to investigate the extent of the problem and to recommend proposals for resolving it (Curtin 1994). Subsequent data from surveys conducted by the NYSDOH suggested a serious health hazard in the Love Canal. Other studies carried out by independent scientists and NEPA revealed other health impacts, though there was much controversy about the epidemiological evidence (Ives 1997). It appeared that health impacts had led to some level of consultation among government departments, scientists and residents, which would then help to develop better control measures to minimise such health impacts due to the risk of chemical exposure (see R9, Figure 42).

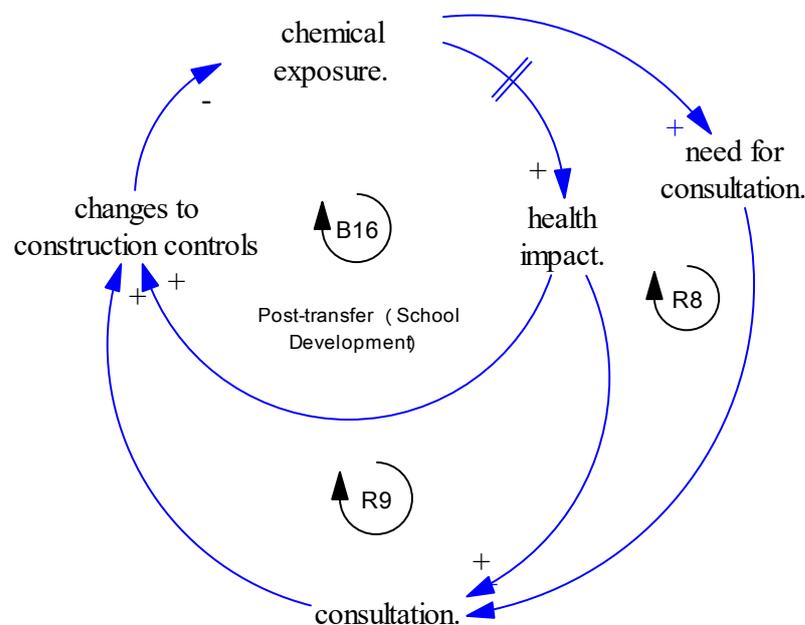


Figure 42: Love Canal's Post-Transfer Waste Disposal

The above incidences of chemical exposure due to construction activities carried out by the School Board and the City resulted in Hooker providing some level of consultation or advice for remedial actions. Although such consultation was triggered only after there had been reported exposure to chemicals, it contributed to changes in the construction controls that mitigated the risk of further exposure to hazardous substances (see R8, Figure 42). The input from

Hooker was considered important, since it appeared that the City or the School Board, as operators and new owners of the site, did little to mitigate the risk of chemical exposure. Indeed, Hooker, being better informed about the toxic chemicals it used, was held to a higher standard of accountability than that of the School Board (U.S. District Court (NY) 1994, p. 999).

Therefore, in terms of consultation, the post-transfer CLD (Figure 42) shares the same structure and feedback loop as that of the pre-transfer CLD (Figure 40). Pre-transfer consultation was involved mainly with employees of Hooker, residents and some government departments, while post-transfer consultation was mainly between Hooker and the School Board, and among government agencies.

6.4.3.2 Operational Controls

In order to minimise legal risks from off-site exposures, the majority of industrial wastes were stored or buried on properties owned by the organisations, which were out of sight and did not burden the public (U.S. District Court (NY) 1994, p. 1053). The management and plant personnel in these organisations would have the responsibility for selecting appropriate disposal methods, but often short-term considerations dictated the control measures used. Furthermore, indiscriminate disposal of industrial wastes in pits, ponds or lagoons were common practice in the 1940s, 50s and 60s (Colten and Skinner 1996).

A long period of chemical exposure could lead to undesirable long-term health impacts (Goldman et al. 1985; Paigen et al. 1987; NYSDOH 2012), which should trigger consideration for better operational controls in order to minimise any risks due to chemical exposure. While there was no total absence of controls, the adequacy and effectiveness of some of these controls (e.g. no fencing of a contaminated swimming/recreational area and/or warning signs to warn others of any potential exposure to hazardous chemicals) were issues facing Hooker Chemical (U.S. District Court (NY) 1994, p. 999).

In accordance with the general industry practice of that time, various operational controls were either explored or implemented to minimise the safety and health impacts of chemical exposure at Hooker (see B15, Figure 40). Evidence of the use of engineering controls to minimise chemical exposure could be seen on several occasions in the 1940s, where incineration was proposed and attempted as a way of reducing DDM (Dodecyl Mercaptan) production waste, even though it cost twice as much to burn as to dispose of (Colten and Skinner 1996). Eventually, the complex engineering problems faced by the incineration method proved to be a non-viable option for the kind of chemical used and the immature technology that was available at that time. Since 1941, when Hooker started to dispose of thionyl chloride, it had been improving its production process to reduce wastes. Other control measures included safety instructions for workers handling DDM to wear personal protective equipment and to use adequate ventilation (Curtin 1994).

Conversely, some of Hooker Chemical's practices demonstrated a lack of basic operational control to minimise the exposure to hazardous substances. For instance, between 1942 and 1953, approximately 22,000 tons of toxic chemicals were dumped in mainly old and rusty metal drums (see Figure 41), which would readily break apart, and sometimes wastes were dumped "directly into the canal" (Hernan 1994, p.52). When the drums broke apart during the disposal, Hooker Chemical's employees were burned by the contact with the flammable chemicals (Ives 1997). While Hooker Chemical intended to dump drums to within 0.5 - 1.2 metres below the original ground surface, and to have at least 1.2 metres of cover, that was not consistently achieved (Mazur 1998). Other non-conformances to planned controls included the non-covering of the drums on the same day they were disposed of until the pit was filled (Curtin 1994).

Such non-compliant disposal practices had facilitated the movement of chemicals due to shifting water tables (Mazur 1998). Some suggested that Hooker Chemical knew it was a matter of time before the drums would

deteriorate and the chemicals would migrate to the surface (Hernan 1994), as can be seen in Figure 43.



Figure 43: Toxic Wastes Migrated to Surface of Love Canal Site (Ploughman 1978)

Another violation of common industry practice was the lack of basic engineering safeguards such as adequate fencing or barricades, which increased the risk of chemical exposure and the insurance premium. Except for the northern section of the canal, part of the waste disposal site had no fence. Also, unfilled sections of the Love Canal were accessible to the public, who were using it as a swimming pool (Colten and Skinner 1996). Neither were there any warning signs to alert nearby residents of the presence of chemicals. According to Rep. Albert Gore, a member of the House commerce investigation committee, Hooker failed to warn residents of the risk from exposure to hazardous chemicals due to its fear of legal liability (Associated Press 1979).

Nevertheless, during the court proceeding (Curtin 1994), an expert witness for the OCC, Mr. Metzler, who was the Deputy Commissioner of the NYSDOH in 1966, and the Deputy Commissioner of the NYSDEC in 1970, provided a different perspective. He testified that Hooker Chemical's practices were adequate for that time and certainly above the industry norm.

6.4.3.3 Post-Transfer

Even after the land was sold to the School Board, Hooker Chemical exercised its condition of sale to continue waste disposal of chemicals and fly ash on the waste disposal site (U.S. District Court (NY) 1994, p. 1027). During the post-transfer period, attention was shifted to the operational controls implemented by the new owners (School Board and the City) of the property. Evidence showed that the School Board lacked the experience and technical expertise to maintain the integrity of the property and had to rely on Hooker for several incident interventions (U.S. District Court (NY) 1994, p. 1028, 1029). For instance, without proper supervision and adequate knowledge of the risks posed by the toxic substances, the City's contractors contributed to the destruction of controls originally placed to mitigate the risks of chemical exposure (Zuesse 1981). The post-transfer CLD (see Figure 42) shares the same structure and feedback loops as that of the pre-transfer CLD (see Figure 40). The only difference is that the 'Operational controls' exercised by Hooker have changed to 'Construction controls' used by the School Board.

On two separate occasions, in August 1953 and in January 1954, the School Board approved the removal of part of the protective clay cap, in order to use a combined total of 5,350 cubic metres of dump ground as fill dirt for other school sites. More inconceivably, in 1957, the City of Niagara Falls workers punched holes in the impermeable walls and clay cover to make way for new water lines and manholes. This breach of the protective wall was repeated in 1960 when the City built another sewer in another part of the property. Further aggravating the already compromised structure of the canal walls, the NYSDOT punctured the protective walls during the construction of the highway in 1968 (Zuesse 1981). Careless treatment of the waste disposal site by state contractors was evident when excavated soil containing hazardous chemicals was left uncovered. It was not until the nearby residents complained about the smell that the contaminated soil was eventually covered, but only with permeable construction material and

other waste (Curtin 1994).

Therefore, poorly planned and implemented controls by the new property owners, the School Board and the City, led to incidences of chemical exposure and long-term health impacts during construction of the school and city infrastructures. Depending on the HSE commitment of the property owners, they could have drawn from the lessons of the negative health impacts and developed better controls to reduce the risk of chemical exposure. Evidence suggested that they did little other than to consider advice from Hooker to install better construction controls (see B16, Figure 42).

6.4.4 Checking and Review

6.4.4.1 Performance Measuring and Monitoring

In order to maintain a proactive approach to incident prevention, there had to be a system to monitor and evaluate HSE performance regularly. Owners of the property would need to develop, implement and maintain procedures for evaluating their compliance with the applicable legislative requirements and best practices. Available evidence suggested that there was a lack of measuring and monitoring of HSE performance by both Hooker Chemicals and the School Board.

According to the American Institute of Chemical Engineers, the Love Canal disaster was not caused by any design lapses, since designs complied with the standards of the RCRA at that time. "What went wrong with Love Canal can be attributed in large part to lack of monitoring, invasion of the site itself, and lack of remedial work" (Zuesse 1981, p. 4). Besides the lack of site monitoring, there was inadequate environmental and health risk assessment carried out by Hooker (Levine 1982). This claim was similarly supported by a private engineering firm, Conestoga-Rovers Associates of Waterloo, engaged by the City to assess the Love Canal waste disposal site (Zuesse 1981).

Poor performance of HSE could be determined from both internal and external reports of work conditions. Over the disposal period, workers of Hooker Chemical noticed the settling and subsiding of the previously filled areas. The loss of soil and top cover caused the buried chemicals to be exposed and the associated odour to increase (Curtin 1994). An internal report written by Hooker Chemical's engineers and doctors strongly criticised the company's handling of toxic chemicals. The report highlighted the undesirable plant condition and identified the C-56 (a component of the pesticides) to have a serious impact on the environment (Love Canal Homeowners Association Inc 1980). Other incidents of unsafe disposal reported by NEPA administrators included disintegrated waste disposal drums, dying plants, a dislodged swimming pool floating on chemicals, and puddles of hazardous wastes that could be seen scattered in various parts of the residential areas and school grounds. Also, children (Figure 44) had chemical burns on their bodies after playing on the contaminated ground (Eckardt 1979b).



Figure 44: Children Playing in a Backyard Adjacent to the Waste Disposal Site (ETF 1978)

6.4.4.2 Incidents, Non-Conformance and Corrective Actions

A healthy HSEMS operates in a manner that uses feedback and inputs to continually improve its management of risks. When an organisation identifies a problem, whether through reported hazards, incidents or non-conformances with guidelines or standards, it implements the necessary corrective actions to prevent their reoccurrences, and to improve its management of HSE. In the case of Love Canal, there was a lack of evidence to suggest that Hooker and the School Board had anything that closely resembled such a comprehensive system.

Before the mobilisation of state government investigation in 1976, there had already been reports of chemical odours, minor explosions and fires (NYDOH 1981). When fires and explosions happened, they exposed the buried chemicals to residents in the area. Existence of these incidents were confirmed by the 1979 congressional investigation, which revealed that city officials and Hooker Chemical had knowledge of the chemical burns suffered by children as early as 1958 (Brown 1979a). Also, the analysis of residue from the Love Canal, and other correspondence to Hooker Chemical, indicated the possible link of a health hazard to the waste disposal site (Love Canal Homeowners Association Inc 1980).

Nonetheless, not all accidents or incidents were reported to Hooker Chemical (U.S. District Court (NY) 1994, p. 1038). Evidence suggested that Hooker Chemical had, on most occasions, taken some kind of corrective action when reports of abnormal events were made known to them. Although Hooker Chemical responded with some level of assistance to all reported complaints of chemical exposure, fires, subsidence, exposed barrels and chemical contact, the State felt that Hooker Chemical could have provided more detailed information to the School Board and residents to better deal with the risks of chemical exposure (U.S. District Court (NY) 1994, p. 1039).

As early as the 1940s, Hooker Chemical employees experienced skin diseases caused by the toxic chemicals. Subsequently, control measures were put in place to bring down the number employees suffering from dermatitis (Curtin 1994). Other chemical exposures were concerned with the spillage of DDM from the drums and its migration to the ground in 1944. Hooker Chemical resorted to site containment for waste disposal after its unsuccessful attempts to get rid of the residues. There were no further incidents of DDM flowing to the surface after 1945 (Curtin 1994). However, starting from the 1950s, the City and the School Board had been receiving reports of strange odours and unknown chemicals seeping through basement walls (Niagara Gazette 1979; Brown 1989).

During the construction of the 99th Street School in 1954, workers uncovered waste disposal sites filled with chemical wastes. The discovery prompted the project architect to warn the education committee that it would be 'poor policy' to build in an area of non-assessed chemicals with, possibly, a compromised foundation (Levine 1982, p.12). Consequently, the school building was shifted about 9 metres from its original plan, citing poor soil condition rather than HSE concerns as the reason for the move. Although a management representative from Hooker Chemical had inspected the site when the chemicals were discovered, he did not recommend an analysis of the chemicals in order to better understand their safety and health implications (Curtin 1994).

In May 1955, a large crater formed in the playground at the 99th Street School and exposed the buried chemicals. One of the children playing in that area was burned by the chemicals and had to be given first aid treatment. Subsequently, Hooker Chemical arranged for ten truckloads of soil to backfill the exposed crater (Curtin 1994). A year later, the school architect instructed the contractors to relocate the kindergarten play area, in order to avoid the waste disposal site that was experiencing continuous subsidence. The School Board was aware of the discovery of the soil subsidence, but it did not seek Hooker Chemical's

advice on the health impacts of such chemical exposure (Curtin 1994).

As far back as 1958, Hooker Chemical was aware that a few children had suffered burns by contacting exposed chemicals on the surface of the canal, which had only been covered with fly ash and soil. To avoid possible legal repercussions, the company chose not to warn the residents of the hazardous chemicals (Brown 1989). Inspection of the site by Hooker Chemical revealed that inconsistent compliance to instructions for the disposal of waste thionyl chloride, and the subsidence of soil that had exposed the benzene hexachloride spent cake, had resulted in increased risks to public health (U.S. District Court (NY) 1994, p. 1033). The lack of periodic monitoring of disposal activities allowed such unsafe practices to go unnoticed and without prompt rectification.

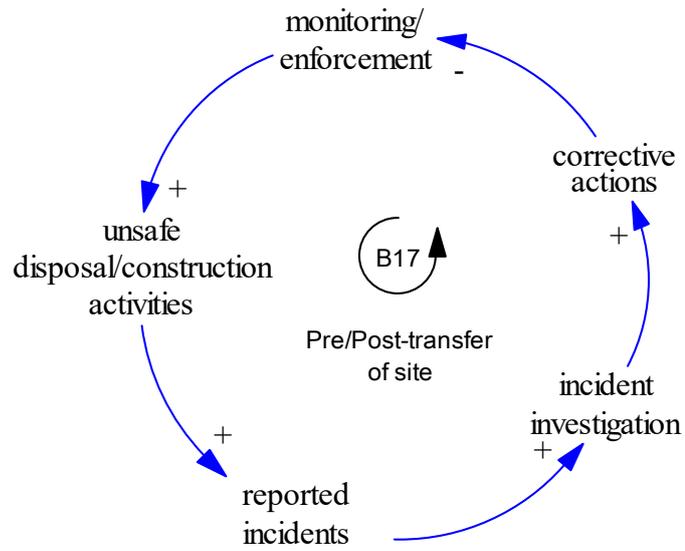
The school principal reported, in 1960, that part of the land near the parking lot and in the playing field had collapsed, exposing chemical drums. Also, puddles of chemicals on the school grounds had come into contact with children going to and from the school (Curtin 1994). Other visible evidence of chemical exposure included reports of visible fumes being emitted from the baseball field in 1969 (Curtin 1994).

During the construction of Reed Avenue by the City, between 1957 and 1962, residents went near an un-barricaded trench and one of them became ill from the chemicals released from the disintegrated drums (Curtin 1994). Residents also complained about odours being emitted from the property in 1971. Consequently, Hooker Chemical investigated and found exposed drums and potholes along the length of the canal. In that same year, Hooker Chemical learned that a child had been burned by chemicals at the northern section of the canal, so the School Board and the City were advised to cover the area with additional earth. There were more incidents of chemical burns sustained by children in the following year. Upon the advice of Hooker Chemical, the Fire Department subsequently hosed the area down (Curtin 1994).

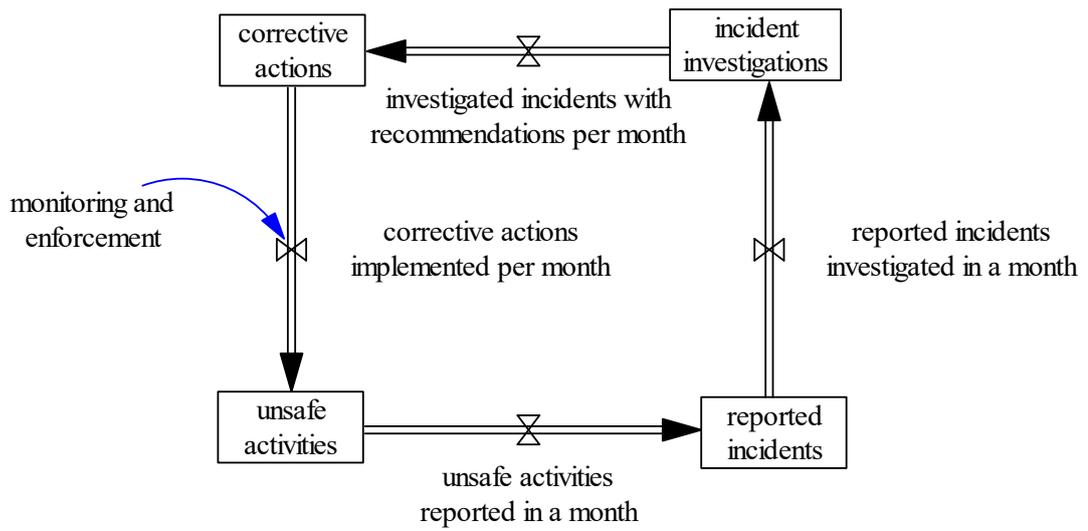
In 1976, there was a complaint about exposed Aliphatic Acid in a hole dug by children. Hooker Chemical advised the NCHD that the hole had to be covered and the children should not play in that area (U.S. District Court (NY) 1994, p. 1037). In that same year, a site inspection confirmed that chemicals had migrated into the sewerage system. Soon after, the Love Canal Study Group was formed to look into preventive measures to stem the discharge of chemicals. As one of the parties in the study group, Hooker Chemical cooperated throughout the remedial planning by contributing to the investigation, and supplying equipment and plant for the site investigation.

Despite the thunder storm and heavy snowfall in 1977 that caused the contents to overflow into the surrounding neighbourhood, and increasing complaints about chemical exposure as a result, the City of Niagara Falls showed no urgency in addressing the issue. Unfortunately, subsequent corrective action to put in place a drainage program was stopped by red tape - deciding who should foot the bill for such a project (Brown 1980).

From the evidence, it was clear that unsafe disposal and construction activities resulted in chemical exposure to workers and residents. The reports of these incidents would require either formal or informal investigation, which should lead to corrective actions. However, the effectiveness of the corrective actions depended on the level of monitoring and enforcement. With more effective monitoring and enforcement of corrective actions, the number of unsafe disposal and construction activities would decrease (Figure 45a and Figure 45b).



(a)



(b)

Figure 45: Love Canal's Pre/Post-Transfer Checking Factors

6.5 Conclusions

Combined external and internal organisational factors were identified as significant contributors to the Love Canal disaster. The inter-relationship among these factors showed the implicit link between organisational strategies such as leveraging on the industry-friendly policies, building goodwill with local government and expanding production capacity to meet market demand and the company's operational activities (Figure 30). From the Love Canal case study, it could be seen that the external organisational factors influenced business strategies to establish operations in Love Canal, which in turn affected internal organisational factors and produced structural dynamics leading to the risk of chemical exposure and irreparable harm to public health. In fact, systemic inadequacies could be seen in all key elements of the HSEMS, from the policy and planning to the implementation and operations, and checking and review.

The proposed CLDs and archetypes in this case study represented the dynamics of complex inter-relationships among these factors. Strong economic demand, shaped by government policies to support the national war machinery, had helped to propel the growth of industrialisation and urbanisation. Coinciding with these powerful reinforcing influences were weak counteracting forces, which included the developing legislative framework in HSE, ineffective enforcement by the regulators, limited technological advancement in waste control and poor societal awareness in hazardous exposure to industrial products. Adding to the dynamic complexity was the protracted nature of this Love Canal case study, with significant time lapses between these causes and the long term health impact of chemical exposure.

These external factors not only contributed to the sufferings faced by the residents in Love Canal, they also influenced the internal HSEMS and industry practices during that period. Priority in meeting operational demand for additional waste facilities and school capacity drove management decisions with

disastrous consequences. Often economic considerations, rather than HSE commitment and policy, were overriding forces in high-level business planning and decision-making. Limited understanding about the risks of exposure to hazardous substances and properties of chemical migration in buried soil provided a false sense of security behind a common industry practice. Also, technical information about the chemicals was not shared with relevant stakeholders that managed and handled them. All these contributing factors and the weak counteracting incident reporting-investigation-correction cycle did not produce lessons learned to prevent the reoccurrence of non-compliances and exposure incidents.

Understanding the systemic causes of the Love Canal disaster would allow organisations to better integrate HSE into their strategic decisions and operational activities. Also, it would enable policy-makers to enact legislative requirements and national policies that promote more sustainable economic development without compromising HSE. A comprehensive and balanced policy approach would enable government agencies to carry out effective enforcement strategies, holding organisations accountable for their harmful practices. Besides these external factors, organisations would need to play their roles in establishing a robust HSE Management System in order to minimise the risk of chemical exposure that could lead to long-term health impacts.

Chapter 7

CASE STUDY – MINAMATA DISEASE

7.1 Introduction

Like the protracted nature of the Love Canal incident, Minamata Disease was another EIPE that spanned over a period of a few decades, between 1932 and 1968. Despite taking place on different continents, both incidents happened around the same historical context. Similar to the approach that was used for the Love Canal study, this case study examined various factors contributing to the Minamata Disease outbreak. Also, CLDs specific to this case study were used to describe the inter-relationships among the causal factors.

Minamata Disease was related to an industrial pollution incident of epidemic proportions, and was due to the consumption of marine animals, such as fish and shellfish, that had been contaminated with toxic methylmercury (MeHg). Initial symptoms of the disease were not promptly identified, or were even ignored, which resulted in the widespread health and environmental impact. Since the official recognition of the disease, more than 3,000 cases were certified by the government as being victims of this severe neurological disorder. In some cases, a lesser exposure to methylmercury could lead to delayed manifestation of the disease (NIMD 2014). Consequently, such cumulative exposure to industrial chemicals, with serious health consequences and accompanying degradation of the environment, made Minamata Disease an ideal case study of EIPE causation. Several studies on the long-term health impacts of Minamata Disease had already been carried out (Igata 1993; Rice 1996; Eto 1997; Kudo et al. 1998; Sakamoto et al. 2010), but there were limited studies on the non-medical causes of this devastating disease.

7.2 Case Overview

The occurrence of Minamata Disease, considered as one of the major pollution-caused diseases of Japan, was first described in the Japanese city of Minamata, in 1956 (Minamata Disease Research Group 1968). Minamata was situated on the north-west coast of the Kumamoto prefecture (see Figure 46) and had a population of 34,000, who were mainly fishermen and farmers. It faced the Shiranui Sea that contained an abundance of fishing resources necessary to support the residents of Minamata.

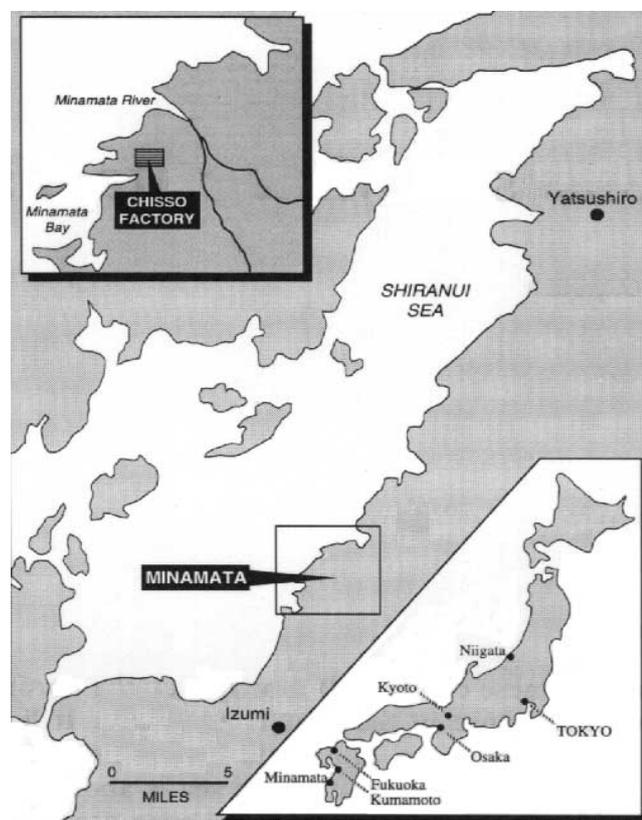


Figure 46: Location of Minamata City (Maruyama 1996)

This disease was a disorder of the central nervous system, which exhibited symptoms such as a lack of coordination of muscle movements, numbness in the hands and feet, narrowing of the field of vision, and damage to hearing and speech. In extreme cases, these symptoms could lead to insanity, paralysis,

coma and, possibly, death. Since it attacked the neurological system, there was no cure for the disease (Minamata Disease Municipal Museum 2001).

Although formal recognition of Minamata Disease was made in 1956, it took the government more than 10 years to officially announce the cause of the disease as being due to the discharge of industrial waste from Chisso. By then, Minamata Disease had resulted in unprecedented environmental damage and the greatest toll of human life due to pollution in the history of Japan. Of the more than 3,000 victims officially certified as having suffered from the disease, 1,784 died and more than 10,000 received financial compensation (Ministry of the Environment Government of Japan 2002). Shown in Figure 47 are areas of the Minamata Disease outbreak. Numbers on the map represent the number of certified Minamata Disease patients.



Figure 47: Areas and Extent of Minamata Disease Outbreaks (Sakamoto et al. 2010)

This disease was also known as Chisso-Minamata Disease and its causal agent could not be determined until 1959, when researchers linked the disease to organic mercury poisoning. Initially, the disease was thought to have been caused by manganese, selenium and thallium. However, medical findings did not support any link between these metals and the disease. Subsequent findings from the research group of Kumamoto University concluded that Minamata Disease was caused by consuming huge amounts of the mercury-contaminated seafood. Eventually, various experiments and studies traced the source of the contamination to the disposing of highly toxic MeHg found in the industrial wastewater from the Chisso chemical plant (Ui 1992, Section VI). Shown in Figure 48 is an acetaldehyde plant where MeHg was a by-product of the acetaldehyde made from acetylene and water. The MeHg produced in the manufacturing process, together with other industrial wastes, was discharged into the sea. As a result, the contaminated marine food chain was consumed by the nearby residents who depended on fish and shellfish as part of their daily diet.

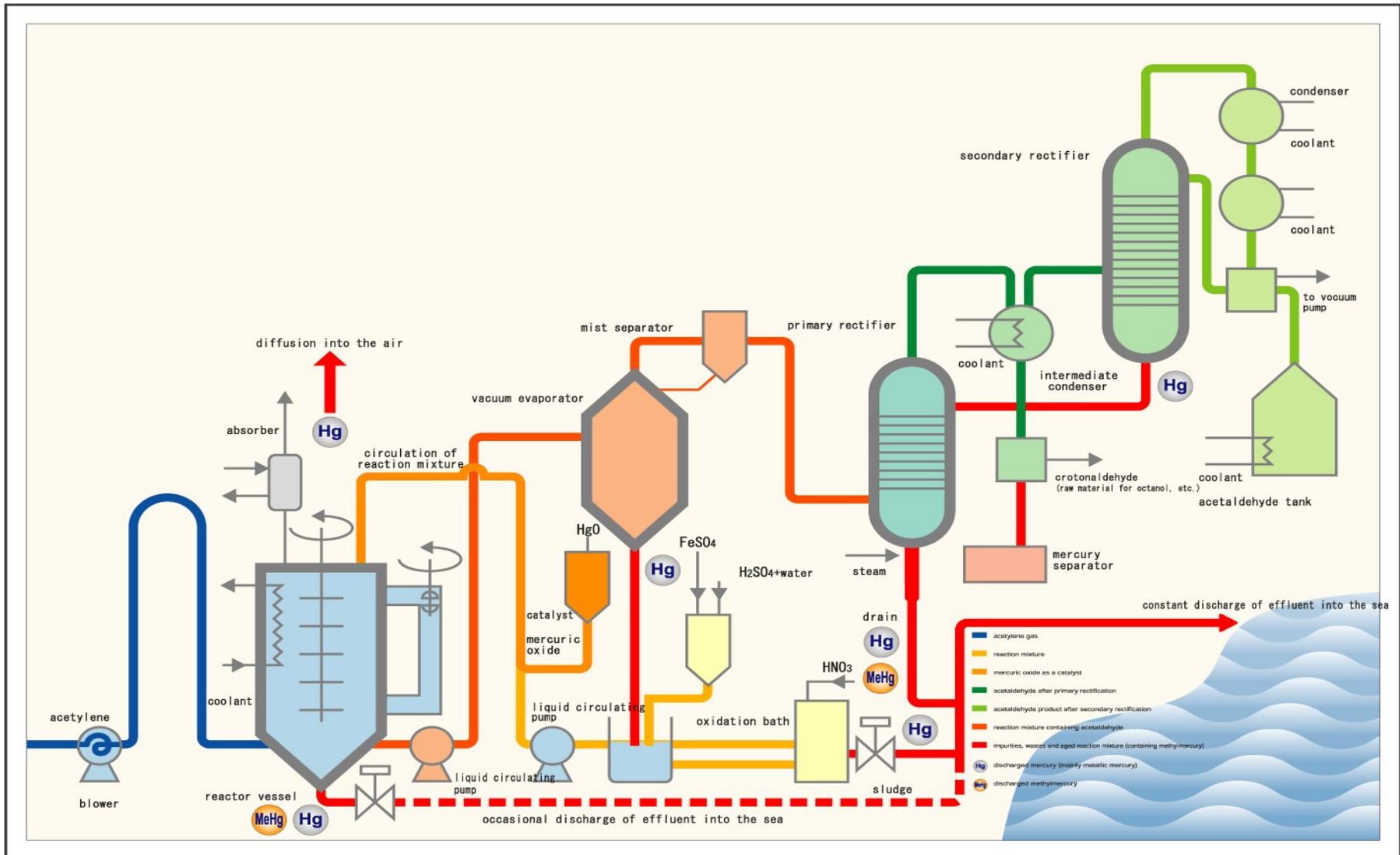


Figure 48: Acetaldehyde Production Process in Chisso Plant (National Institute for Minamata Disease 2001)

Chisso disposed of an estimated 27 tons of MeHg between 1932 and 1968. As a result, a large quantity of this toxic chemical found its way into the marine animals. Also, fishing catches decreased by 90% since the outbreak of the disease in 1956 (Hernan 2010). It was later discovered that the accumulation of MeHg in the larger species of fish, through the consumption of contaminated smaller fish, could be several thousand times higher than that found in the sea water. By the time residents ate the fish as part of their staple food, the fish would have contained MeHg at a poisonous level (Tsuchiya 1987). The higher than normal absorption of this toxic substance by an organism in a food chain is known as bioaccumulation, while biomagnification is the higher than normal absorption of a toxic substance from only one link in a food chain to the next (see Figure 49).

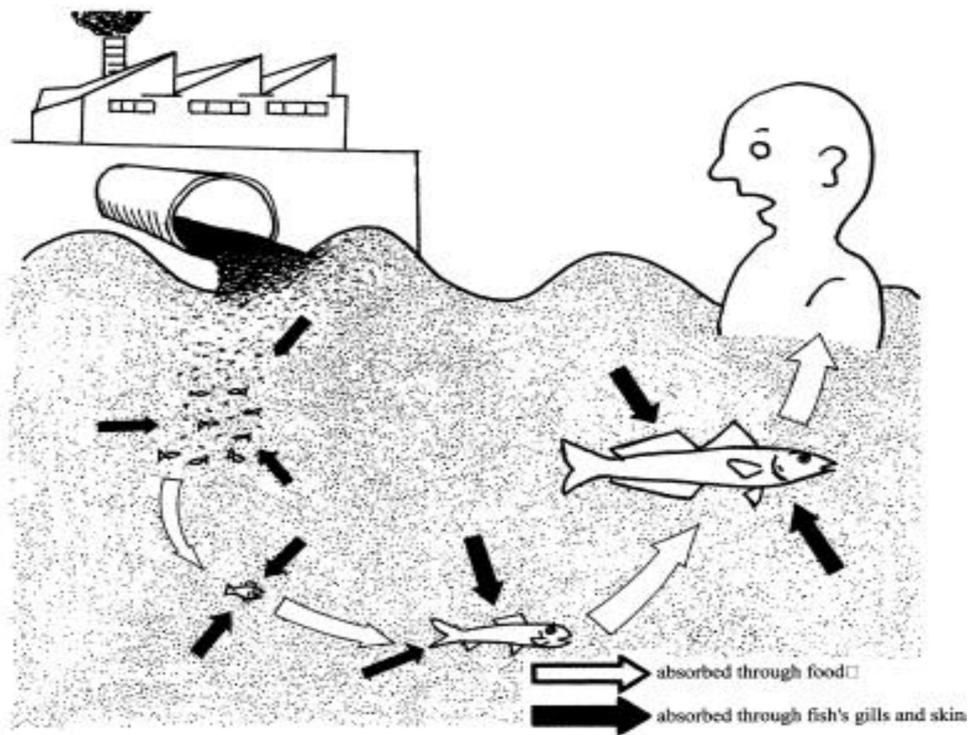


Figure 49: Source of Pollution Travelling Through the Food Chain (Minamata Disease Municipal Museum 2001)

In 1907, residents of Minamata persuaded the founder of Chisso to build a factory in their town. Hence, Chisso opened its first chemical plant in Minamata in 1908 (see Figure 50). It started producing fertilisers before branching out into producing chemicals such as acetylene, acetaldehyde, acetic acid, vinyl chloride and octanol (George 2001, Part 1). The production of acetaldehyde generated toxic MeHg, which was then disposed into the Minamata Bay.



Figure 50: Chisso Chemical Plant at Night (Smith 1971)

The post-World War II period spurred the growth of Chisso whose expanding production, in turn, benefited the local economy, to the extent that the production of acetaldehyde jumped from over 200 tons per year in 1932, to 6,000 tons per year in 1951 and, in 1961, it hit 45,245 tons per year. By 1959, it had accounted for 85% of the domestic production of octanol, which required the raw material production of acetaldehyde (Social Scientific Study Group on Minamata Disease 2001, p.13).

Around 1953, residents began to notice unexplainable behaviours by victims diagnosed with degeneration of the nervous system. Similar behaviours were observed in cats and animals. In other cases, birds dropped from the sky and

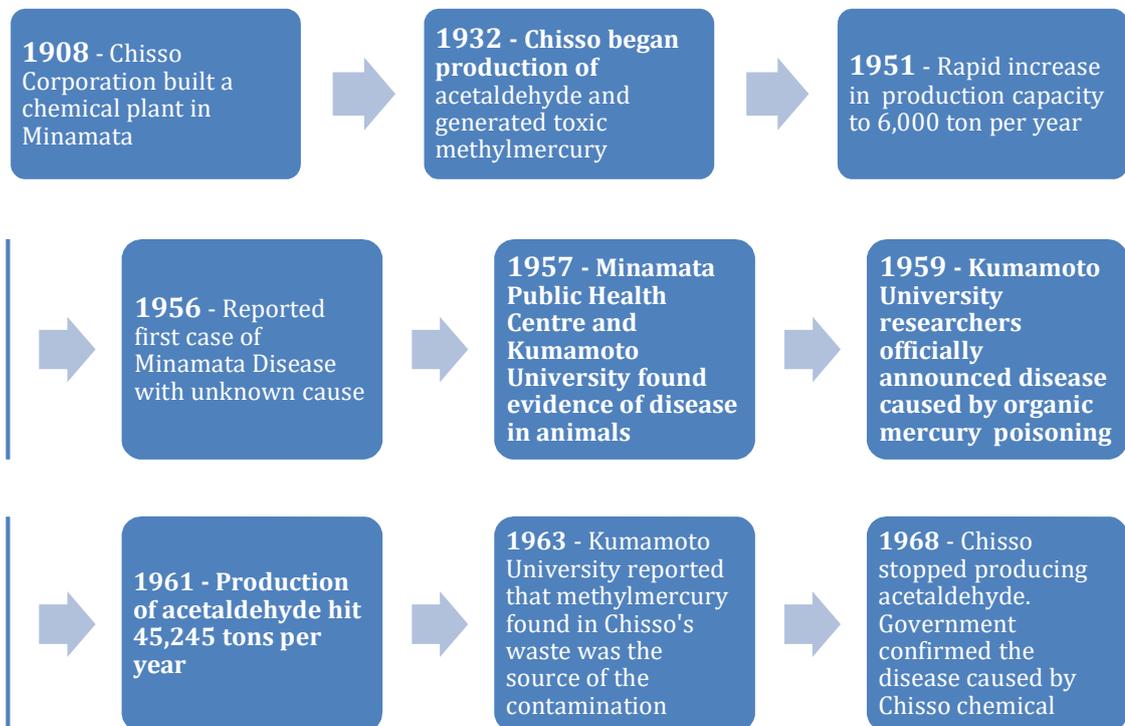
dead fishes floated on the sea. Eventually, marine populations started to disappear from the once fertile fishing village (The Kumamoto Daily News 1954). The outbreak of the disease led to the formation of an epidemiological research group between the Minamata Public Health Centre and Kumamoto University. Despite a report from Dr. Hajime Hosokawa, in May 1956, about the outbreak of the nervous system disease, Chisso denied any part in the development of the disease and, with the tacit approval of the government, continued to pollute the environment. To prevent possible links of the disease to the contamination from its industrial waste, Chisso re-routed its waste discharge from Minamata Bay to the mouth of the Minamata River in 1958. Unfortunately, such negligence led to more victims around the Shiranui Sea suffering from the incurable disease (George 2001, Chapter 3).

It was not until late 1958 that a visiting neurologist from Britain linked the symptoms of the disease to the possibility of organic mercury poisoning. The findings were quickly confirmed by researchers at Kumamoto University in 1959. Under pressure to silence the dissenters, Chisso quickly agreed to pay 7,000 affected families a lump sum compensation of Yen35 million (USD447,000), and another Yen65 million (USD830,000) as a loan for restoration of the fishing grounds. After this initial settlement, the Council for the Verification of Minamata Disease was established to certify victims proven to be affected by the disease. Over this period, Chisso continued to refute findings that were negatively linked to its waste discharge and, instead, promoted other possible theories in an effort to derail objective investigative studies (George 2001, Chapters 3 - 5).

In 1963, researchers from Kumamoto University publicly released their report concluding that Minamata Disease was caused by the MeHg found in Chisso's industrial waste discharge. A few years after the release of the report, the enactment of the Pollution Victims Relief Law, in 1968, saw the national government taking over the victim certification process. In that same year, Chisso stopped the production of acetaldehyde due to the product having been

made obsolete. Only after the production had ceased did the government officially confirm the cause of the Minamata Disease outbreak to be Chisso's contaminated wastewater (George 2001, Chapters 5-7).

In June 1969, thirty certified families filed a lawsuit against Chisso. After almost four years, the trial verdict was delivered and the families were awarded Yen937 million (USD12 million), in 1973. Four years later, the local government began the arduous task of cleaning up the Minamata Bay. It was only after 20 years and with Yen359 million (USD4.6 million) spent on chemical remediation that the government declared the area safe. Nonetheless, it was not before another law suit was brought by the victims and families, in 1980. Acknowledging the culpability of multiple parties contributing to the public health and environmental impacts, the Courts found first Chisso, then the prefecture government and the national government, liable for the Minamata disaster (George 2001, Chapters 7 - 8). The key events between 1908 and 2004 are represented in Figure 51.



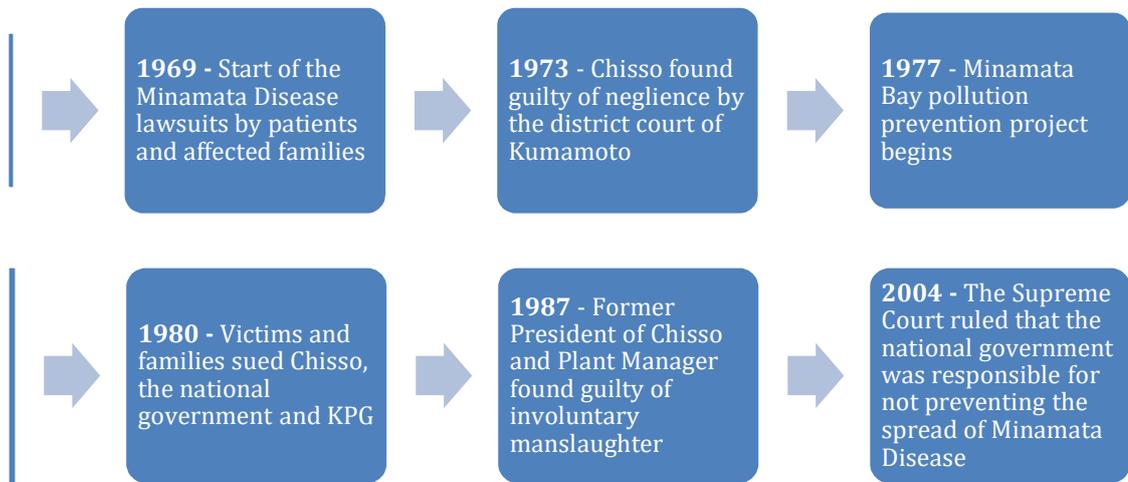


Figure 51: Sequence of Key Events of the Minamata Disease Outbreak

7.3 External Organisational Factors

For the purpose of case comparison in Chapter 9, the same categories of external organisational factors, i.e. PLETS, as those examined in the Love Canal disaster were used in this Minamata Disease case study. Examples of these main contributors were a combination of political apathy in public health, poor public awareness about hazardous industrial wastes, an inadequate legislative framework for health and environmental protection, economics taking priority over HSE concerns, and technological investment in production efficiency and capacity rather than preventive measures for chemical exposure. As in the Love Canal, these external factors influenced Chisso's organisational decisions and operational activities that contributed to the Minamata Disease.

7.3.1 Political

Efforts to rebuild the post-war economy put emphasis on production at the expense of long-term health and environmental impacts. During the first World War, priority was given to industrial development to meet the demands of the military. This focus on industrial policy carried on after WWII, when nation

rebuilding was the main agenda at all levels of government (Imura and Schreurs 2005). To avoid over-reliance on imported chemicals, the high-growth policy aimed to enhance the competitiveness of the local chemical industry in the global market (George 2001, Chapter 1). Thus, a reinforcing loop (R1, Figure 52a) represents the favourable national policy that was protecting corporate interests, which in turn supported the government's priorities. Other aspects of the political interplay between Chisso, national government, prefecture authority and the community are also represented in this CLD (Figure 52).

To achieve economic success, regulators and industry often cooperated with each other to ensure minimum disruption to production activities (Harada 1994). Especially in the 1950s, the Ministry of International Trade and Industry (MITI) was tasked with converting use of the conventional electrochemical system into the petrochemical system that could be used by the chemical industry (Social Scientific Study Group on Minamata Disease 2001, p. 14). Unfortunately, powerless residents and workers were often victims of such industrial policies, developed at the expense of public health and environmental protection. A significant turning point in the Japanese post-war political landscape in the late 1960s and early 70s saw more societal engagement with greater influence on policy decisions (Pempel 1987).

Besides being closely allied with the military power in the early colonisation period, Chisso also worked closely with the local government, where it had an operational presence and company interests (Maruyama 1996). The reinforcing loop (R, Figure 52a) shows the tied connection between Chisso and the City that contributed to the local political landscape. Corporate executives of Chisso reinforced the belief that the company and community were partners in the growth and development of the city. In order to protect the company's growth and interests, the management of Chisso instructed its employees to actively engage in municipal affairs by seeking influential roles that allowed them to exert control of the city's affairs. As early as 1925, Chisso nominated its own

employees for the City Council elections. In addition to ensuring representation in the Council, Chisso's plant director was also the mayor of the city for the majority of the period between 1950 and 1969 (Maruyama 1996). Furthermore, as a major employer of the city, Chisso exerted significant control over the affairs of the local community, to the extent that complaints about pollution were handled directly by Chisso without any intervention from the municipal government. In fact, "after the official discovery of Minamata Disease in 1956, Chisso learned that it could rely on local and national elites to allow it continue to pollute, and to "solve" the problem with token "sympathy" payments to victims and "pollution control" equipment that did not remove the mercury from its waste" (George 2017). Consequently, the possession of such influential relationships within the city by Chisso ensured that complaints or negative publicity did minimal damage to the interests of the company.

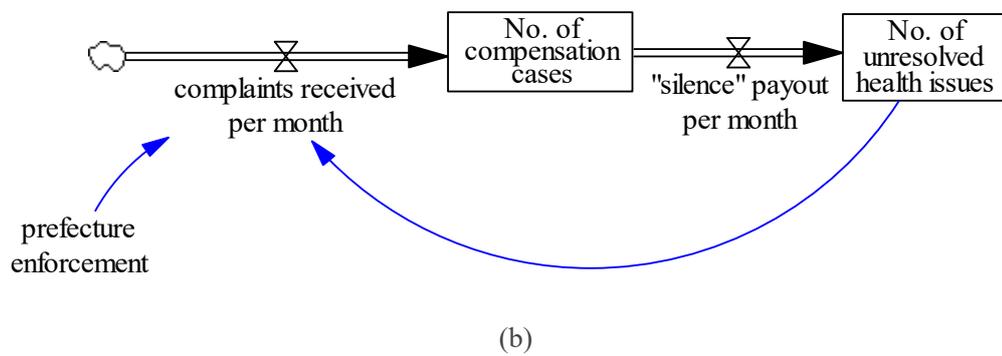
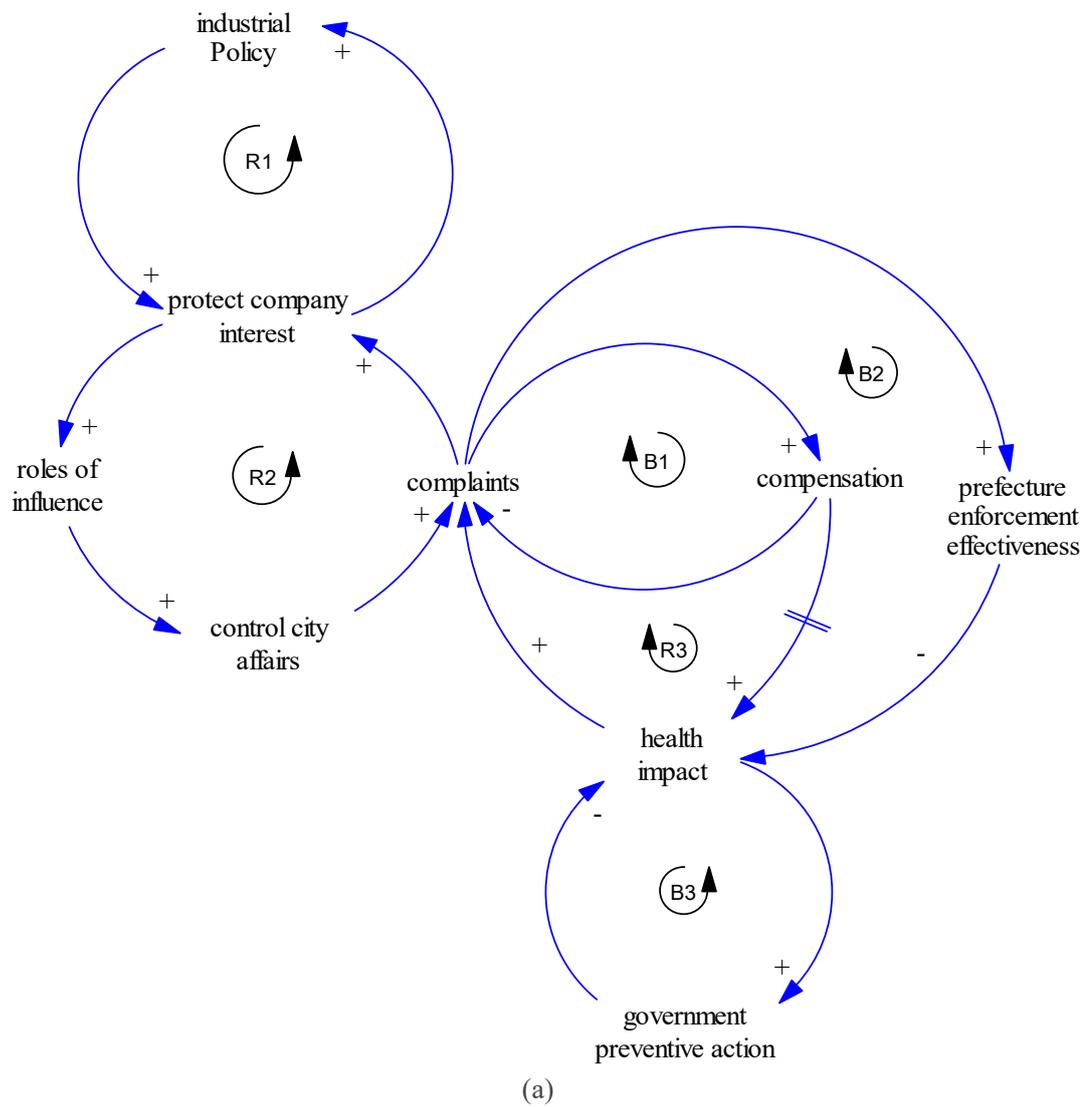


Figure 52: Minamata Disease's Political Factors

Chisso used its influence to limit compensation payouts for complaints resolved between 1943 and 1954 (Maruyama 1996). However, the compensation merely masked the seriousness of the health risks and delayed addressing the underlying causes. A “Fixes that Fail” archetype (Senge 2006) was used to describe this causal relationship. It displayed a worsening health impact (R3, Figure 52a) contributed to by addressing the complaints with payments to the affected residents (B1, Figure 52a). The delay ‘II’ in the reinforcing loop represents the time lapse for the symptoms of Minamata Disease to become visible. The SFD highlights the fact that the number of complaints did not necessarily lead to a reduction in long-term health issues, due to Chisso’s use of financial incentives to mask the underlying problems (Figure 52b).

After the possible cause of the Minamata Disease outbreak was identified, strict guidelines from the Kumamoto Prefectural Government (KPG) forbade fishermen from fishing activities and selling of catches from affected areas, in 1958. However, the requirement was not effectively enforced and some fishermen continued with their trade and accelerated the spread of the disease. Furthermore, calls for a mandatory ban and changes to the legislation had produced limited actions from the government (Maruyama 1996). Therefore, the inadequate enforcement activity has been represented by a weak balancing loop (B2, Figure 52a), which could have minimised the spread of the disease.

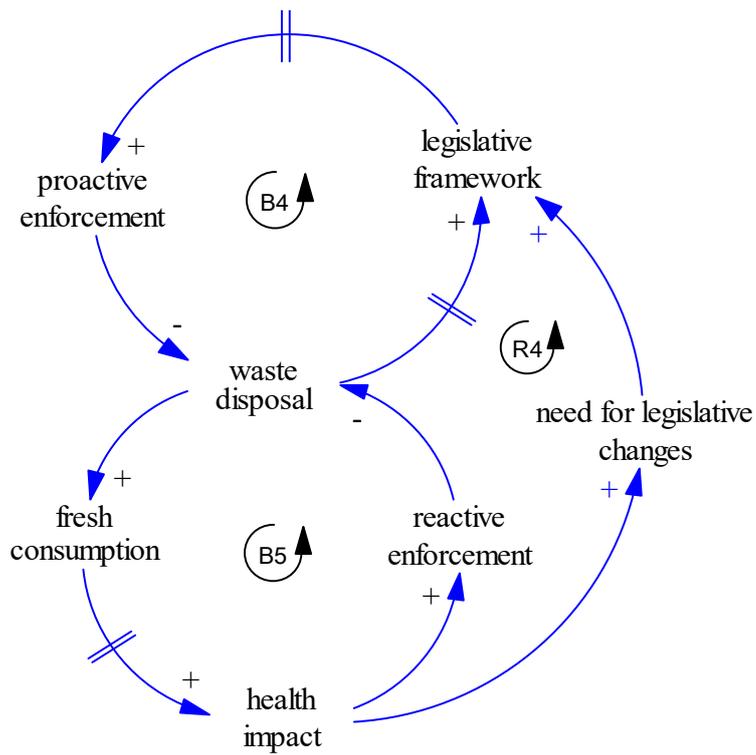
Another balancing loop (B3, Figure 52a) of more effective government actions could have minimised the negative health impacts, but politics got in the way of public health protection. Some studies went further to suggest that the delay in carrying out control measures to eliminate any suspected hazardous substances was a failure in policy-making decisions (Mazur 1998; Social Scientific Study Group on Minamata Disease 2001). When further studies linked the cause of the Minamata Disease to the toxic mercury in Chisso’s waste discharge, regulators such as the Ministry of Health and Welfare (MHW) and the MITI became embroiled in inter-ministry disputes regarding the resolution of the increasingly

political issue. Ultimately, ministries were more concerned with protecting the international competitiveness of the manufacturing industries, and minimising the nation's dependence on imports. After all, Chisso played a key role in fulfilling the MITI's plan of developing the petrochemical industries. Essentially, concerns for public health impacts caused by manufacturing activities gave way to the national interest for economic growth (George 2001).

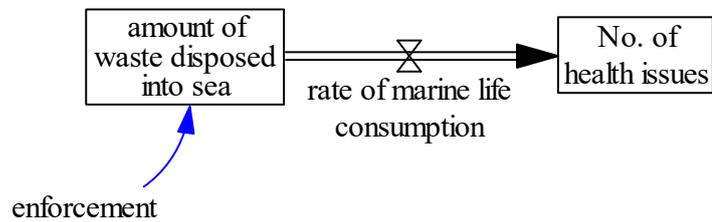
7.3.2 Legal

While it was evident that national policies designed to restore the post-war economy ran counter to the primary responsibility of the government authorities to protect the health and welfare of the people, the extent of the legal responsibilities of the national and local governments would not be possible to determine in this case study. Whatever legislative framework existed during that period was not established to be in conflict with the main objective of promoting economic growth; therefore, it was inadequate to prevent the occurrence of EIPEs such as Minamata Disease (Environmental Health and Safety Division 2011).

Primarily, there were two approaches to controlling and minimising exposure to industrial waste. The CLD in Figure 53a illustrates this complex behaviour, consisting of two balancing loops (B4) and (B5) and one reinforcing loop (R4). One approach was through the proactive enforcement (e.g. regular site and HSEMS inspections) of waste disposal activities before the health impacts of chemical exposure could be suffered (see B4, Figure 53a). The other approach was through reactive enforcement (e.g. penalties for non-compliances) after health impact incidents had occurred; either through residents' complaints or workers' incident reports (see B5, Figure 53a). The reinforcing loop (see R4, Figure 53a) captured the causal relationship between health impacts and improving the legislative framework (ACS 1973). Each of these loops is described in more detail below.



(a)



(b)

Figure 53: Minamata Disease's Legal Factors

In the days of Chisso's operation, there were little legislative requirements for minimising exposure to organic mercury. Earlier post-war pollution regulations, such as the Pollution Control Ordinance 1959, were ineffective due to the lax criteria and opposition from industry. Several laws relating to pollution control were not enacted until the late 60s and early 70s. Examples of such laws were the Basic Law for Environmental Pollution Control 1967, Air Pollution Control Law 1968, Water Pollution Control Law 1970, Waste Disposal and Public

Cleansing Law 1970, Nature Conservation Law 1972 and Chemical Substances Control Law 1973 (Takemoto 2010). Unfortunately, the implementation of these laws came after the Minamata Disease had already caused widespread public health impacts and environmental damage (ACS 1973). Therefore, presented in the reinforcing loop (see R4, Figure 53a), the positive influence of health impacts on the legislative framework is reactionary in nature. The time lapse in the review and enactment of more stringent legislative requirements for health and environmental protection is represented by the delay 'II' sign in R4 (see Figure 53a).

Aside from the immature legislative framework, there was no national agency tasked to enforce the various legislative requirements. It was not until 1971 that the Environment Agency was formed to address the problems of industrial pollution. Before the existence of this government agency, there was a lack of any coherent national environmental policy, and the control of industrial pollution was left to various government departments (Sumikura 1998). Therefore, inadequate legislative requirements and the lack of coordination among government departments contributed to ineffective enforcement, which led to unchecked hazardous waste disposal activities. After a long period of destructive practices involving waste disposal, the Japanese government was compelled to enact a more robust legislative framework (Takemoto 2010). Such a causal relationship embedded with multiple time delays produced a weak balancing loop (B4, Figure 53a).

In response to the health impacts from continued consumption of contaminated fish and shellfish, government agencies did little to enforce waste disposal activities in order to prevent or minimise the occurrences or spread of Minamata Disease (see B5, Figure 53a). The relationship between the disease incidence and waste contamination was closely linked to the rate of consumption of polluted marine life (Figure 53b). To make matters worse, various government

agencies failed in their responsibilities in helping with the effort to minimise the spread of the disease and health impacts (Satoshi 2004).

After Dr. Hosokawa's report of the first disease outbreak in 1956, the MITI did nothing to stop Chisso's production. The MITI was not the only government department that could have exercised its regulatory authority. Even though the MHW was responsible for national health services, including policies for waste management and drinking water, it did not enforce the Food Sanitation Act. Instead, the MHW cited the lack of conclusive evidence of mass poisoning to the entire marine life population. Similar inaction could be seen from the Ministry of Agriculture, Forestry and Fisheries (MAFF), which did not invoke the Fishery Act to suspend Chisso's operations (Harada 1994). As a result, residents continued to consume the contaminated fish with the false sense of security about the non-seriousness of the consequences (Tsuda et al. 2009). The absence of reactive enforcement is represented by the causal relationship of health impact, reactive enforcement and waste disposal (B5, Figure 53a).

7.3.3 Economic

The economy was the main factor that brought Chisso to the town of Minamata and it was also one of the key contributors to Minamata Disease. Driven by the high demand for certain chemicals, such as sodium hydroxide and polyvinyl chloride, Chisso greatly benefited from its market monopoly for the production of these chemicals. However, market demand alone was not enough to help propel Chisso to become one of the key pillars of economic growth. There had to be sufficient resources to support its manufacturing activities, and the Minamata township, with its abundant land and facilities, and its supply of low-cost labour, was able to meet those requirements (George 2001, pp. 13-25).

The other favourable business condition was the government focus on rebuilding the nation's economy with policies that promoted manufacturing activities. However, this view was pushed without understanding the long-term public health consequences of its economically driven initiatives. Figure 54 illustrates the inter-relating factors between economy and health impacts. The system archetype "Limits to Growth" (Meadows et al. 1972; Braun 2002), with an added reinforcing loop (R6), was selected to explain such a dynamic relationship. It consists of a reinforcing loop (R5) and a balancing loop (B6).

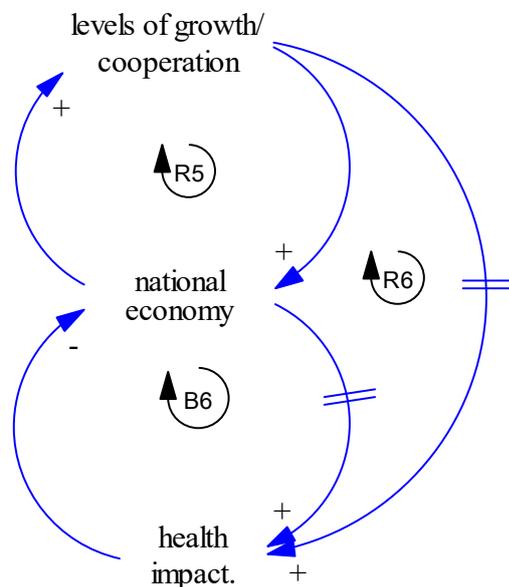


Figure 54: Minamata Disease's Economic Factors

Expansion of the national economy benefited and facilitated growth of the industry, organisations and city. In turn, the prosperity experienced by these beneficiaries contributed to the national economy and GDP. This cycle of growth, filtering from the macro economy at the national level to the micro economy at the various lower levels is captured by the reinforcing loop (R5, Figure 54). The following evidence was found when examining the extent of growth experienced by Chisso and the Minamata township.

At the turn of the century, when hydroelectric power replaced coal-powered electricity, which previously had supported several businesses in Minamata, residents were compelled to source other growth industries to revive their local industries. A group of leading residents from Minamata actively pursued Chisso to set up a manufacturing plant there. Within a short time, Chisso became one of the leading chemical producers in post-war Japan. Integration of Chisso's activities into Minamata's economy included a cooperative department store, which sold a wide range of daily basic necessities to the employees (George 2001).

In 1950, Chisso was capitalised at USD\$1.1 million and this figure grew to USD\$6.7 million in 1956 (Molony 1990). As the main employer in Minamata, Chisso employed around 20% of the workforce, and accounted for 30% of retail sales and more than 60% of all shipping activities (Maruyama 1996). The fortunes of the city reflected the growth of Chisso because, even with special tax privileges, Chisso contributed almost half of the city's total income in 1960 (Masatomi 1973). Its impact on the national economy was similarly significant. By 1960, Chisso plant produced 39% of the national total production of acetaldehyde (George 2001, p. 21). Clearly, Chisso was one of the chemical companies that benefited from the government's high-growth policies and it played a major role in propelling Japan's post-war economic expansion. Nonetheless, such aggressive industrial transformation and economic expansion also coincided with an increase in negative environmental and health impacts due to the discharge of polluted wastewater from chemical plants into the environment (Matsuo 2002).

Parallel to the cycle of growth seen in reinforcing loop R5 (Fig. 54) was the strength of cooperation among stakeholders who benefited from such growth. Rapid industrialisation was characterised by close cooperation among the manufacturers, unions and government. These intertwined partnerships led to a slow acknowledgement by government of the possible link between Minamata

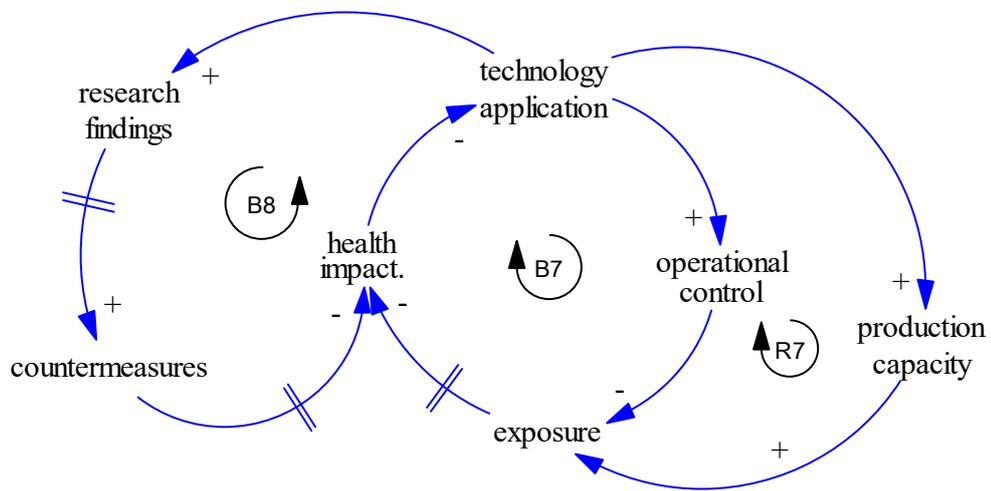
Disease and mercury poisoning from Chisso. The close economic relationship between Chisso and the city of Minamata was also the reason that some residents were reluctant to support the Kumamoto Prefectural Alliance of Fishing Cooperatives' (KPAFC) protest against Chisso. Mindful of Chisso's contribution to Minamata's economy and the small businesses that depended on its operation, several unions such as the Shin Nitchitsu Union, Minamata Regional Association of Labour Unions (MRALU) and the Teachers' Union petitioned the prefecture not to shut down the factory (George 2001).

From the above, a balancing loop (B6, Figure 54) was developed to illustrate the influence of the national economy on the quality of health, or health impacts. Especially when the prosperity of the city was so closely tied to the survival of polluting organisations, a trade-off between economic growth and protection of public health and the environment could be expected (Fusako and McCormack 2004). Each level of growth, from the industry to the organisations and the city itself, contributed to the degradation of public health, as shown in the reinforcing loop (R6, Figure 54). Invariably such undesirable health impacts would eventually lead to productivity losses at various socio-economic and organisational levels, which would subsequently affect the economy.

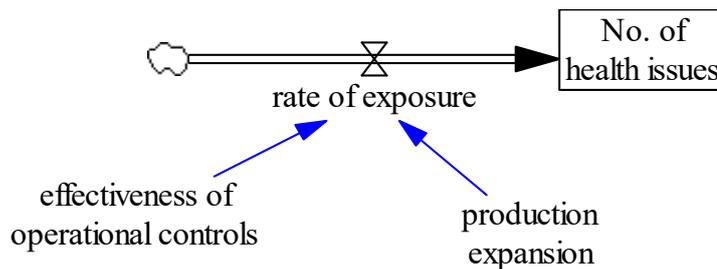
7.3.4 Technological

Chisso was considered to be the technological leader of the chemical industry in its time, by adapting European technology for its own manufacturing processes . Also, its ability to innovate and differentiate itself from other organisations was partly to do with its entrepreneurial management, which was made up of scientists and engineers rather than workers with no technical background (Pizza 2003).

In 1941, it developed a proprietary technology for acetaldehyde production and successfully synthesised vinyl chloride from acetylene for the first time in Japan (Chisso 2017). Moreover, profits gained by Chisso allowed for investment in new technology to lower its production costs. For instance, technological advancement enabled Chisso to increase its acetaldehyde production capacity by ten-fold in the decade since 1950 (George 2001). As a result, there was a corresponding increase in the exposure to toxic mercury. These inter-relating factors of technological applications, production expansion and exposure are represented in the reinforcing loop (R7, Figure 55a).



(a)



(b)

Figure 55: Minamata Disease's Technological Factors

In the same Figure 55a the balancing loop (B7) illustrates that a similar level of investment into production expansion was not as evident in operational control (e.g. waste treatment). The lack of understanding regarding the seriousness of mercury exposure meant that Chisso was not compelled to invest in adequate control measures, with the exception, in 1959, when the MITI provided advice for the design of a waste water management system to Chisso. Unfortunately, the so-called purification system did not remove the toxic mercury from the production process (Murata and Sakamoto 2011). Consequently, residents continued to be exposed to the toxic chemical and suffered from Minamata Disease (Figure 55b).

While technology used for chemical production and waste control could minimise the level of chemical exposure, technology used for chemical analysis and epidemiological studies could provide insights into the medical cause of the disease in Minamata. Findings of such medical research could produce useful countermeasures to minimise the health impacts from chemical exposure (see B8, Figure 55a). Unfortunately, during the pre-war period and the beginning of post-war Japan, there was a general lack of awareness of the environmental and health impacts of increased chemical exposure. This was partly due to the limited scientific studies on chemical poisoning, and the lack of means for analysing minute concentrations of MeHg, which resulted in a lengthy search for the causes of Minamata Disease (Social Scientific Study Group on Minamata Disease 2001, p.39). Additionally, research work establishing the cause of the disease had to be carried out in Kumamoto University, away from the subjects and the area where the patients resided, because the knowledge and equipment needed for the studies were not available in Minamata (George 2001).

Complex political and national interests prevented the release of breakthrough research findings. Upon discovery of the connection between the disease and the MeHg discharge from Chisso's plant by the Minamata Food Poisoning Committee (MFPC), the government authority (MHW) that organised this study

group immediately disbanded it (Harada 1994). Further delays in uncovering the true causes of the disease were due to the employment of diversionary tactics such as the provision of deceptive information by Chisso, and its unwillingness to cooperate with investigators in regard to its production processes (Social Scientific Study Group on Minamata Disease 2001, p. 26). In Chisso's defence, the Japan Chemical Industry Association published a report in 1959, refuting claims of any links between the disease and mercury (Jenks 2010).

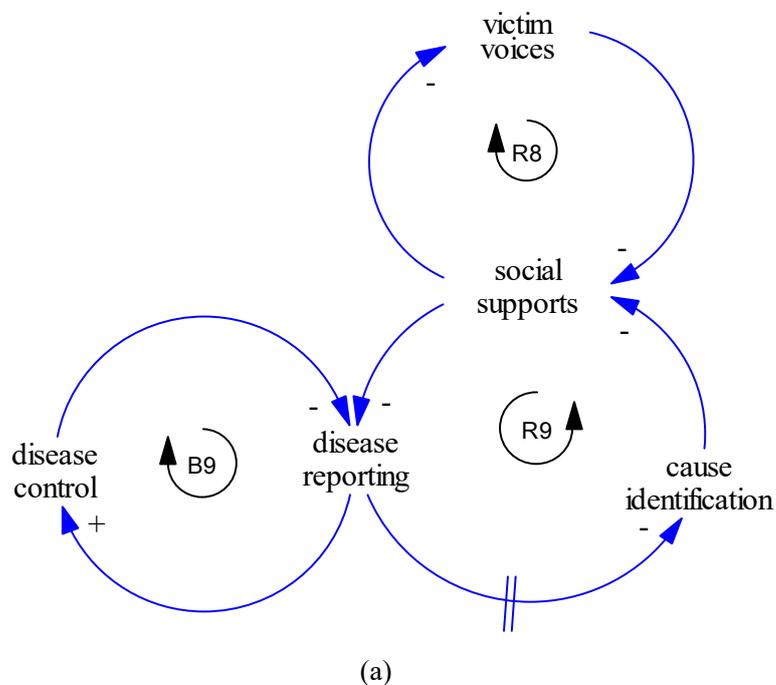
As a result of all these impediments, it would take 12 years (see delay 'II' between 'Exposure' and 'Health impact') from the first outbreak of the disease before the official announcement of its cause, linking Minamata Disease to the pollution source from Chisso's waste discharge (Takizawa 2000). The announcement stated that Minamata Disease was a condition of the central nervous system, due to the long-term consumption of marine animals from Minamata Bay. The identified culpable chemical compound was MeHg produced in Chisso's Minamata factory (Allen and Burns 2009). Had the various scientific studies and warnings been taken seriously by Chisso and the government agencies, then more efficient countermeasures (see the multiple delays 'II' in B8, Figure 55a) could have been installed to further mitigate the health impacts of such chemical exposure.

7.3.5 Social

Minamata grew from a population of about 12,000 in 1908 to about 50,000 in 1956 (Fuwa 1994), but it still retained much of its feudalistic structure and social values. Its geographic isolation from the main capital city strengthened the residents' consciousness and affinity with Chisso. Therefore, challenging Chisso or its polluting activities was considered to be antisocial and against national progress. Before fully recognising the serious health impacts of Minamata Disease, the mainstream society would accept some level of damage or harm in order to preserve the greater interest of the nation (Social Scientific Study Group

on Minamata Disease 2001, Chp. 6).

The presence of Chisso had brought much needed prosperity to the residents and transformed the town of Minamata. However, in its support for Japan's imperial ambition, Chisso took advantage of the nationalist fervour among the residents, and imposed its centralisation of coercive power on the society. Through Chisso's powerful influence on the affairs of the township, it defined the inequitable relationship between the residents of Minamata and the organisation (George 2001, Chapter 2). The identity of the community was so closely intertwined with the performance and survival of Chisso that it influenced the societal support network during this epidemic and even inhibited the prompt identification of the disease's cause. The CLD in Figure 56a captures this causal relationship consisting of one balancing loop (B9) and two reinforcing loops (R9) and (R10), which are examined in more detail below. With hindsight into this outbreak of Minamata Disease, the social cost of modernisation could not be ignored by policy-makers, government agencies, industry, unions and residents.



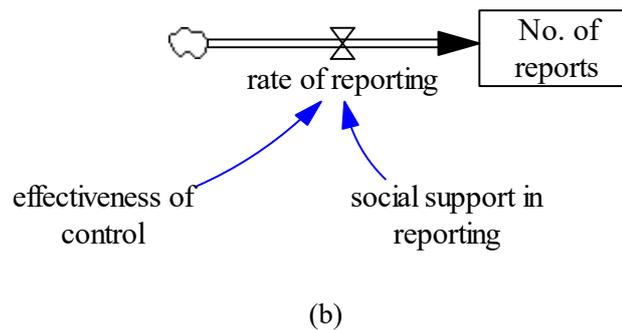


Figure 56: Minamata Disease's Social Factors

As Chisso's manufacturing activities grew, so did the population in Minamata. From a village in 1912, Minamata grew to become a city in 1956 (George 2001). Throughout the period of prosperity experienced by Minamata, Chisso maintained strong political prominence in the city's development and management. In fact, employees of Chisso and its subcontractors made up around 24% of the total industrial population (Social Scientific Study Group on Minamata Disease 2001, p. 11).

Strong social cohesion and other cultural characteristics of Japanese society played important roles in contributing to Minamata Disease. The legacy of feudalism and the expectation of employees' loyalty to their company reinforced the strong influence of Chisso over the city of Minamata (Jenks 2010). Also, several management staff of Chisso held important council roles in the city, which cemented the sense of shared destiny between the city and Chisso. That is, the prosperity of Minamata was greatly underpinned by the success of the Chisso plant (Ui 1992). Therefore, the social support depicted by R8 in Figure 56a was shaped by a combination of cultural characteristics and historical developments of the nation.

Expectedly, when victims of the disease demanded financial support from Chisso, they did not gain much sympathy due to the close ties between the company and the municipal government (Keiji 2006). The lack of social support for their cause made it difficult for the victims to pursue redress for their

sufferings. Instead, local authorities and residents jointly condemned any opposition to Chisso, for fear of losing valuable tax revenues and livelihoods. Such actions were considered to be harmful to the community and a cause of conflict between the company and the City. Also, it did not help that most of the victims were fishermen, often despised by others due to their lower strata within the society (Jenks 2010). Therefore, the ability for the voices of the victims (victim demand) to be heard depended on the level of social support that was accorded to them. i.e. The weaker the social support, the weaker the voices of the victims, as shown in the reinforcing loop (R8, Figure 56a).

Some financial support was eventually offered to the victims in 1959, but the money was provided in the form of a condolence, rather than compensation. The same mode of sympathy payment was used to provide for the less fortunate, who would be expected to be grateful for such a 'gift.' Otherwise, compensation could be seen as admission of wrongdoing and Chisso did not want to admit its negligence. Also, the one-time sympathy payment was handed out with the condition that victims would be prohibited from making further claims (Hernan 2010).

The R9 reinforcing loop (Figure 56a) shows a lack of reporting culture in the society, which influenced the lack of promptness (see delay 'II' between disease reporting and cause identification) in diagnosis of the disease's cause. Since any disruption of social cohesion was considered undesirable, public opinion was not supportive of the actions of fishermen demanding compensation. Challenging Chisso was seen as rebelling against national progress (Jenks 2010). Adding to the societal expectation to conform to social norms, powerful unions too pressured their members not to report new cases of Minamata Disease. Even within families, the disease had become a social taboo where members would be discouraged from reporting any symptoms of the dreadful disease. This led to further delay in identification of the disease's cause, which was the necessary first step toward any actions to mitigate further spread of the

disease. This lack of understanding about the disease's cause did not help to raise awareness among residents or provide justification for the right kind of social support (Ui 1992, Chapter 4).

Reports of the disease or its symptoms would facilitate the identification of possible medical causes and provide critical information for developing necessary controls (see B9, Figure 56a) to mitigate the disease's impacts. Initial ignorance about the non-infectious disease led to the isolation of patients in an effort to prevent the disease from spreading to others. Unfortunately, this counterproductive measure worsened the social isolation and ostracism faced by the patients, because victims would rather suffer in silence than to bring disgrace to their entire families (Hernan 2010). As a result, such well-intended measures (disease control) not only failed to encourage active reporting of the disease, they couldn't overcome the negatively reinforced societal consequences of perceived disharmonious behaviours from individuals (see R9, Figure 56a). As a result, the lower than actual number of reported incidents was a direct reflection of the poor reporting culture (Figure 56b).

7.4 Internal Organisational Factors

Supported by the above- mentioned external organisational factors, the internal organisational factors significantly contributed to this EIPE and its impact lasted long after the official recognition of the disease's cause. This was clearly articulated by Shiro Takakura of the Minamata Disease Centre that "Chisso knew the cause of the disease. We'd like them to take responsibility for the surviving patients. There are 18,128 victims across the country still waiting to be formally acknowledged as Minamata patients..." (The Gazette 1988). Analysis of the evidence could be heavily drawn from articles, reports, documents and news that described the organisational behaviour of Chisso since the installation of the Minamata Plant and before the official recognition of the disease. Examples of such evidence were government reports, such as "In the Hope of

Avoiding Repetition of the Tragedy of Minamata Disease” by the Social Scientific Study Group on Minamata Disease, published in 2001, and “Lessons from Minamata Disease and Mercury Management in Japan”, published in 2011 (Social Scientific Study Group on Minamata Disease 2001; Environmental Health and Safety Division 2011).

7.4.1 Policy and Planning

7.4.1.1 Policy

As in the Love Canal case study, there was no specific mention of Chisso’s HSE policy or any written expression of its commitment to health and safety. However, from the management’s decisions and actions, it was evident that Chisso aligned its corporate direction with the national priority, by focusing on production growth and business expansion.

The joint efforts of the government, industry and people to increase Japan’s international competitiveness had provided the platform for Chisso to push production at the expense of public health and environmental protection. Despite production activity taking a hit by the bombing raid in 1945, Chisso managed to restore its acetaldehyde and synthetic acid (raw material used in plastics) production to reach 10,000 tons in 1955, and that capacity increased to more than four-fold within the next five years (Social Scientific Study Group on Minamata Disease 2001, p. 13).

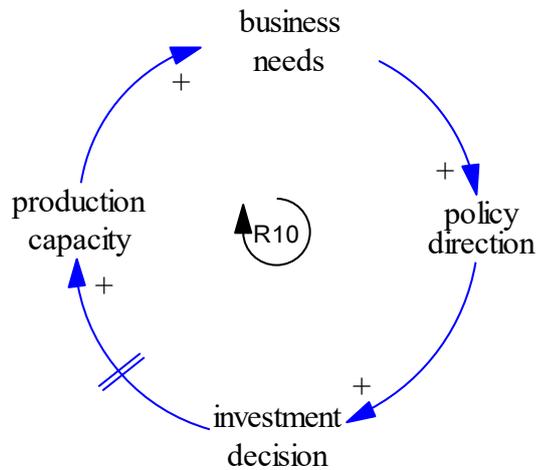


Figure 57: Minamata Disease's Policy and Planning 1

Besides favourable government initiatives that supported the manufacturing industry, Chisso was attracted to set up their manufacturing plant in Minamata City because of its proximity to abundant resources: a vast expanse of water and cheap labour supply (Environmental Health and Safety Division 2011). These reasons and the persuasion from residents to assist in transforming their village into a vibrant economy had convinced Chisso to invest in Minamata. The investment in Minamata reinforced its reputation as an innovative organisation managed by a team of technical experts.

Therefore, with a huge demand for industrial chemicals that was supported by a strong national and corporate direction to expand manufacturing activities, Chisso invested in new products, processes, plant and equipment, with little considerations for their HSE implications (R10, Figure 57).

7.4.1.2 Planning

As mentioned earlier, production rather than HSE had been the impetus behind Chisso's decision to invest in Minamata. This corporate policy was translated into a production-driven approach to its manufacturing activities. Spectacular growth in production capacity was achieved at the expense of poorly-paid workers and residents who were ignorant of the long-term health impacts of chemical exposure (Ui 1992, Chapter 4, Section 2). There was little evidence to show that Chisso had developed, implemented and maintained a strategy for the identification of hazards, assessment of their risks and determination of the necessary controls before implementing its operations. This was supported by Judge Saito's 1973 verdict on the corporate negligence perpetrated by Chisso, which stated that the company should have foreseen the risks of chemical exposure from its waste discharge, and that it should have researched into ways of ensuring the safety of its production methods (Huddle and Reich 1973). This dominant theme of production-driven focus is presented in the balancing loop (B10) in Figure 58.

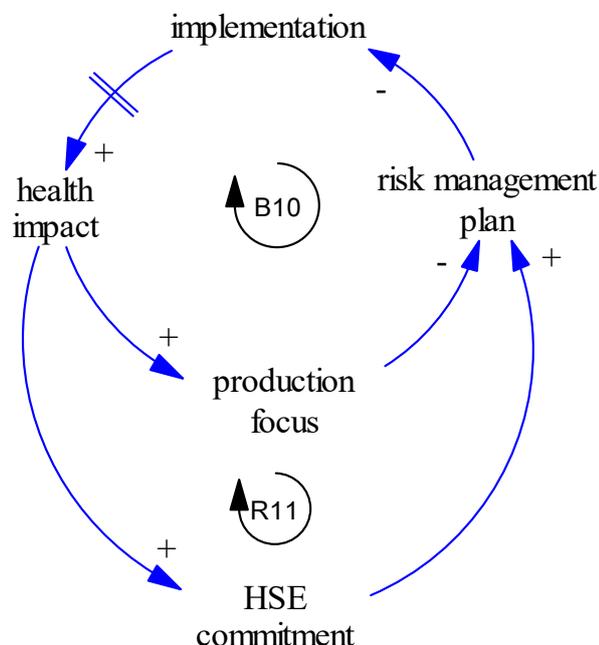


Figure 58: Minamata Disease's Policy and Planning 2

Counteracting this production focus loop is the reinforcing loop (R11, Figure 58) of HSE commitment. However, a strong production focus mindset influenced Chisso's decisions and planning for the Minamata plant. HSE considerations played little role in such operational planning and decision-making. For instance, the high risk of explosion encountered on several occasions using the Casale method for its mass production of ammonium sulphate production (a process that used iron oxide as a catalyst for synthesis of ammonia from nitrogen and hydrogen) in its Korean plant, did not stop Chisso from using the same process in the Minamata plant (Ui 1992). Thus, greater commitment to HSE would have contributed to better risk management planning, which would have allowed Chisso to carry out its production with minimum impact to health and environment.

7.4.2 Implementation and Operation

From the policy and planning phase to the subsequent phases of implementation and operation, and checking and review, there was sufficient evidence to show that the production-focused approach taken by Chisso often superseded considerations for the health and safety of workers and residents. The investigation of the implementation stage looked at the on-going consultation between Chisso and residents affected by its manufacturing activity, and the controls used during the operation to minimise the HSE impact. Since there was an absence of consideration for HSE during the planning stage, it was not unexpected that senior management had not provided sufficient resources for implementation, control and improvement of the HSE Management System. Rather than seeking to understand management decisions that could have long-term HSE implications, Chisso focused on production at the expense of exposing residents to the harmful effects of its waste discharge.

7.4.2.1 Consultation and Communication

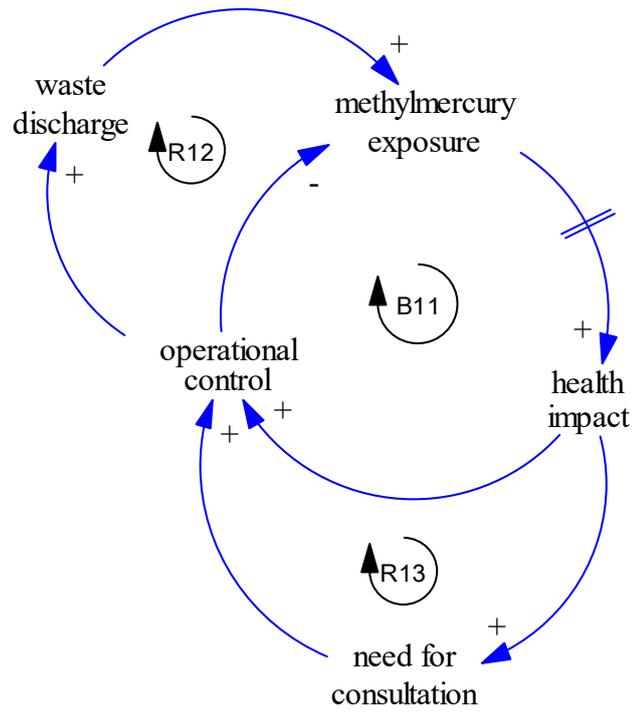
Against the backdrop where individual or group interests (e.g. victims of Minamata Disease) were suppressed by the larger community's interests, there could hardly be any genuine consultation and communication between Chisso and residents (Social Scientific Study Group on Minamata Disease 2001, pp. 11-13). Besides the Social factor described in Section 7.3.5 Social, following are more examples where the external social factor impacted the internal organisational factor - implementation and operation.

Due to the traditional mindset of the Japanese society, residents viewed that it was acceptable or even necessary to sacrifice lives for the collective effort of nation-building (Social Scientific Study Group on Minamata Disease 2001, p. 108). Rather than proactive consultation with residents to prevent long-term health impacts, Chisso was compelled to negotiate with victims suffering from the symptoms of Minamata Disease. However, Chisso would rather remunerate the fishermen with a sympathy payment than admit responsibility for its role in causing the disease (George 2001, pp. 76-81). Furthermore, complaints from the fishermen were treated by Chisso as unscientific and not supported by empirical research, knowing full well that the lowly educated fishermen and farmers depended on the technical expertise that resided with Chisso employees, government officials, university researchers and other external experts to provide information on the disease and its prevention (George 2001, p. 73).

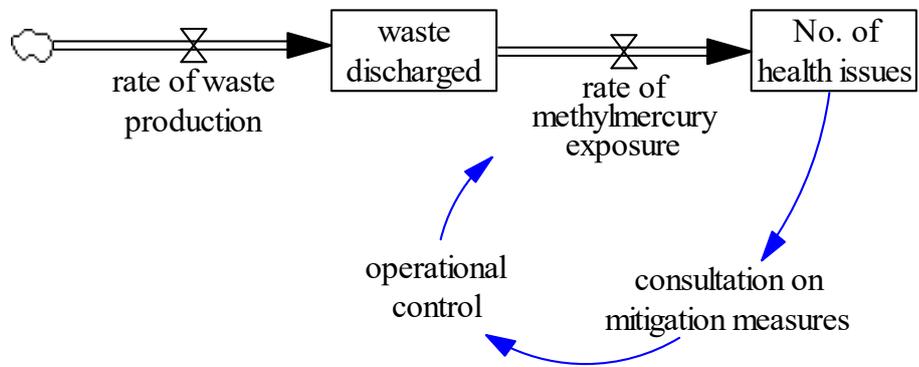
After a 1959 report from Kumamoto University about the hypothesis of Minamata Disease being due to exposure to an organic mercury compound, affected fishermen demanded that Chisso should install a treatment system for the waste discharge and suspend its production activity until such a system had been commissioned (Environmental Health and Safety Division 2011). More evidence demonstrated the link between the industrial chemical and Minamata

Disease, when Dr. Hosokawa's 1959 experiment showed that cats fed with Chisso's waste discharge were exhibiting symptoms of the illness. In an effort to hide such damaging information from the public, Chisso's management banned its own doctor from carrying out further experiments (Allen and Burns 2009). Further damaging findings came from Professor Irigayama, who reported, in 1962, that Chisso's wastes were the cause of Minamata Disease. Instead of consulting with Irigayama, Chisso instructed Dr Hosokawa to provide evidence to disprove this. Around the same time, the KPG tested the hair of residents and found high levels of mercury contamination. Like Dr Hosokawa's work, the important findings from the KPG were never made public (Ui 1992, Chapter 4, Section 6).

From the evidence, it appeared that the health impacts from the MeHg exposure did not trigger any meaningful consultation between Chisso and its stakeholders. Instead of cooperating with researchers, Chisso was resistant to third party attempts to investigate the suspected source of contamination in its production process (Social Scientific Study Group on Minamata Disease 2001, p.26). This causal relationship involving lack of consultation, negative health impacts and inadequate operational control is captured in the poor reinforcing loop (R13) in Figure 59a. As a result of the two ineffective balancing loops against the vicious cycle of waste discharge, the number of health issues related to the exposure of hazardous chemicals continued to rise. (Figure 59b).



(a)



(b)

Figure 59: Minamata Disease's Implementation

7.4.2.2 Operational Control

To achieve better production performance, in 1951, Chisso made use of a technical innovation to speed up the manufacturing process. Unfortunately, there was no corresponding investment in operational control to cope with the greater volume of organic mercury waste resulting from the process change (R12, Figure 59) (George 2001, p.34). Despite observing symptoms similar to those of the Minamata Disease in experiments conducted on animals by Chisso's in-house doctor in 1956, and the revelation of similar studies by Kumamoto University linking organic mercury to the disease's cause in 1957, Chisso ignored these findings and continued to increase production of acetaldehyde (Social Scientific Study Group on Minamata Disease 2001, p.28, 29). Also, Chisso's knowledge of the presence of organic mercury in its production process (e.g. formation of MeHg in the synthesising chamber), and subsequent public revelation of this discovery in 1963 did not result in any improvement of or changes to the operational controls. Neither did it prompt the prefecture and national government to further investigate the significant findings (George 2001, p.68-70). Therefore, B11 in Figure 59 illustrates a weak balancing loop that was not able to achieve better operational control to minimise the exposure to MeHg and, thereby, reduce the impact on health.

Another example of Chisso's emphasis on production over safety was its blatant disregard for warnings about the harmful impact of its wastewater discharge. Court testimony in 1979 from a former factory manager acknowledged the inherently dangerous working conditions in the Minamata plant (George 2001, p.245). Initially, there was no treatment or any attempts to minimise the harmful discharge into Minamata Bay (Social Scientific Study Group on Minamata Disease 2001, p.16, 17) (see Figure 60). In order to avoid the disease being traced to its waste discharge, and believing that the waste would be sufficiently diluted to a harmless level, Chisso redirected its discharge to the mouth of the Minamata River in 1958. Unfortunately, this caused the spread of the disease to

other coastal towns around the Shiranui Sea (George 2001, pp. 54, 55). Therefore, the reinforcing loop (R12, Figure 59) shows that insufficient commitment to operational control led to the decision to redirect the waste discharge that exposed even more residents to the toxic MeHg.



Figure 60: Chisso's Waste Discharge Into the Sea (Smith 1971)

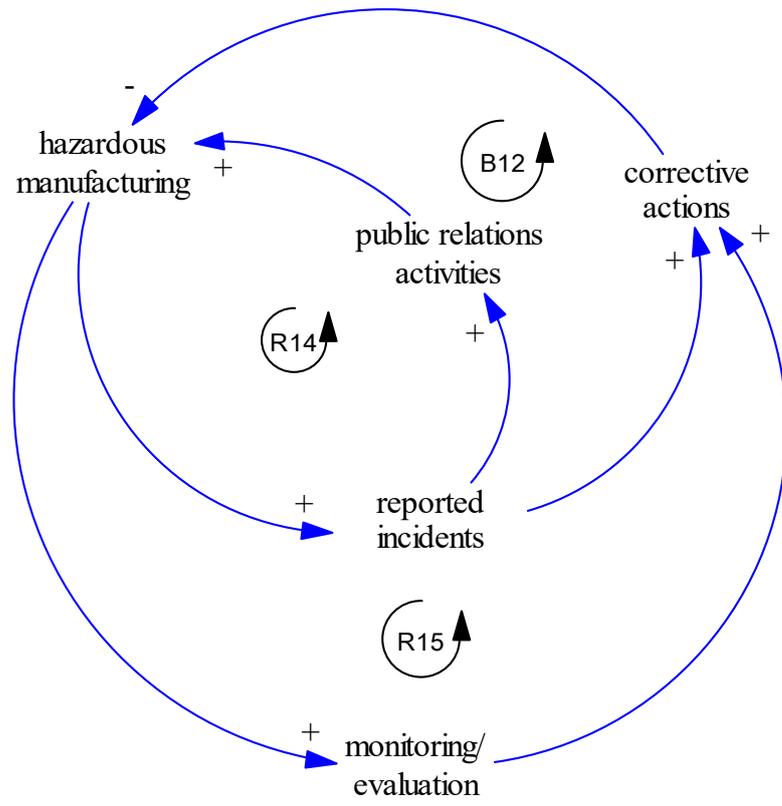
In response to subsequent reports of links between the disease and the mercury discharge, and the riots of fishermen, Chisso was compelled to install a waste treatment system. It was later discovered that the so-called treatment system was actually a sedimentation basin, which was not designed to remove toxins in the wastes (Funabashi 2006).

7.4.3 Checking and Review

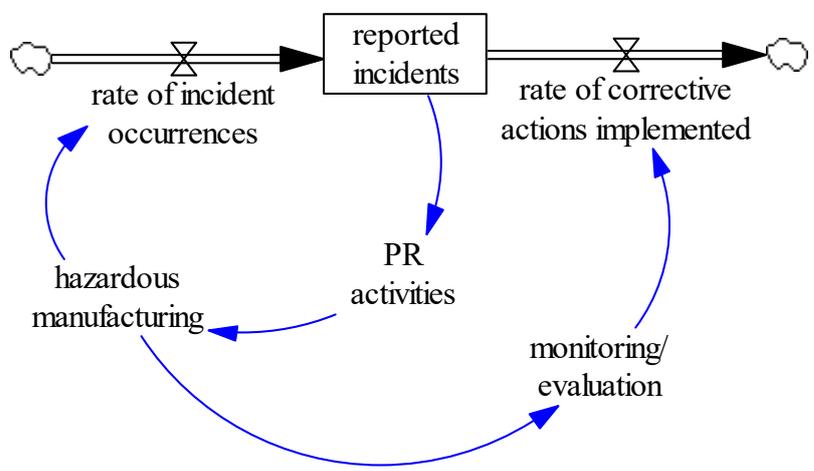
As shown in Figure 61a and Figure 61b, two major approaches could be taken by Chisso to improve its EHS performance. One was through the reactive approach of responding to reported incidents to implement the necessary corrective actions (B12, Figure 61a). The other was through the proactive monitoring and measuring of its EHS performance and making the necessary adjustment or corrective actions before the occurrence of incidents (R15, Figure 61a).

One of the more common methods of proactive performance evaluation was health surveillance of workers, which was not evident in Chisso's procedures (R15, Figure 61a). Workers' safety was not highly regarded by the management of Chisso. In fact, they were treated like work horses and were expected to operate in dangerous conditions for very little pay (Ui 1992, Chapter 4, Section 2). Moreover, the higher-than-industry frequency rate of accidents at Chisso should have prompted management to investigate their possible causes and to take the necessary measures to prevent their recurrences (Social Scientific Study Group on Minamata Disease 2001, p. 87).

For the residents, it was not until 1960 that the local health department carried out any kind of health surveillance by measuring the mercury levels of residents affected by the chemical exposure (Ui 1992, Chapter 4, Section 4). Therefore, overwhelming evidence indicated that Chisso initially took neither approaches, whether it was proactive or reactive evaluation, in its management of EHS, but only demonstrated its intention to maintain the status quo. Expectedly, the rate of exposure incidents increased, without any effective mechanism, nor management's commitment to reduce their occurrence (Figure 61b).



(a)



(b)

Figure 61: Minamata Disease's Checking and Review

7.4.3.1 Public Relations Activities

Chisso was concerned about any negative publicity that would impact upon its productivity and profitability (Institute for International Cooperation 2005). Therefore, instead of taking a proactive approach to incident prevention by investigating reports of organic mercury as the possible cause of the disease, Chisso invested in a series of public relation campaigns to refute reports and scientific findings linking its industrial discharge to Minamata Disease (Johnston 2006). Part of Chisso's strategies to protect its corporate image involved funding national committees, such as the Minamata Disease General Investigation and Research Liaison Council (MDGIRLC) and the Japan Medical Association's Minamata Disease Research Consultation Group (JMAMDRCG) to promote counter theories to the findings from Kumamoto University. Moreover, without concrete evidence about the exact pollution source, Chisso and the government maintained that no drastic public action was required. At the same time, in an attempt to divert attention from Chisso's activities involving chemical disposal, the City Mayor notified the Ministry of Health and Welfare (MHW) that chemicals used in agriculture could be the source of pollution (Maruyama 1996). As a result, these delaying tactics only exacerbated the underlying cause and allowed Chisso to continue with its hazardous manufacturing (see R14, Figure 61).

7.4.3.2 Industrial Waste Treatment

After the fishermen had refrained from fishing in Minamata Bay for fear of consuming contaminated seafood, in 1957, Chisso secretly changed and redirected the waste discharge system in the following year. From discharging MeHg directly into Minamata Bay, the waste was subsequently diverted to a holding reservoir before being discharged at the mouth of the Minamata River. Chisso believed that this alternate discharge location would dilute the contaminants in the industrial waste within the Shiranui Sea. Unfortunately, this operational change led to the residents surrounding the new discharge area contracting Minamata Disease (Environmental Health and Safety Division 2011).

After reports confirmed that the cause of the disease was due to mercury poisoning, local fishermen pressured Chisso to install a treatment system for its waste discharge and, until such time, to suspend further operations (Environmental Health and Safety Division 2011). However, Minamata Disease continued to spread despite the installation of the industrial waste purification system in December 1959. It was later discovered that the so-called purification system had only provided a cosmetic solution without actually removing the harmful MeHg compounds from the production process. Instead of treating the toxic discharge, Chisso had merely constructed a settling basin and sedimentation tank for holding the discharge (Harada 1994). This mistaken belief and the fact that residents had stopped consuming Minamata seafood led doctors to ignore possible new cases of the disease.

Based on the above evidence, the weak balancing loop (B11, Figure 61a) shows that the corrective actions taken by Chisso were ineffective in mitigating the health and environmental risks created by its hazardous manufacturing. This was supported by the judgement in Chisso's negligence case where it was found to have inadequate preventive measures to ensure the health and safety of the residents (Huddle and Reich 1973). If the corrective measures had been effective, then there should have been a subsequent reduction in the mercury levels found in residents. However, readings from tests carried out by Kumamoto University between 1960 and 1961 revealed high levels of mercury contamination. As in several past studies, these damaging results were kept hidden from the residents (Ui 1992, Chapter 4, Section 4).

Furthermore, as shown by the weak reinforcing loop (see R16, Figure 61a), there was little evidence to support that Chisso regularly monitored and evaluated its industrial processes to ensure that its production and discharge did not cause any public health and environmental impact. Consequently, the weak reinforcing (R15) and balancing loops (B12) were not sufficiently strong to counteract the reinforcing loop (R14) of public relations activities to justify the

continued hazardous manufacturing activity (see Figure 61a).

7.5 Conclusions

Beyond the internal organisational factors, external organisational factors played significant roles in contributing to the outbreak of Minamata Disease. Evidence from the case study showed the strong relationship between the PLETS factors and Chisso's business strategies, which were in alignment with the favourable national policies of high industrial growth. In turn, these productivity driven approaches such as adapting more advanced technology to increase production capacity impacted the execution of the operational activities and poor management of HSE (Figure 30).

This case study showed that the influence of these inter-relating factors was complex and not immediately obvious to investigators during that time. Thus, CLDs were used to better understand the complex interactions among external factors, namely political, legal, economic, technological and social factors. Often these produced powerful and destructive structural dynamics that contributed to the serious health impacts, with far reaching consequences that extended beyond the cessation of manufacturing activity that created the source of chemical pollution in the first place.

Against the backdrop of an aggressive rehabilitation of the post-war economy, and the support of favourable Japanese industrial policies, Chisso, the business community, government and unions were united in their pursuit of high economic growth. These powerful and vicious growth cycles overwhelmed the ineffective enforcement activities, which were supported by an immature legislative framework. Consequently, Chisso was able to discharge a huge amount of toxic mercury without much regulatory intervention.

Corporate social responsibilities did not enter the consciousness of Chisso, and local communities did not have the autonomy to check on Chisso's activities. On the contrary, societal culture and values demanded that residents and stakeholders put national and community interests above individual needs, or victims suffering from exposure to the industrial wastes. As a result, the poor incident reporting culture and ineffective follow up by Chisso exacerbated the health impact.

An inadequate EHS management system in terms of policy and planning, implementation and checking was clearly evident. These internal organisational factors were either non-existent or too weak to counteract the dominant theme of high productivity and growth. An effective EHS management system would require the determination of the disease's cause and identification of the contamination source, in order to prevent worsening of the epidemic. Chisso not only failed to investigate the cause of the disease, but they also deliberately obstructed and obfuscated the efforts of independent researchers to determine the source of pollution. As a result, Chisso and government agencies delayed taking countermeasures to eliminate the suspected toxic mercury, and to minimise the spread of Minamata Disease. In the meantime, pollution and production continued.

The Minamata case study showed that national policies of economic development should not be established at the expense of HSE risks and environmental destruction. Considerations for EHS should be taken into account at the planning stage and before commencement of any manufacturing activity that involves hazardous substances. Effective risk management combined with an effective monitoring regime would have provided opportunities for Chisso to promptly address its EHS issues before they became unmanageable. This could only be achieved with genuine consultation among stakeholders, especially residents who could be directly affected by the control measures put in place by the
polluting
company.

Chapter 8

CASE STUDY – ESPERANCE LEAD POLLUTION

8.1 Introduction

This occurrence of lead pollution in Esperance did not share the same historical context as the circumstances of the Love Canal and Minamata. Nonetheless, as in the other two earlier cases, there were several stakeholders such as the government regulatory agencies, port authority, Magellan Metals and the community that played important roles in contributing to this Esperance incident. Additionally, both the external and internal systemic factors were examined and specific CLDs were developed to provide valuable insights into the underlying dynamic behaviour of this complex EIPE.

This EIPE is considered to be one of the worst HSE disasters in Western Australia (WA). The deaths of thousands of birds in 2006/07 triggered a parliamentary inquiry and the largest blood lead survey ever conducted in WA. The 2007 Inquiry Report No. 8, convened by the Education and Health Standing Committee, was the result of more than 100 submissions and 1,000 documents, including evidence transcripts from more than 50 witnesses. It revealed a complex web of interrelated causal factors contributing to this EIPE. The findings from the inquiry concluded that residents of Esperance had been exposed to lead dust emissions during the Esperance Port's handling processes. As a result, the main organisational player in this case study, the Esperance Port Authority, was convicted of lead contamination in August 2007.

8.2 Case Overview

This detailed case study starts from the point where, in September 2004, the Esperance Port Authority (Esperance Port) applied for variation of its licence to allow for the export of lead, and concludes with the departure of the final quarantined lead concentrate in August 2009. Events prior to the handling of the lead concentrate were explored as well, such as the experiences of nickel and iron ore operations at the port, which provided valuable insights into the causation of the lead pollution.

In August 2004, Magellan advised the Western Australian Department of Environment (WADOE) that they might change their original proposal to export lead concentrate via Esperance instead of Geraldton. Subsequently, Esperance Port applied to WADOE to vary its licence to allow the loading of lead carbonate, in September 2004. From the outset, Esperance Port maintained that they had a better 'enclosed' system compared to that of the 'partially enclosed' system at Geraldton. Two months later, the licence to export lead carbonate was approved (Education and Health Standing Committee 2007a, pp. 275, 279).

In October 2004, Magellan Metals formally applied to the WADOE to amend the original proposal to export lead concentrate through Esperance. With the Western Australian Environmental Protection Authority's (WAEPA) recommendation, the Ministerial Statement was varied, in December 2004, to allow export via Esperance based on the understanding that the changes would not have a substantial environmental impact. This approval was achieved without any community consultation or reference to the original WAEPA Bulletin (Education and Health Standing Committee 2007a, pp. 104, 107, 108, 109).

In April 2005, the first 5,000 ton load of lead carbonate, transported in tarpaulin-covered kibbles, made the 900km journey from the Wiluna mine site to the port handling facilities, along which the rail section would pass through Kalgoorlie,

Norseman and several townships (Education and Health Standing Committee 2007a, p. 401). The original plan from Magellan was to build a smelter plant at the mine to convert the lead into ingot form before transporting it, but the plan never materialised (Education and Health Standing Committee 2007a, pp. 138, 139). At the port, the lead was stockpiled in a large storage shed and loaded onto ships via a series of transfer points and conveyors (see Appendix D and Figure 62, Figure 63 and Figure 64).



Figure 62: Lead Concentrate was Tipped Into a Dumper by Forklift (Education and Health Standing Committee 2007a, p.6)



Figure 63: Exterior View of the Conveyor (Education and Health Standing Committee 2007a, p.11)



Figure 64: Lead Concentrate was Loaded via the Telechute to the Ship's Hull (Education and Health Standing Committee 2007a, p.12)

In December 2006, the discovery of the deaths of thousands of birds within the Esperance community triggered a series of tests conducted by the WADOE and the Western Australian Department of Environment and Conservation (WADEC). Results of the tests revealed evidence of lead poisoning, which was traced to the lead dust escaping during the in-loading and out-loading of Magellan's lead product at the Esperance Port. Subsequently, Western Australian Department of Health's (WADOH) blood testing results showed an elevated blood level among Esperance's residents. Of greater concern was that almost a quarter of the children under 5 had blood lead levels equal to or in

excess of 5 micrograms per decilitre ($\mu\text{g}/\text{dl}$) (Education and Health Standing Committee 2007a, pp. xxiii, 1, 17, 464, 465), because studies have shown that there can be adverse impacts in children from exposures resulting in blood lead levels under $10\mu\text{g}/\text{dl}$ (Canfield et al. 2003). Although nickel and lead were discovered in the soil, air, dust and rainwater samples taken in Esperance, identification of the geographical extent of the pollution was not definitive.

In March 2007, Magellan was subsequently banned from exporting lead from the port, and the mine and processing plant, 1,000km south-east of Perth, was put on a care and maintenance schedule, until a government-approved method of exporting lead concentrate could be determined. At the time the ban was imposed, around 8,000 dry metric tons of lead carbonate was in the storage shed at Esperance, with another 22,000 dry metric tons at the mine awaiting shipment (Education and Health Standing Committee 2007a, pp. 3, 285).

In April 2007, Parliament commissioned the Education and Health Standing Committee to inquire into the cause and extent of lead pollution. Its report, containing 46 recommendations and 192 findings, was tabled in September 2007 (Education and Health Standing Committee 2007a, pp. xxxiii-xcix). Subsequently, Esperance Port was convicted on several charges relating to lead contamination and nickel odour emission. Esperance Port pleaded guilty to all charges in October 2009 and was fined AUD525,000, the highest environmental fine in Western Australian history (Weber 2009).

In December 2008, Magellan agreed to contribute AUD9 million to the Esperance clean up. In addition, Magellan established an AUD1 million fund for community-based projects, to be administered by the Shire of Esperance (Magellan Metals 2008). More than two years of negotiation and collaboration with the government of Western Australia and Esperance Port was needed to resolve the Esperance lead pollution issue (Government of Western Australia 2012a). After developing an acceptable, safe disposal export method, final shipment of the quarantined lead carbonate at the port storage left Esperance in

May 2009. This export was to be the first step toward a final clean-up (Styles 2009).

In August 2009, Magellan secured approval from the Minister for Environment using a similar process to bag, containerise and transport lead carbonate from its mine and process it through the Port of Fremantle for export. In addition, the WADEC imposed strict licence conditions on the port to avoid further health or environmental problems. Also, an AUD5 million bond was lodged with the State Government (International Lead Association 2017). The key sequence of events is outlined in Figure 65.

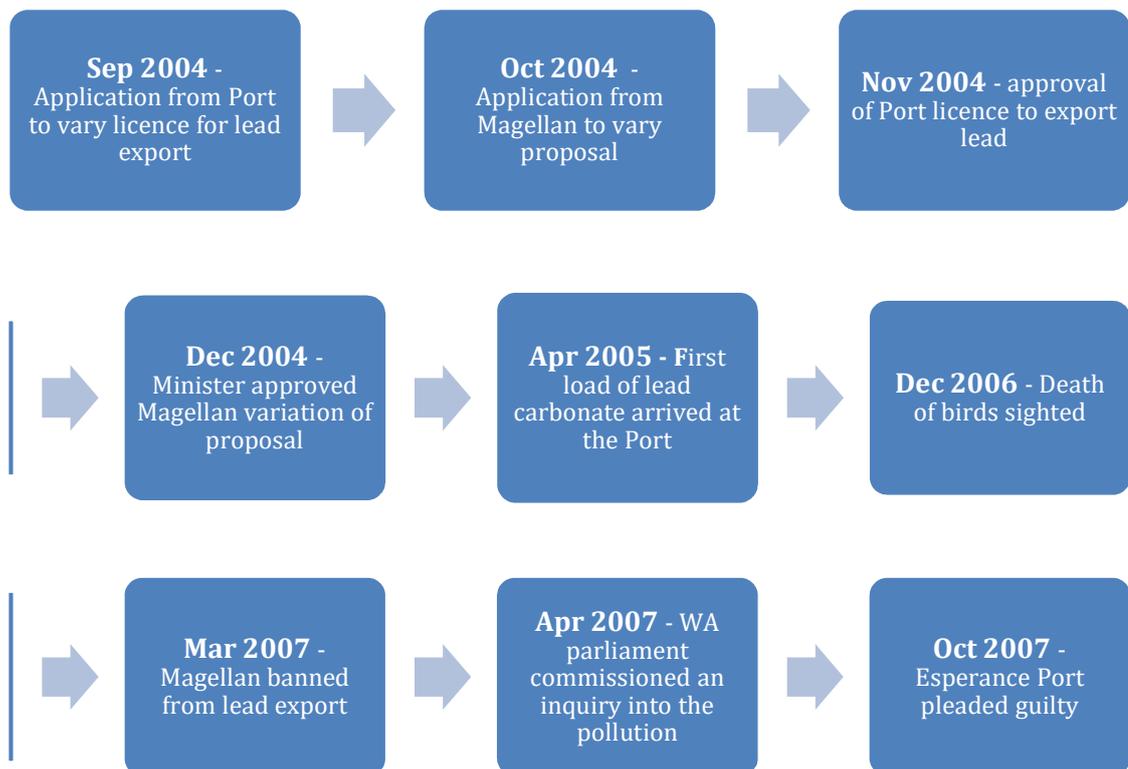




Figure 65: Timeline of Key Events in Esperance Lead Pollution

8.3 External Organisational Factors

External organisational factors are influences outside of the organisation. Although Esperance Lead took place in different historical context and geo-political environment from those of the Love Canal and Minamata Disease, these external factors - political, legal, economic, technical and social – similarly influenced the operational activities of Esperance Port. These are important systemic factors that need to be viewed as part of the overall environmental impact on an organisation. The significance of such an approach is aptly described by one of the witnesses for the Esperance Lead Pollution Inquiry, “... the cause and effect of lead pollution in the Esperance area is not an isolated instance of neglect but is part of a system and framework within, where these abuses are inevitable” (Education and Health Standing Committee 2007h).

8.3.1 Political

Like any ports in Western Australia, the Esperance Port Authority had to comply with the Port Authorities Act 1999. Although the state government sets the strategic direction for all state ports, the Esperance Port Authority was not part of the public sector, and neither were its officers (e.g. CEO) and staff members considered to be public servants. This was to ensure the independence of its operations, and to minimise possible conflict of interest between the roles and functions of the government agencies and those of the operator. Unless there were specific directions given by the Minister, the port had complete control over its operations (Government of Western Australia 2014).

Nonetheless, the Department of Transport worked closely with the ports to ensure that the infrastructure funding and planning that was carried out was able to attract private sector investment. For instance, in 1992, the federal and state governments jointly funded a AUD16.5 million upgrade of the Esperance to Leonora railway, which helped to reduce operation costs for miners shipping minerals to Asian markets via the port of Esperance (Taylor 1992).

At the time the parliamentary inquiry on Esperance Lead Pollution was taking place, there were concerns about the involvement of former state and commonwealth politicians in the government's approval of Magellan's lead concentrate. The relationship between the CEO of Esperance Port and a state politician, who was linked to the inquiries conducted by the Corruption and Crime Commission (CCC) into lobbying and alleged public sector misconduct, gave rise to reasonable doubts as to whether the government approval process had been circumvented by the efforts of political lobbyists. Despite this suspicion, evidence presented to the committee did not reveal any information to suggest that representatives of Magellan Metals, Esperance Port or the WAEPA had been involved in lobbying for the approval of the Magellan proposal, or that any impropriety was involved in the approval process (Education and Health Standing Committee 2007s, 2 May, 7 June, 28 June).

8.3.2 Legal

The HSE and environmental legislative framework in Western Australia at the time consisted of the relevant Acts, Regulations, Standards, Codes of Practice and other guidance materials. Unless referenced in the regulations, standards were not legally enforceable (Department of Environment Regulation 2017; WorkSafe WA 2017). While codes of practice were not legally enforceable, they could be used in court as evidentiary documents to support legislative compliance. Therefore, this legal framework provided an important platform for

the enforcement of legislative requirements to ensure the protection of workers, contractors, residents, public and other stakeholders covered under the scope of the legislation. Penalties, such as fines and/or imprisonments, were possible consequences for violations of these enforceable legislative requirements. State government agencies such as the WADEC and WorkSafe WA were responsible for administering their legislative roles and functions to promote HSE protection (Department of Environment Regulation 2017; WorkSafe WA 2017).

Comparatively, Esperance Port was operating in a more comprehensive and robust legislative framework than those found in the Love Canal and Minamata Disease case studies. Even then, the inquiry found that certain legislative requirements, such as the Australian Dangerous Goods Code and National Environmental Protection Measure for lead in ambient air, were either inadequate or had not kept up with the latest international requirements (Education and Health Standing Committee 2007a, Finding 173). The inter-relationship of the causes and effects associated with these external organisational factors are represented in Figure 66.

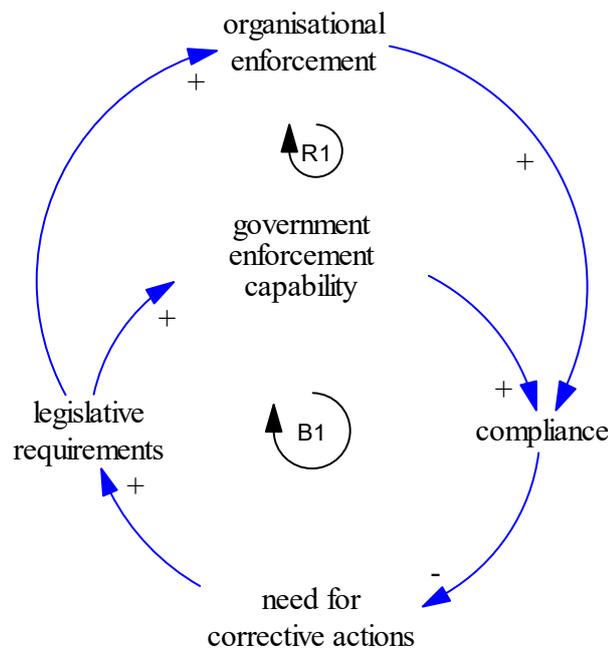


Figure 66: Esperance's Legal Factor 1

8.3.2.1 Legislative Framework

Although the Port Authorities Act 1999 required port authorities to ensure the safe operation and environmental preservation of the port, there was no specific requirement in the Act that port authorities minimise the impact of port activities on public health (Education and Health Standing Committee 2007a, p. 66). Despite this lack of a prescriptive framework in addressing the risk of lead pollution, the Esperance Port Authority was aware of the negative impact to the community in the event of any hazardous pollution from the port (Education and Health Standing Committee 2007a, pp. 323, 324).

The reinforcing loop (R1, Figure 66) displayed the industrial approach to self-regulation or enforcing the legislation within the organisations (e.g. Dangerous Goods legislation). The legislative framework adopted by the WA government allowed an industry to establish measures to ensure the safety and health of the community. For example, legislation for mining operations detailed specific requirements for the safe management of hazardous substances. Part 7, Division 3 of the Mines Safety Inspection Regulations 1995 included the need for hazard identification, risk assessment and controls, such as the monitoring of contaminants and health surveillance (Department of Mines and Petroleum 2017). Moreover, Chapter 4.3 of the Environmental Protection Act 1986 mandated that the port operator must take all reasonable and practicable measures to prevent or minimise exposure to harmful emissions (Department of Environment Regulation 2017).

Essentially, the effectiveness of these industry compliant measures was determined by the correct understanding and diligent application of these legislative requirements. Unfortunately, there could be confusion in the way compliance should be achieved. Initially, the Western Australian Department of Minerals and Energy (WADME) was not able to conclusively determine whether the lead concentrate should be classified as dangerous goods, and Magellan did

not have an accurate MSDS of its product once it was in production, as was required by the Mines Safety Inspection Regulations 1995 (Education and Health Standing Committee 2007a, p. 303).

Esperance Port argued that it did not have to comply with the Australian Dangerous Goods legislation, even though the MSDS had stated the product as Class 9 dangerous goods, because it was not classified by the Resources Safety Division as such. However, the port would still have been under the duty of care to verify the correct classification of the lead concentrate (Education and Health Standing Committee 2007a, p. 310), especially when it had earlier received a generic MSDS classifying the product as dangerous class 6.1, which would require a host of preventive actions including specific training in handling of such dangerous goods (Esperance Port Authority 2007c, p. 15).

A further example of the failure in self-regulation could be seen in August 2005, when Main Roads issued BIS Industrial Logistics permits to cart the lead product from the mine site to the port, even though carting of the product had been going on since April 2005. Although BIS was given the specific MSDS of the lead carbonate that was listed as dangerous goods, incorrect advice about the product classification was provided to Main Roads for the permit application. The committee further found that BIS did not meet its legislative obligations in providing workers adequate personal protective equipment (PPE) when handling the product (Education and Health Standing Committee 2007a, pp. 304, 307).

Besides inaccurate interpretation of the various legislative requirements governing the handling of hazardous substances, it appeared that such an industry self-regulatory approach had thus far been inadequate and that the regulatory framework did not consistently address the risks of lead pollution. Otherwise, there would have been no need to review the adequacy of legislation and regulations, which was one of the inquiry committee's functions and powers.

The balancing loop (B1, Fig. 66) in the same CLD illustrates the causal factors required for legislative compliance. In the applicable Acts (Occupational Safety and Health 1984; Environmental Protection Act 1986; Mines Safety Inspection Act 1994; Port Authorities Act 1999), there were no specific legislative requirements to incorporate a Health Impact Assessment (HIA) into the planning and approval process. Neither were there specific requirements in the Port Authorities Act 1999 to ensure that port activities did not adversely impact public health (Education and Health Standing Committee 2007a, p. 66).

As for other enforceable legislative requirements, Findings No. 18 and 21 from the parliamentary inquiry revealed the gross inadequacy of compliance monitoring and enforcement by the WADEC (Education and Health Standing Committee 2007a, pp. 76, 87). These reasons and the absence of corrective or remedial actions for regulatory non-compliance did little to encourage companies to invest in safety while attempting to be profitable at the same time (Education and Health Standing Committee 2007s, 7 June). Therefore, effective organisational and government enforcement measures were both needed to achieve satisfactory compliance outcome.

8.3.2.2 Functions and Roles of Government Agencies

Following is a synopsis of the functions and roles of key government agencies: the WADEC, the WAEPA, the WADOH and the Western Australian Department of Industry and Resources (WADOIR). Other government agencies, such as the Western Australian Port Operations Task Force, the Sea Freight Council of Western Australia, and the Department for Planning and Infrastructure's Marine Pollution Unit, did not seem to play any role in this EIPE.

Naturally, the ability of the government agencies to carry out their responsibilities depended on the availability of resources given to them. From the Bellevue catastrophe in 2001 (McGlew 2015) and the Esperance Lead Pollution case, the general perception seemed to be that government agencies

could do more to protect environmental and public health. The relationship between their roles and functions, inter-agency coordination, resources allocation, agency restructuring, ability to address public complaints and perceived government performance is represented in the CLD in Figure 67.

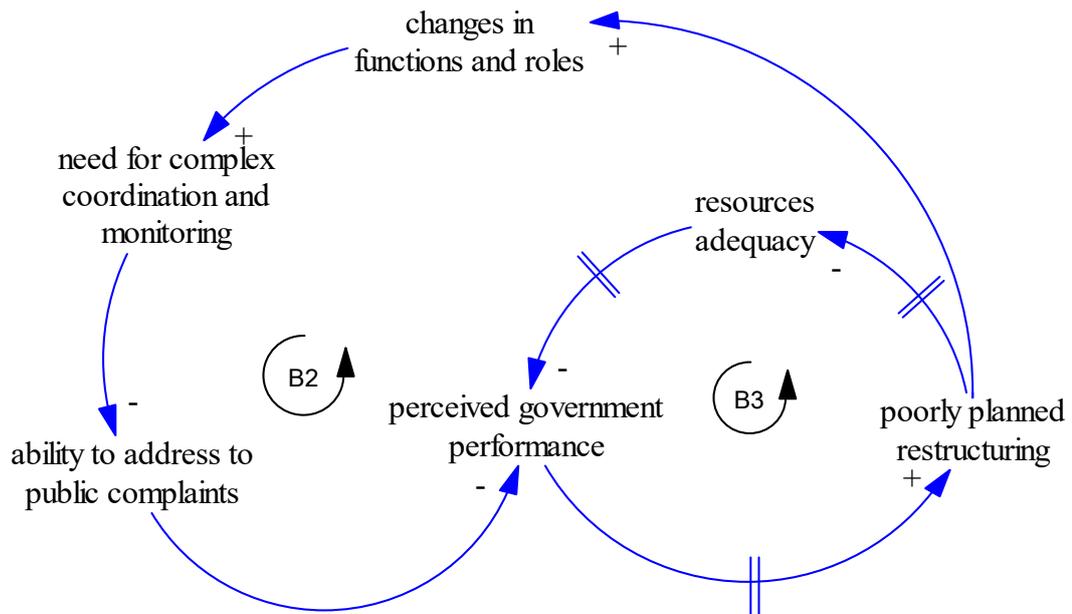


Figure 67: Esperance's Legal Factor 2

Besides administering and enforcing the Environmental Protection Act 1986, the roles of the WADEC included: assessing applications for licence and works approvals; supporting the Environmental Impact Assessment carried out by the WAEPA; setting environmental conditions relating to the management of environmental pollution; carrying out inspections; and monitoring compliance with environmental conditions. Similarly, the lack of inspectors in the Resources Safety Division to cover all licensed dangerous goods sites and their associated regulatory functions was noted by the committee (Education and Health Standing Committee 2007a).

An independent strategic review, the Welker Review 2003, revealed that the then Western Australian Department of Environmental Protection (WADEP) was

too focused on assessing licences, to the detriment of the establishment of resources and competencies needed for compliance monitoring (Welker 2003). Another report, the Robinson Review 2003, highlighted a lack of clarity in the department's enforcement role and its relation to other activities within the same department (Robinson 2003). Other obstacles to "effective industry regulation by the WADEC was constant restructuring which, combined with insufficient resources, resulted in ongoing staffing changes and a loss of corporate knowledge. This led to a lack of experience and capability in monitoring the complex and diverse operations subject to the Department's regulatory powers" (Education and Health Standing Committee 2007a, p. 286). The balancing loop (B3) captures the impact upon government performance of this restructuring and lack of resources.

The WAEPA acts as the independent body providing advice to government (Environmental Protection Authority 2012). Part VI, Section 40 of the Environmental Protection Act 1986 states that, if the Authority decided to assess a referred proposal under Section 38, then the WAEPA would set the requirements for the environmental impact assessment. The proponent would then prepare documentation outlining the proposal, its potential consequences on the environment, and the control measures that are to be put in place for mitigating those consequences (Government of Western Australia 1986, pp. 48 - 57).

One of the branches of the WADOH was the Environmental Health Directorate, which consisted of five units – Environmental Hazards Unit, Food Unit, Radiation Health Unit, Science and Policy Unit and Water Unit. One of its key roles was to "provide provision of adequate environmental health services to all population centres and communities, and the safety of public buildings" and to "promote safe use of chemicals and minimise the risk of harm from chemical exposure" (Department of Health 2012). Through the Environmental Health Directorate, the WADOH collaborated with state and local government and equipment manufacturers to undertake risk assessments of lead exposure from playground

facilities. This was done to assist in the Esperance clean-up and recovery program (Environmental Health Directorate 2011).

Since the WADOH acted purely as an advisor by providing health information and advising other government authorities regarding likely health impacts associated with the proposed activities, the parliamentary inquiry found that it lacked the legislative provision to respond to industrial activities that had significant public health impacts (Education and Health Standing Committee 2007a, pp. 89, 90). For instance, it merely assessed and provided advice to the WAEPA on the safety of food and drinking water, wastewater management, mosquito control and possible exposure protection from emissions. Other decision-making authorities, such as the WAEPA, would decide if there was a need to seek advice from the WADOH (see Figure 68).

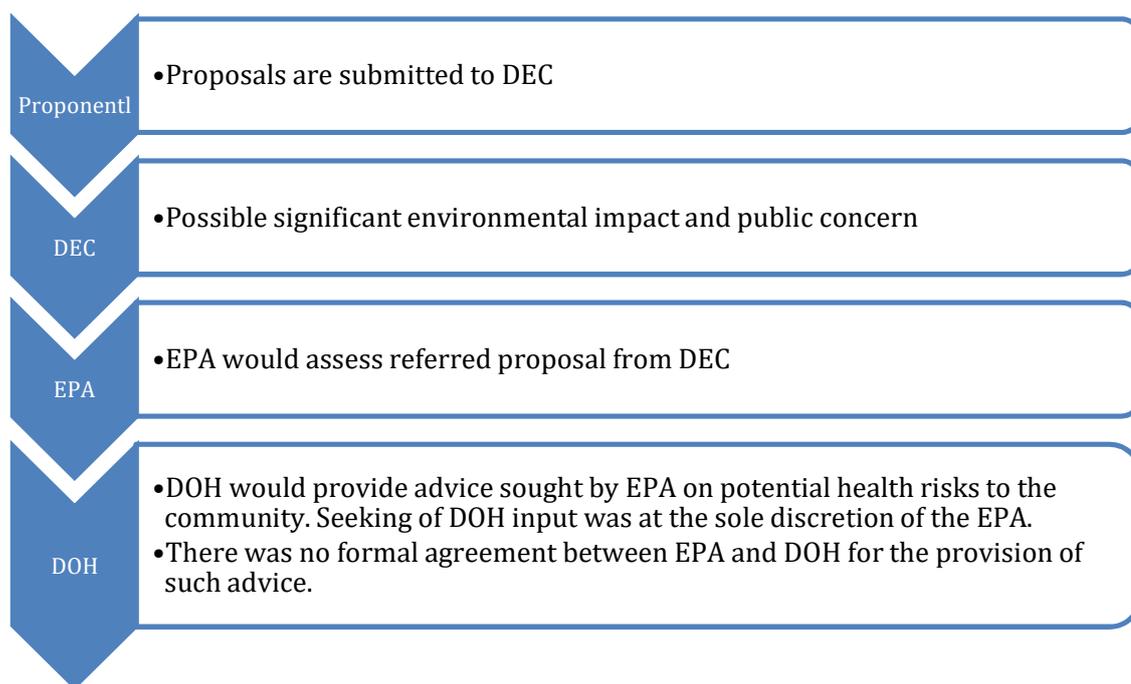


Figure 68: Proposal Process Involving Government Departments

The Western Australian Department of Industry and Resources (WADOIR) was established in 2003. It was previously known as the WADME and the

Department of Industry and Technology, and is now known as the WADMP, which administers the Mining Act 1978 and the Mines Safety and Inspection Act 1994. The main objective of the Mines Safety and Inspection Act 1994 (MSIA) was to promote and improve occupational safety and health for people who worked in mines in Western Australia.

The Safety Health and Environment Division of the WADOIR was comprised of: the Mining Safety Branch, which administered the MSIA; the Dangerous Goods Branch, which administered the Explosives and Dangerous Goods Act 1961 and the Dangerous Goods Transport Act 1998; and the Environment Branch, which administered the environmental conditions of the Mining Act under which the Minister may impose conditions on the granting of a mining tenement to prevent or reduce injury to the land. These functions are now handled by Resources Safety under the new WADMP. Despite the important role of the department in industry's safety and health, "(WA)DME's involvement in public safety only applies to safety associated with Dangerous Goods regulation and the provision of risk advice to the (WA)DEP" (Education and Health Standing Committee 2007a, p.365).

Cooperation among the above mentioned government agencies could create efficiencies in the provision of regulatory and support services. Additionally, sharing of critical expertise across various departments could help to facilitate a concerted approach to regulating industrial operations, which would enhance government performance in managing public health and environmental issues. However, as shown in the balancing loops (B2 and B3 Figure 67), frequent restructuring (e.g. amalgamation of the Department of Environment and the Department of Conservation and Land Management in 2006) led to frequent adjustment to new roles and functions, which negatively influenced the coordination effort between government departments. For instance, when seeking safety and health guidance and information, residents were sent on a hopeless quest from one government department to another (Education and

Health Standing Committee 2007c). The poor coordination among government agencies was also evident during the initial response to the lead pollution, where there was a lack of understanding about their roles and responsibilities.

8.3.2.3 Approval Process and Conditions

Part of the inquiry was to understand the approval process associated with changes to the handling of lead at Esperance, instead of Geraldton as originally planned, and the absence of public consultation, even though it was required for such variations. A finding of the inquiry concluded that “the approval processes for, and the regulatory regimes applicable to, the transport and handling of dangerous goods such as lead concentrate in Western Australia failed” (Education and Health Standing Committee 2007a, p.14).

Concurring with the findings, both the Director General and Deputy Director General of the WADEC admitted that there were lapses in the system and in carrying out its functions. “The Department has acknowledged that there were inadequacies in its regulatory processes at the port. The Department considers that these were departmental deficiencies in terms of its processes, instructions and training, and not of individual officers” (Education and Health Standing Committee 2007a, p. 73). Furthermore, the inquiry reported that the WAEPA, the WADEC and Magellan Metals had failed to implement the WADOH’s recommendations and advice during the approval process (Education and Health Standing Committee 2007a, p. 94).

Regardless of initial concerns about the inaccurate identification of the hazardous substances, which had implications for the appropriate mitigation controls to be applied throughout the entire management and handling of the dangerous goods, the Minister for the Environment had approved the Magellan proposal on 28 November 2000. (Education and Health Standing Committee 2007a, p. 92). This approval was subject to the conditions and commitments recommended by the WAEPA (Environment Protection Authority 2000).

Included in the conditions was the requirement for Magellan to develop a Health, Hygiene and Environmental Management Program (HHEMP). Among other conditions, the program should: detail the process that would be used to assess, monitor, evaluate and control the risk of lead contamination; address the review of existing facilities and the risks mitigation system at Geraldton Port; and determine further control measures. A further requirement was referenced to the Explosive and Dangerous Goods Act, to be administered by the WADME (Minister for the Environment 2000).

Even though the Ministerial Conditions required that a HHEMP be submitted for approval prior to any ground-disturbing activities, Magellan commenced construction on its mining site after receiving works approval from the Swan-Goldfields Regional Office of WADEP, and approval for its Project Management Plan by the WADOIR. A draft HHEMP was subsequently submitted in August 2004, which required a review of the port facilities. However, without the port being nominated at that time, there were limited comments on the plan from the government agencies (Education and Health Standing Committee 2007a, pp. 93, 111). The finalised HHEMP, in November 2004, contained commitment to not only conduct a formal risk assessment of the transport route and port facilities, but also to carry out “ongoing roadside monitoring surveys on a yearly basis, and sampling of rainwater tanks within 50 metres of the proposed route initially and ongoing” (Esperance Port Authority 2005b). Neither of these commitments was fulfilled, and the absence of such important information did not prevent Magellan from receiving an approval on the variation proposal from the WAEPA in November 2004 (Education and Health Standing Committee 2007a, p. 93).

After Geraldton had withdrawn its offer to store the lead concentrate at its port, Magellan applied, in October 2004, for variation to the Ministerial Statement to instead use Esperance Port’s facilities. This was done a few weeks after Esperance Port had applied to the WADOE to vary its licence to allow the

loading of lead carbonate. Despite the discovery of non-compliance to the Ministerial Statement, the WADOH's concern about dust generation, and complaints about the strong chemical odour from the port, Esperance received its licence variation to export lead carbonate in December 2004 (Education and Health Standing Committee 2007a, pp. 108, 128).

The WAEPA recommended that the Environment Minister approve Magellan's application for the export of lead from Geraldton to Esperance, which was based on the assessment of Esperance's enclosed conveyor system by Magellan (which was later found to be inaccurate), the assumption that Magellan would put in place a HHEMP, and the port's licence variation for lead carbonate export. As thorough as the WAEPA Bulletin was for the original Magellan proposal for Geraldton Port, the WAEPA did not suggest the detailed standards to be part of the conditions in the original Ministerial Statement. Therefore, when the Ministerial Statement was amended to allow for lead carbonate export through Esperance, there was no assessment of compliance with any standards since they were not referenced in the first place (Education and Health Standing Committee 2007a, pp. 107, 108).

In September 2005, the WADOH raised concerns to the WADEC about the lack of prescriptive approval conditions and health guidance, and inappropriate standards for the licensing of the port. To ensure adequate protection of public health, the Department further recommended air quality assessment and monitoring for both the transportation route and the facilities at the port. Similar advice had been given to Magellan a year earlier. In fact, as early as 2003, there had already been internal discussion within the WADEC about the use of dust monitoring equipment and possible health impacts from the dust exposure. This same concern about the need for some kind of lead exposure monitoring was raised in the licensing inspection conducted in 2005. However, these concerns were not followed up by the WADEC (Education and Health Standing Committee 2007a, pp. 48, 269, 279, 280).

8.3.2.4 Compliance Management System

Periodic monitoring and licence inspections to ensure the compliance of Esperance Port's operations with the conditions of approval, and with environmental management requirements, were among the legislative responsibilities of the WADEC. However, lapses in the compliance management system led the inquiry committee to believe that there was a culture of non-enforcement of regulatory compliance by the WADEC (Education and Health Standing Committee 2007a, pp. 78, 80, 288, 289). The interacting factors relating to the compliance management system are represented in the CLD in Figure 69.

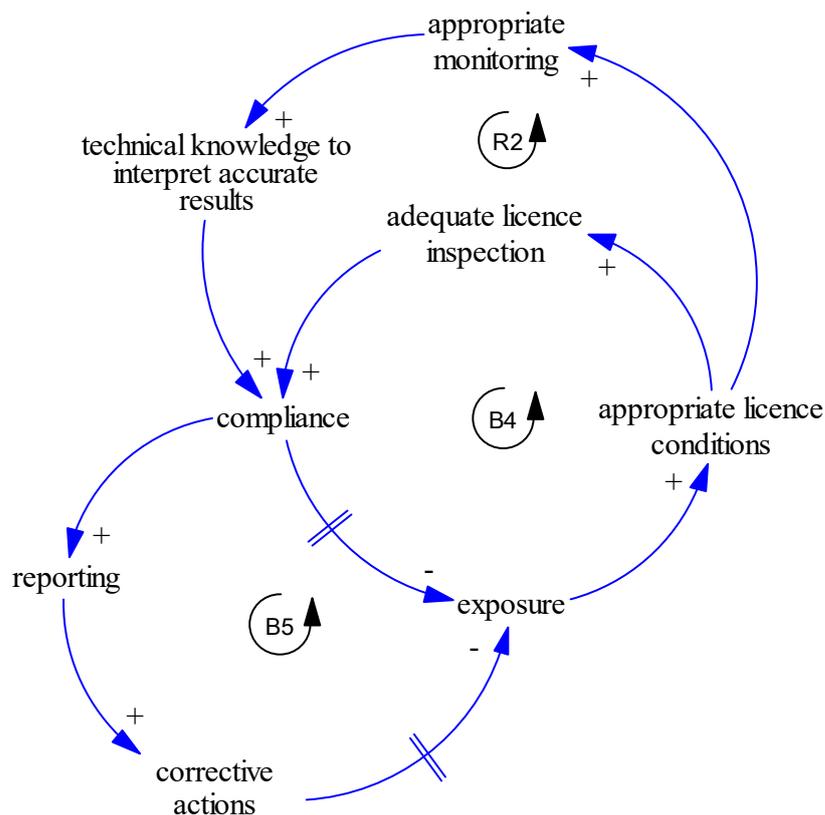


Figure 69: Esperance's Legal Factor 3

The Education and Health Standing Committee believed that the inadequate environmental monitoring requirements imposed on Esperance Port may have compromised the undertaking of a more robust assessment and development of a treatment plan for potential contamination. For instance, the amended licence issued by the WADEC to the port in November 2004 did not include any requirement to monitor benthic levels for the protection of the marine environment. Neither was there any compliance requirement for lead detected beyond the port's operational boundary. Compliance monitoring was irrelevant when the relatively lax guidelines for 'nuisance' dust that the WADEC adopted had values far higher than those reported by the port. Also, meaningless compliance targets that were set for high volume sampling could not be converted to an equivalent standard for the depositional dust sampling method used by the port (Education and Health Standing Committee 2007a, pp. 152, 154, 155, 173, 175). Hence, these less than adequate monitoring requirements that produced a less than satisfactory compliance outcome are represented by the inadequate reinforcing loop (R2, Figure 69).

Even when there had been any monitoring of exposure to hazardous materials, the flawed interpretation of the results led to a false sense of compliance. For instance, when measured against the Australian Drinking Water Quality Guidelines (2004), most of the rainwater tank samples collected had elevated nickel, above the recommended level. The WADOE had attributed the presence of nickel in the rainwater to the accumulation of dust from past handling practices, because they had incorrect knowledge about Esperance Port's closed materials loading system. Although three out of the ten monitored sites indicated very high levels of lead within the port and in residential areas beyond the port's operations, the WADEC did not consider them in the Annual Environmental Monitoring Report (period October 2005 – September 2006) since these were voluntarily monitored sites outside the testing requirements. Additionally, the port was required to provide Contamination Monitoring (CONTAM) samples to the Resources Safety Division of the Western Australian Department of

Commerce (WADOC). However, the port did not always meet the quota periods and occupational distribution requirements of the WADOC (Education and Health Standing Committee 2007a, pp. 21, 148, 157, 204, 205, 250, 282). All this evidence indicated a broken compliance system, represented by the balancing loop (B5, Fig. 69), which had not produced accurate reporting and necessary corrective actions to minimise hazardous exposure.

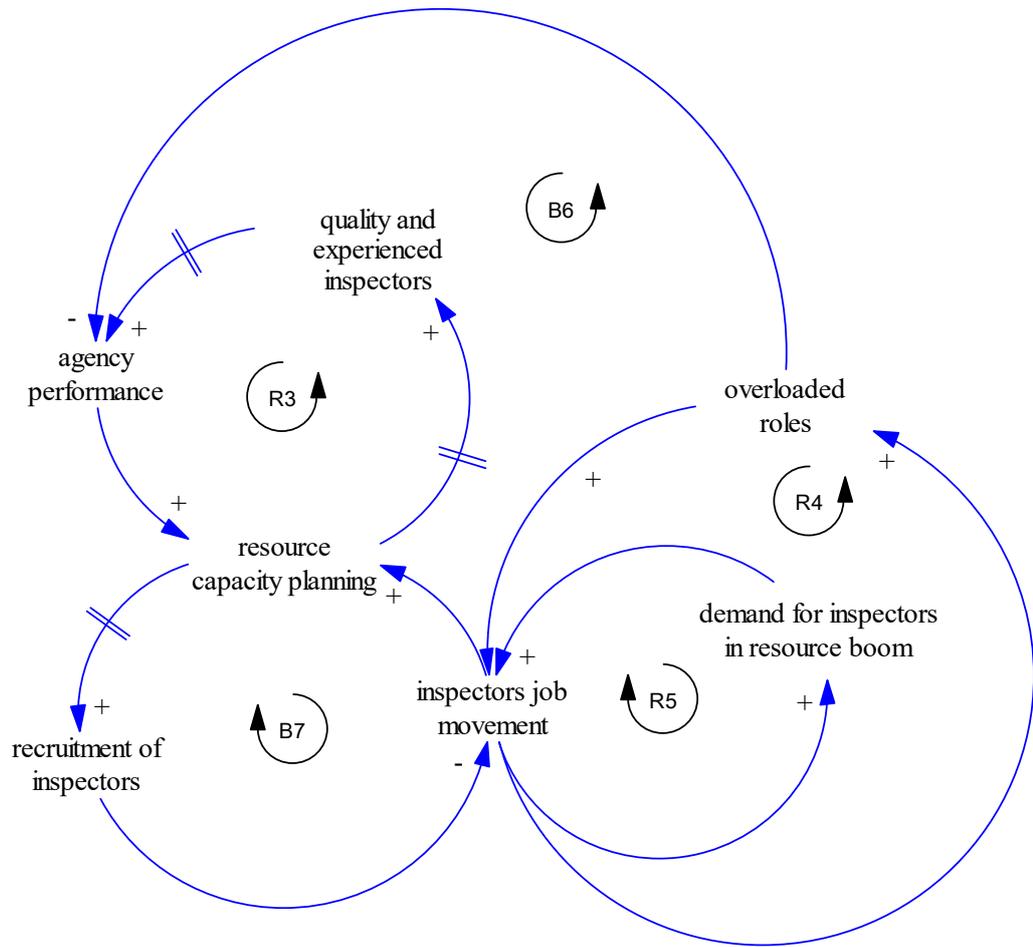
After an inspection of the port in May 2005, a WADEC officer notified the Esperance Port that it was in full compliance with the licence conditions, but noted that the licence was focused on the handling of iron ore, with a lack of similar measures for lead and nickel. A succeeding inspection, not including the shed, which was conducted by the Esperance Shire and the WADEC in February 2007, also found the port to be compliant with all conditions of the licence. The regulatory agencies did not seem to be concerned with the fact that the port had previously submitted a dust management plan that closely resembled that for the iron ore, and had proposed similar infrastructure and procedures used for nickel-handling to manage the lead concentrate (Education and Health Standing Committee 2007a, pp. 160, 206, 278, 285, 313). Essentially, the inadequate licence inspection program, targeting only the management of iron ore, produced a compliance result that did not identify inadequacies of the facilities to handle lead and nickel. These causal factors that contributed to further exposure of lead and nickel are depicted in the weak balancing loop (B4, Figure 69).

8.3.2.5 Government Resources

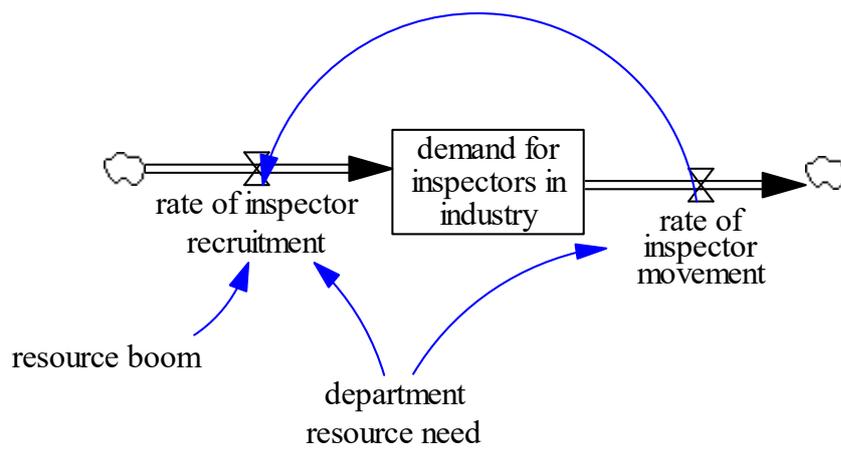
The WADEC staff carrying out enforcement activities were the same staff that were required to perform “assessments of works approvals, new and renewed licences, investigations and enforcement actions, advice and guidance to the community and industry, and (to) investigate all complaints received relating to pollution or environmental harm, whether or not they relate to a licensed premises. In addition to the aforementioned tasks, the same officers also

provide regional input to the EPA's assessment process" (Education and Health Standing Committee 2007a, p. 75). A similar resource crunch was experienced by the Resource Safety Division, where a relatively small number of dangerous goods inspectors were required to cover a large number of licensed dangerous goods storage sites and other activities related to dangerous goods (Education and Health Standing Committee 2007a, Finding 175).

As a result, not only did the overloading of these roles affect the performance of the government departments, as seen in the balancing loop (B6, Figure 70a), but they were also push factors for employees to search for more fulfilling roles in other organisations, resulting in more movement of inspectors within the workforce. Consequently, the remaining smaller number of inspectors would then need to shoulder the same workload, which led to even more attrition due to unsustainable resourcing of manpower. This vicious cycle of increasing workforce movement and workload is captured in the reinforcing loop (see R4, Figure 70a).



(a)



(b)

Figure 70: Esperance's Legal Factor 4

Besides raising concerns about the extensive workload faced by the WADEC officers, the Union (Civil Service Association of WA) highlighted the inadequate numbers of appropriately qualified or competent officers. This serious shortage of staff was similarly highlighted by a previous manager of the WADEC, who testified that the number of officers assigned to project assessments was ten times larger than that assigned to post-approval compliance activities, to the extent that a small team of full-time audit officers had to survive on a small operating budget to cover about 490 major projects (Education and Health Standing Committee 2007a, pp. 46, 77). Moreover, the disproportionately low number of officers available in the country areas compared to the large number of licensed premises meant that the WADEC was not able to adequately cover its responsibilities in regulating industry activities (Education and Health Standing Committee 2007a, pp. 320, 321). From resource planning to raising the inspectors' competencies and performance would require some time (R3), which was difficult to support with a recruitment cycle (B7) that could not keep pace with the active job market, because of strong demand for inspectors from the booming resource sector (R5) (Figure 70a).

Nonetheless, the emphasis on project assessments was not unexpected, given that the WADEC's regulation program was funded entirely from licences, works approvals and registration fees. Even with a 50% increase in the licence fee structure, it would not reflect the true cost of the approval process and administrative support work that went along with the regulatory management of the licensed premises (Education and Health Standing Committee 2007s, 5 June).

Traditionally, the issue of staff shortage had been a perennial problem where government departments had to compete with the private sector for the recruitment of staff (Fig. 70b). The lack of resources was not unique to the WADEC; the WADOIR faced a similar staff shortage situation. The

disproportionately low number of 16 inspectors, compared with the 6,700 licensed dangerous goods storage sites in WA, made it difficult for the Resources Safety Division to ensure that all licensed operators complied with the dangerous goods legislative requirements (Education and Health Standing Committee 2007p).

In the case of the WADEC, their loss of inspectors to the private sector was made worse during a mining boom when skilled labour was in short supply, to the extent that only a minimum level of service could be provided (DEC 2007; Education and Health Standing Committee 2007j). The balancing loop (B7, Figure 70a) illustrates the positive contribution from the recruitment of inspectors to minimise staff movement or reduce the number of inspectors leaving the service (Figure 70b). However, it appeared that the employment conditions offered by the WADEC could not stem the tide of inspector attrition caused by the mining boom (see reinforcing loop R5, Figure 70a). Thus, B7 in the same figure can be considered a weak balancing loop in achieving the necessary resource level for the proper functioning of the department.

All these resource constraints were affecting the department's ability to meet its risk-based inspection target and reporting requirement, which is further evidence of the impact that resourcing had on the department's performance (see reinforcing loop R3, Figure 70a). Out of the 860 licensed premises, 130 were classified as medium-high to high risk, 180 as medium risk and the remaining as low risk. The WADEC policy mandated that 100% of the medium-high to high risk premises must be inspected annually. Over a period of nine months, to April 2007, only 28% of the annual target had been achieved (Education and Health Standing Committee 2007a, p. 75). Poor fulfilment of the inspection target was not the only undesirable outcome; the number of dust reporting submissions had to be cut back as well. Rather than having a more rigorous dust monitoring program to address complaints about dust emissions in 2002, the WADEC changed the port's reporting frequency from half yearly to annually, due to a lack

of manpower to manage the high workload (Education and Health Standing Committee 2007q).

From the above evidence, it appears that the stronger reinforcing loops of (R5, Figure 70) and (R4, Figure 70) dominated the balancing loops (B7 and B6, Figure 70), whose combined influence contributed to the department's inability to maintain a sustainable resources pool of competent inspectors to enhance its performance (R3, Figure 70).

8.3.2.6 Government Culture

It appeared that the WADEC had perpetuated a culture of non-enforcement by continually ignoring environmental pollution by industries. This was partly due to the lack of resources that limited the department's ability to effectively carry out its regulatory functions. As a result, evidence presented to the parliamentary inquiry showed a perceived support for the industry by the WADEC at the expense of the environment and community health (Education and Health Standing Committee 2007h, 2007i). According to the Kwinana Progress Association Inc. and the Kwinana Watchdog Group, little had changed in the WADEC's regulatory practices and culture, despite all the inquiries and reviews. In fact, they claimed that the community had lost faith in the department's ability to protect the residents from public health and environmental harm (Education and Health Standing Committee 2007o).

The inquiry found that there was a failure for prompt actions to be performed by various government agencies. For instance, critical advice from the WADOH in September 2005 was not followed up by the WADOE until February 2007 (Education and Health Standing Committee 2006). The lack of response and scrutiny of the dust monitoring results by the WADEC further reinforced the perception of putting industrial interests above those of the community (Education and Health Standing Committee 2007b).

In spite of the evidence highlighting the WADEC's inadequacies in its regulatory enforcement, the WADEC was adamant that the Environmental Protection Act 1986 placed the complete onus on Magellan and Esperance Port to comply with its requirements (Education and Health Standing Committee 2007s, 20 April). A similar lax enforcement culture was observed in the EPA when only a desktop review was conducted on the information provided by Magellan Metals in its application to vary the Ministerial Statement to allow the export of lead through Esperance (Education and Health Standing Committee 2007s, 7 June).

Capturing all these inter-relating causal factors is the negative reinforcing loop of (R6) in Figure 71. It depicts how the unsatisfactory performance of government agencies in such areas as their slow responses to HSE issues, the superficial assessment of risks, and the lack of attention to monitoring results and enforcement, could influence the residents' confidence in the ability of the department to carry out its legislative role and functions. The loss of public confidence decreased the motivation for residents to engage with government agencies, which further eroded their performance.

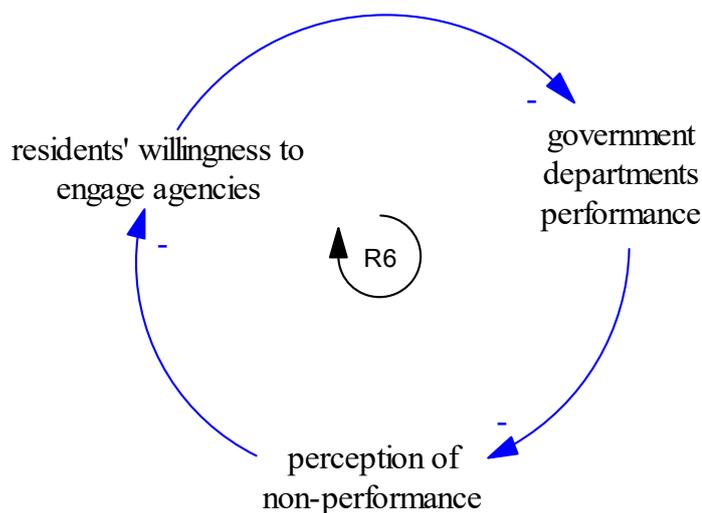


Figure 71: Esperance's Legal Factor 5

8.3.3 Economic

One of the key roles of the Department of Transport was to market Western Australia's ports to facilitate trade and development. To achieve commercial success, Esperance Port had to be market-driven and responsive to the needs of its clients. Due to the exceptional surge in Western Australia's resource sector, the port had expanded its role to meet increasingly complex policy demands. Additionally, Esperance Port would need to work with other government agencies and industry to meet its trade facilitation role, in order to provide economic benefit to the state. However, the committee was of the opinion that this emphasis on trade facilitation by the Esperance Port had been achieved at the expense of neglecting its EHS legislative obligations (Education and Health Standing Committee 2007a, p. 66).

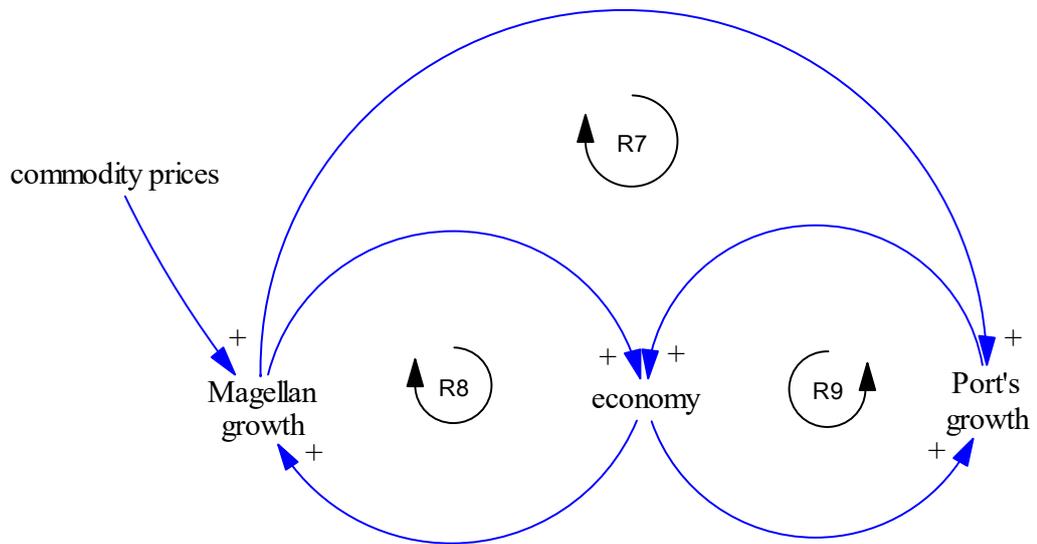
In 2005/6, the Goldfields/Esperance region had contributed about AUD7,322 million to the Gross Regional Product, or 6.1% of the total for Western Australia. Its AUD136,326 per capita was more than twice that of any other region. Mining constituted the most significant economic sector in the region, worth around AUD6 billion in 2005/6 (Department of Local Government and Regional Development 2007). In terms of production, as measured by total factor income (the total payments received by labour and owners of capital used in the production of goods and services), contribution by the mining industry to the state's production between 2004 and 2010 was around 29% (ABS 2012).

Against this backdrop of growing mining activities and improving lead prices in 2004, a Canadian listed company, Ivernia, acquired a 100% stake of the Magellan lead mine. Activities from the Magellan mine site was Ivernia's and Magellan Metals' only source of revenue (Education and Health Standing Committee 2007a, pp. 53, 54). The economic contribution from Magellan Metals in terms of the annualised benefits to the people and businesses of WA was around AUD184.4 million in 2005 and AUD275.3 million in 2006. It paid AUD1.2

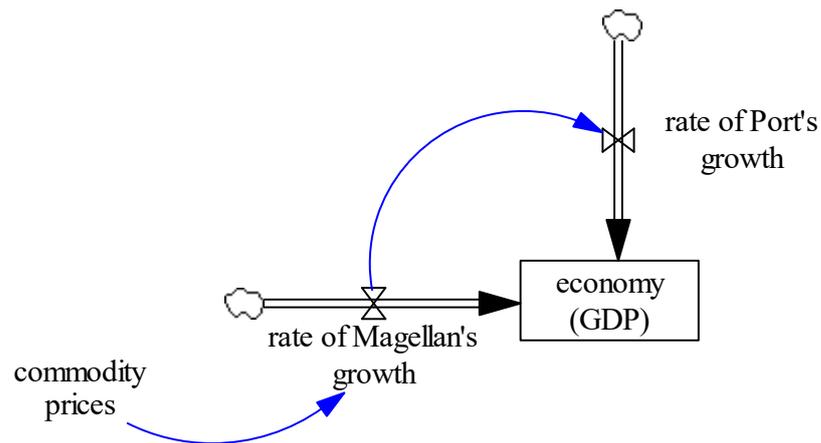
million and AUD4.1 million in royalties in 2005 and 2006, respectively (Magellan Metals 2007, p. 32).

Clearly, mining investment and activities had positive economic impacts for most industries, especially for those such as port services that are closely aligned to them. Of the total AUD12.3 million that port authorities paid to the government, Esperance Port contributed about AUD1.6 million (Government of Western Australia 2007, p. 244). An independent report found that the port's operations generated: AUD45 million in gross revenue; AUD24 million in added value; more than AUD10 million in household income; 250 full-time jobs; and AUD11 million for value of services relating to land transport and storage (EconSearch Pty Ltd 2001). Esperance Port's annual gross revenue was AUD27 million and the value of goods handled by the port, based on commodity prices, was within the range of AUD4.5-5.5 billion. The gross profit for Esperance Port in 2005/6 was AUD3.5 million, of which 50% of the profit was paid to the state government, with the remainder being used either for the port's improvement or poured back into the community (Esperance Port Authority 2007c, pp. 8, 15).

Underpinned by the rising Asian economies, the robust economy in WA supported and created more opportunities for growth for organisations like Magellan and Esperance Port in the resource-rich Goldfields Esperance Region. In Esperance Port's annual reports, between 2004 and 2007, the organisation reported an upward trend of revenue and profit growth (Esperance Port Authority 2004, 2005a, 2006, 2007a). These complementary growth relationships between the state's economy and industries are represented by the reinforcing loops (R8) and (R9) in Figure 72a. Moreover, healthy commodity prices allowed Magellan to expand their mining operations, which in turn created increased demand for Esperance Port's services, and consequent growth (see R9, Figure 72a). Both complementary growth rates at the port and within Magellan contributed to the overall increase of the state's economy (Figure 72b).



(a)



(b)

Figure 72: Esperance's Economic Factor

8.3.4 Technological

The resources boom in Western Australia had put pressure on Esperance Port to increase its efficiency in handling of trade through its facilities. In an effort not to create a barrier to entry for port users, Esperance Port needed to periodically invest in bulk handling technology and infrastructure to keep pace with the growth of demand (Education and Health Standing Committee 2007a, pp. 53,

54). Hence, technological factors played an important role in contributing to this EIPE. They included the infrastructure and facilities of the port, the equipment and technology used to monitor dust emissions, and upgrades or engineering works carried out to improve the handling of heavy metals.

In November 2000, Esperance Port commenced the AUD54 million-upgrade of its facilities. The upgrade, which took 14 months to complete, consisted of 23 hectares of reclaimed land and a new 300,000 ton capacity shed for iron ore, with a fully enclosed conveying and storage system (Esperance Ports Sea and Land 2009). Magellan used this upgrade as justification to support its application for proposal variation by stating that: “The Esperance Port has contemporary infrastructure including dedicated storage and ship loading facilities with self-contained reclaim hoppers, covered conveyors and ducted vacuum systems” (Education and Health Standing Committee 2007a, p. 106).

Despite the upgraded facilities, the port had also been experiencing a nickel odour problem from the ship-loading activities. A study conducted in 2001-2002 attributed the main causes to the weather conditions and the loading/unloading of nickel at the port. Other complaints from residents about iron ore dust found in residential properties prompted Esperance Port to undertake dust sampling and marine sediment sampling in 2002. The WADEP’s dust monitoring report in November 2002 stated that there was an increase in nickel dust between February and May 2002 (Education and Health Standing Committee 2007a, pp. 373, 375-376).

It was only much later that the WADEP discovered that the upgraded facilities applied only to the iron ore-handling systems, and they did not cover the heavy metal loader that was constructed much earlier, in 1992. One of the port’s workers thought that the system was “relatively primitive” (Education and Health Standing Committee 2007s, 28 June). Even though the upgraded facilities were inadequate for handling nickel and lead, it did not prevent the port’s CEO from

purporting misinformation by stating that they would adhere to high operating standards for the export of lead, using the existing enclosed conveyor system. Since the “port expected lead concentrate to behave in the same manner as nickel concentrate, and was aware that the water quality guidelines applicable to lead are half the level for nickel,” Esperance Port ought to have known about the risk of lead contamination, especially when the same processes are used for handling both products (Education and Health Standing Committee 2007a, p. 205).

Far from being an enclosed system, as claimed by the port’s CEO and the incorrect advice provided to the EPA by Magellan Metals on the port’s facilities, the entire bulk handling process, from receiving to shipment, consisted of partially covered dumpers, conveyors and open structures, which easily caused the hazardous substance to spill into the environment. Based on the experience with loading nickel concentrate, port workers had similar concerns about the adequacy of the system to safely handle the lead (Education and Health Standing Committee 2007a, pp. 48, 49, 105, 106, 207) (Figure 73 and Figure 74).

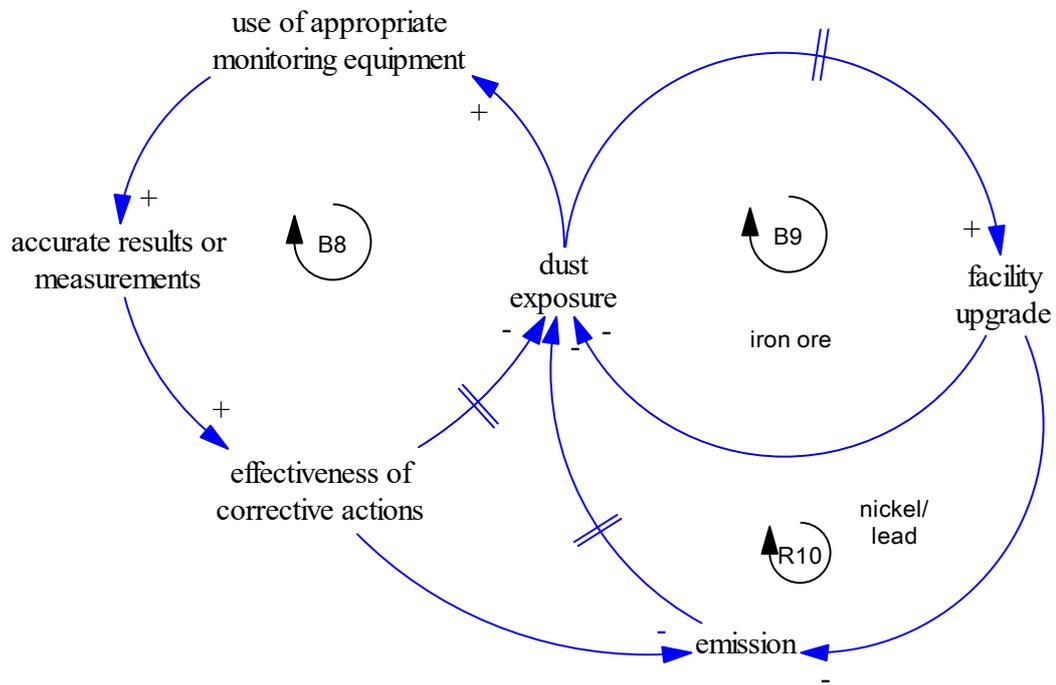


Figure 73: Interior View of the Conveyor Without Floor (Education and Health Standing Committee 2007a, p.11)

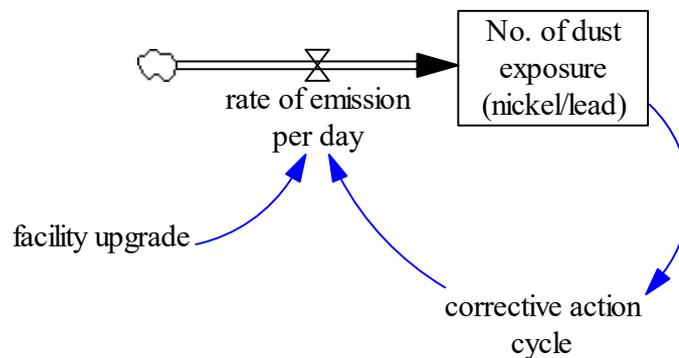


Figure 74: Open Structure of Lead Transfer from CV3 to CV5, 6 and 7 (Education and Health Standing Committee 2007a, p.12)

A “Fixes that Fail” archetype (Senge 2006) can be used to describe this causal relationship between facilities and exposure. While, the upgraded facilities helped to minimise exposure to iron ore (see balancing loop B9, Figure 75a), they (e.g. partially enclosed bulk handling system) did not mitigate the risks of exposure to nickel and lead. In fact, the WADEC, Magellan and even top management of the port appeared to have the mistaken belief that the improved facilities for iron ore handling would be more than adequate to meet the requirements for lead-handling (Education and Health Standing Committee 2007a, pp. 275, 276). This misinformation prevented the installation of appropriate facilities, and allowed the continuing emissions of lead and nickel dust, leading to exposure of such emissions to the residents and workers (weak reinforcing loop R10, Figure 75a). The number of heavy metal-exposure incidents was a direct result of the rate of emission from the handling of these hazardous products (Figure 75b).



(a)



(b)

Figure 75: Esperance's Technological Factor

A dust monitoring regime is a critical component of any health and environmental management system, in providing accurate inputs about the levels of exposure to hazardous substances. Although the CEO of Esperance Port acknowledged the availability of a more reliable method (high volume air sampling) for the dust monitoring program than the land-based method used by the port, he contended that the 'older' method, or dust deposition monitoring,

had been accepted by the WADOE (Education and Health Standing Committee 2007s, 2 May). In fact, Esperance Port started its dust monitoring program using high volume air samplers in 1994 for slightly more than a year. It switched to dust deposition monitoring, citing high maintenance and stating that it was unnecessary for the operating conditions (Education and Health Standing Committee 2007s, 3 May).

Instead of encouraging the use of more reliable technology for dust monitoring, the WADOE recommended Magellan to change from high volume sampling to depositional dust monitoring in 2005, because the National Environmental Protection Measure (NEPM) standards only applied to mining operations within or near a township where the health and amenity of the residents could be impacted (Bell 2005). Although the WADEC later acknowledged the usefulness of the high volume dust monitor and recognised the advancement made in air monitoring technology, it did not insist on its usage until 2007 (Education and Health Standing Committee 2007a, pp. 269, 282).

Since a less reliable technology for dust monitoring was employed by the port, inaccurate and non-representative results from the dust deposition method had deprived the port from taking prompt corrective actions against the unacceptable level of dust exposure (see weak balancing loop B8, Figure 75a).

8.3.5 Social

Compared to the population of the Love Canal and Minamata, the township of Esperance had a smaller number of residents, with about 13,000 people in an area of more than 42,000 square metres. It was managed by a council of elected members consisting of a Shire President and councillors, with an executive team consisting of a CEO and directors of various services. The public perceived a conflict of interest with the appointment of the Esperance Shire President to the Board of the Esperance Port, who eventually decided to step

down as the director of Esperance Port in April 2007 (Education and Health Standing Committee 2007a, pp.67, 68; Esperance Port Authority 2007a).

A post-lead pollution survey by the port identified the top social concerns among the residents as: poor reputation of the town; fragmentation and fear within the community; negative impact on the local economy and the environment; and mistrust of the port management (Esperance Port 2008). During the lead operations at the port, there already had been some level of community distrust toward the port and Magellan. This was mainly due to the numerous concerns raised by the community to the port, which had not been adequately addressed. The perceived conflict of interest did not help in the matter when the Esperance Shire President was appointed to the Esperance Port's board.

Concerns about these and other HSE issues, and their long-term environmental and health impacts, resulted in societal pressure on those organisations from which the source of pollution originated. To gain a bigger voice and better understanding of the operational impacts, residents organised among themselves to raise their concerns. Some of these community groups included the Local Environmental Action Forum Inc. (LEAF), Locals for Esperance Development (LED); Recherche Advisory Group Inc. (RAG); and Residents for Esperance Development (RED). Ultimately, an advisory group called the Esperance Community Reference Group (ECRG) was formed to facilitate the sharing of information about lead and nickel contamination between the government and the local community (Education and Health Standing Committee 2007a, pp. 52, 328).

Earlier experiences had shown that the formal consultation process or Consultative Environmental Review (CER) involving residents would achieve a better outcome. For instance, the RED had lobbied for the iron ore to be housed in a pressure-negative shed and to cover all conveyors and elevators, instead of the original plan to store it in open heaps with a water suppression system

(Education and Health Standing Committee 2007s, 3 May). This contributed to the award-winning construction of the iron ore-bulk handling facility at Esperance Port (Esperance Port 2006). Unfortunately, due to the perceived absence of the any additional adverse impact of the proposal change, similar substantive consultation process was not required by WAEPA. Hence, the same collaborative model was not duplicated in Magellan's operations, where the Esperance community could have been included in the decisions related to the handling of lead concentrate by the port. Furthermore, no formal public consultation was carried out for variation to the environmental approval of the lead-handling project (Education and Health Standing Committee 2007a, pp. 104, 108, 109, 139).

The CLD in Figure 76 compares the social factors between two different projects, for iron ore and lead, in Esperance Port. In the stronger balancing loop (B10), the proactive engagement of residents, government agencies, Magellan and Port operator led to more effective control measures in addressing HSE issues. Consequently, the reduction in HSE issues through more inclusive collaboration between the port and the community contributed to lesser social pressure on Esperance Port. Contrary to the iron ore experience, there was an absence of a thorough public consultation for the approval variation of lead-handling at Esperance, and residents were not engaged to the same extent as they were for the iron ore project. Therefore, the controls implemented were not as effective in reducing the HSE issues impacting the community. Not unexpectedly, the societal impacts from such issues raise the social pressure on organisations to promptly address them (see B11, Figure 76).

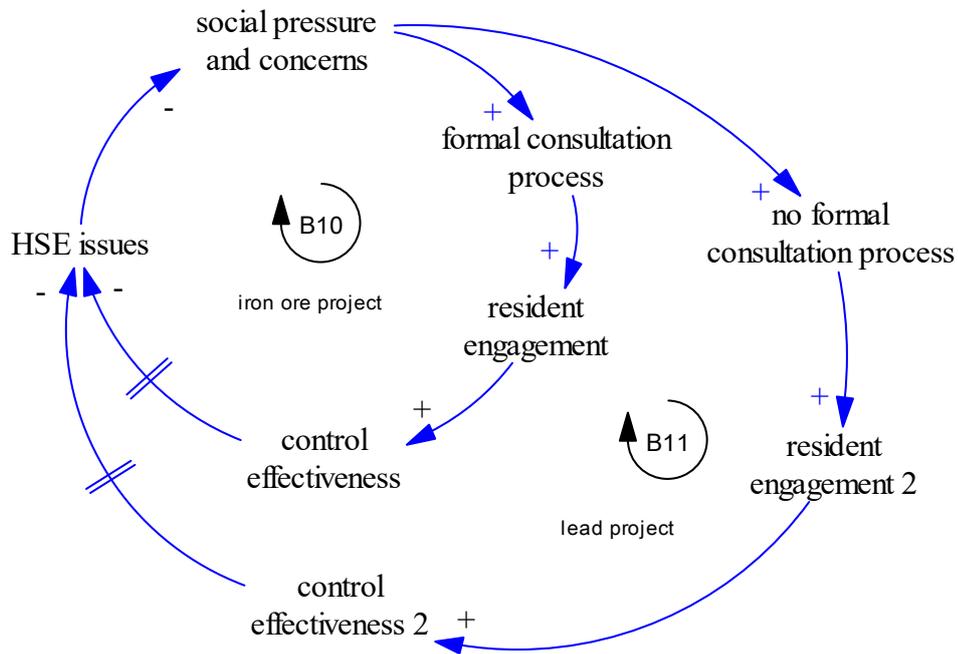


Figure 76: Esperance’s Social Factor

8.4 Internal Organisational Factors

Internal organisational factors refer to the characteristics found in Esperance Port that influenced and contributed to the lead pollution event. They included organisational culture and the HSE Management System working together to support the broader business strategies, which were informed by the external PLETS factors. Typically, organisations have more control of these internal factors than the external factors. According to the Esperance Port’s Annual Report (2005a, p2), the port was described as “a profitable, cost effective and efficient organisation that facilitates trade and provides efficient logistics through the use of existing and new infrastructure.” Besides its principal function of facilitating trade to make a profit, Esperance Port must comply with other legal obligations prescribed under Section 30 of the Western Australian legislation governing ports (*Port Authorities Act 1999*). For instance, ports must “be responsible for and promote the safe and efficient operation of the port” and

“protect the port environment and minimise the impact port activities have on the environment” (Government of Western Australia 2012b).

8.4.2 Board of Governance

While the Port Authorities Act 1999 provided the power for the Minister to appoint board directors of the Esperance Port, it did not prescribe the selection process for their appointment. The board consisted of a chairperson and four directors who met 11 times a year, which had been the practice for the 40 years of the port’s establishment. This board structure and arrangement for its oversight had not changed, even though the tonnage handled at the port had grown by 4,500% from 1966 to 2004/5, and the value of exports was expected to reach AUD7 billion in 2008 (Education and Health Standing Committee 2007s, 2 May). Furthermore, the CEO had been serving the Esperance Port for 23 years before retiring in 2007 (Esperance Port Authority 2007a).

The reinforcing loop (R11) in Figure 77 illustrates increasing project approvals and trade volume from the corresponding increase in demand from the mining industry. The volume of trade was an important determinant of the appropriate board skills that Esperance Port should have maintained, which would facilitate the proper functioning of the corporate governance system (see balancing loop B12, Figure 77). Nevertheless, in the absence of undesirable events, coupled with an award-winning port operation, the Minister for Planning and Infrastructure was not compelled to revamp the board, considering that it did not seem to hinder the port’s success. Furthermore, it was difficult to recruit board members who had the right skills and sufficient commercial experience in running listed companies (Education and Health Standing Committee 2007s, 7 June). In fact, CEO of Esperance Port for 23 years only stepped down in 2007, which was represented by the delayed balancing loop (B13, Figure 77).

It was clear from the case evidence that the management structure of the port was inadequate to handle the growing complexity and scope of its operations.

Thus, without a proper board structure filled by the right kind of directors with the necessary skills, there was a lack of board competency to carry out effective corporate governance.

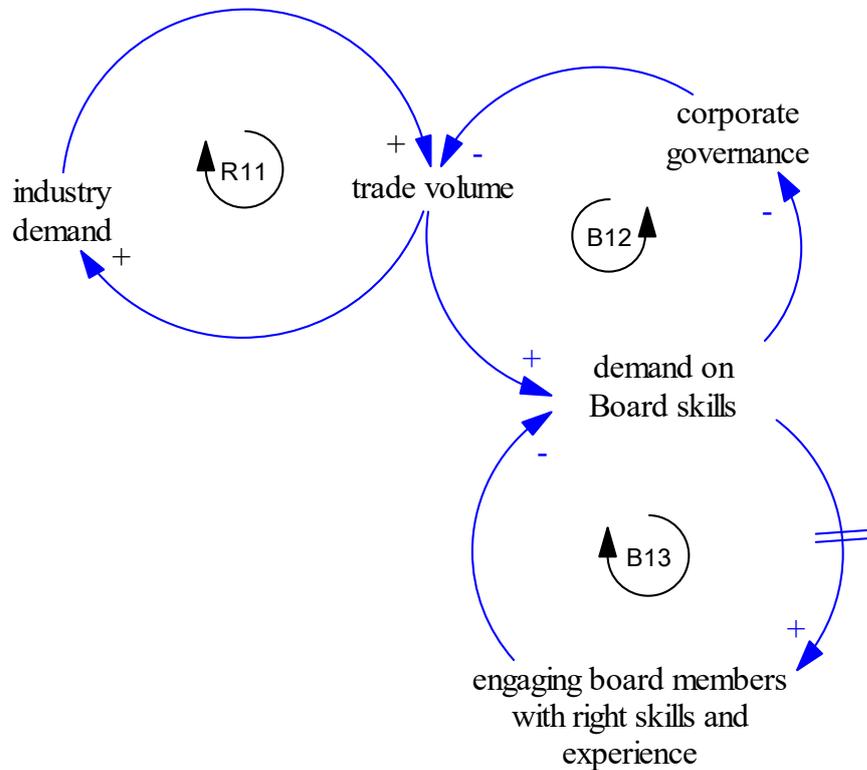


Figure 77: Esperance's Board 1

Contrary to the evidence provided to the committee by the former Chairman of the Board and the Director of the Esperance Port, minutes of the board meeting on 23 February 2004 recorded the detection of nickel in rainwater tanks near the port in early 2004 (Education and Health Standing Committee 2007a, p. 254). In fact, monitoring results between 1995 and 2004 consistently indicated the presence of nickel beyond the port's boundaries. This awareness led the board to ask for a quarterly report on environmental issues to be prepared by the CEO (Education and Health Standing Committee 2007m, 2007n). Although the board had implemented periodic reporting of environmental issues, it appeared that the same board did not pay enough attention to meeting papers and Environment

Status Reports (Education and Health Standing Committee 2007a, p. 256). Therefore, the knowledge of contamination and regular reporting of emissions did not result in an adequate response from the board to mitigate the health impacts (see weak balancing loop B14, Figure 78). Also, it should have alerted the port to the potential for lead pollution if the same process was to be adopted.

In March 2005, the port's Safety and Health Representative tabled a list of infrastructure deficiencies to the board, highlighting concerns about the proposal for the handling of lead concentrate. From November 2005 to December 2006, the board had been advised on several occasions of heavy metals pollution beyond the port's boundaries. Specifically, in May 2005, the workforce's email to the CEO identified five priority issues regarding necessary safety improvements to the infrastructure. These were included as part of the recommendations by the CEO to the board in June 2005 (Education and Health Standing Committee 2007a, pp. 256-258). Based on the extensive series of measures that would be implemented to protect the health and safety of employees and residents, the board accepted the Magellan Lease and Handling Agreement, with the first shipment of lead to occur on 4 July 2005 (Education and Health Standing Committee 2007m, 2007n).

Therefore, reinforcing loop (R12) in Figure 78 illustrates the board's decision process, where the assumption of the implementation of planned controls before the first shipment of lead influenced the decision to approve the lead-handling proposal. It was not until 9 November 2006 that the board formally reviewed the implementation of the recommendations and control measures. Almost a year after the first shipment in July 2005, infrastructure improvements remained outstanding (Education and Health Standing Committee 2007a, pp. 259 - 261). These reasons led the committee of inquiry to believe that the board had not exercised due diligence in ensuring the completion of the infrastructure improvements before approving handling of the lead.

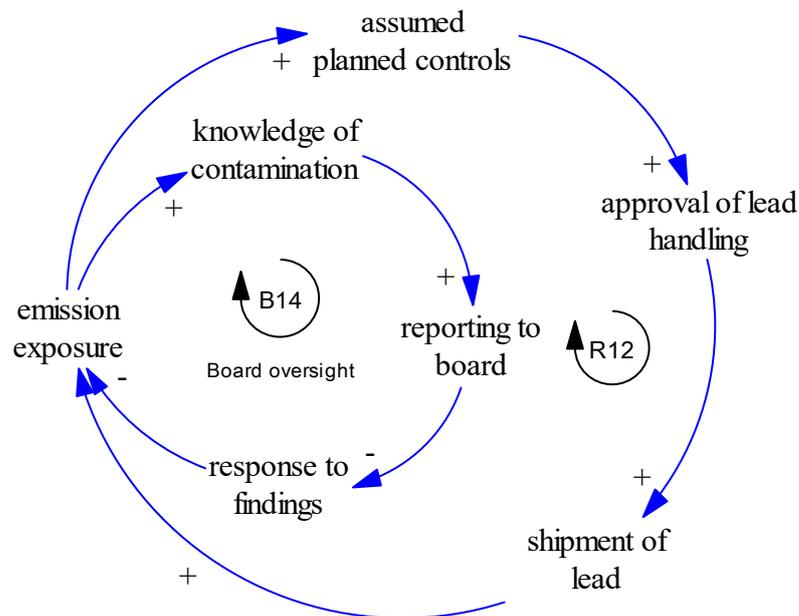


Figure 78: Esperance's Board 2

After the reported deaths of hundreds of birds in March 2007 and the estimated deaths in the thousands between December 2006 and February 2007, the WADEC advised the WADOH that there was evidence of lead poisoning as the cause of these mass bird deaths. On 12 March 2007, the board had to suspend the handling of lead and a prevention notice was issued by the WADEC a few days later. Consequently, Finding No. 137 of the inquiry (2007a) corroborated the above evidence that the board did not respond adequately to manage the risks of lead exposure, despite the knowledge of contamination and regular board reporting (see B14, Figure 78). Based on the available evidence, it appears that the board did not strategically incorporate HSE into its corporate governance (Lo 2012).

8.4.3 Organisational Culture

According to the Minister for Planning and Infrastructure, the port had a culture of running its own operations without much oversight from the board. Rarely would the board challenge the CEO since the members felt that it was not within

their expertise (Education and Health Standing Committee 2007a, pp. 63-65). Before the installation of the new board in 2007, the port did not have board members who had the experience of running listed companies and who understood the importance of their roles (Education and Health Standing Committee 2007s, 7 June).

Based on the evidence provided by the CEO of Esperance Port, the parliamentary inquiry found that the CEO of Esperance Port had focused too much on the facilitation of trade for the port, at the expense of other legislative responsibilities (Education and Health Standing Committee 2007a, p. 66). Furthermore, there were other competing priorities, such as the fact that iron ore accounted for more than 70% of the total export volume by tonnage, compared to just 1% for lead, in 2006. This huge difference in handling volume between products made it difficult for operational staff to bring to the attention of management their concerns about lead-handling (Education and Health Standing Committee 2007s, 28 June).

Other evidence suggested a disturbing trend of “failure to place public health considerations on the same basis of other considerations” (Education and Health Standing Committee 2007a, p. 93). For instance, when issues about lead emissions were raised through informal conversation or formal documentations, concerns from port workers about the inadequate management system and infrastructure to deal with lead contamination were often ignored by management. As stated by one of the workers who eventually resigned, “I was sick and tired of the disrespect, ignorance and total inaction from the management and systems they had in place” (Education and Health Standing Committee 2007k, 28 June).

A similar theme of production-over-safety could be observed in Magellan Metals as well. A series of operational decisions with public health implications that were taken by Magellan Metals had contributed to the emission of lead dust

(Figure 79). Due to the slower loading rate and lower productivity caused by the problems with the agglomerator and the poor condition of the transportation route, Magellan Metals decided to transport the lead concentrate in an un-agglomerated form in April 2005 (Education and Health Standing Committee 2007a, p. 136). Pressured by the need to sustain the operation to generate cash flow through product export, Magellan applied for temporary storage of the lead concentrate on a dedicated drying pad, to overcome the problems with the filter and hopper. This was done at the expense of quality control of the lead moisture content, which was supposed to be the determining factor in the amount of dust emission. (Education and Health Standing Committee 2007s, 28 June). Thus, such concern about productivity over HSE is represented in the balancing loop (B15, Figure 80), where there was evidence of tension between operational pressure and HSE pressure.



Figure 79: Non-Air Tight Kibbles Used for Transferring Lead Concentrate (Education and Health Standing Committee 2007a, p.5)

Emphasis on increasing productivity and ignoring HSE outcome usually came at the expense of weak HSE commitment. This led to more hazardous operations that produced a higher level of harmful emissions. On the contrary, reinforcing

loop (R13, Figure 80) shows that HSE pressure could lead to stronger HSE commitment. This would result in less hazardous operations that, in turn, would minimise harmful emissions. Since there was little evidence to suggest an organisational culture of putting HSE before operational needs, the weak reinforcing loop was not able to counteract the more dominant operationally driven culture.

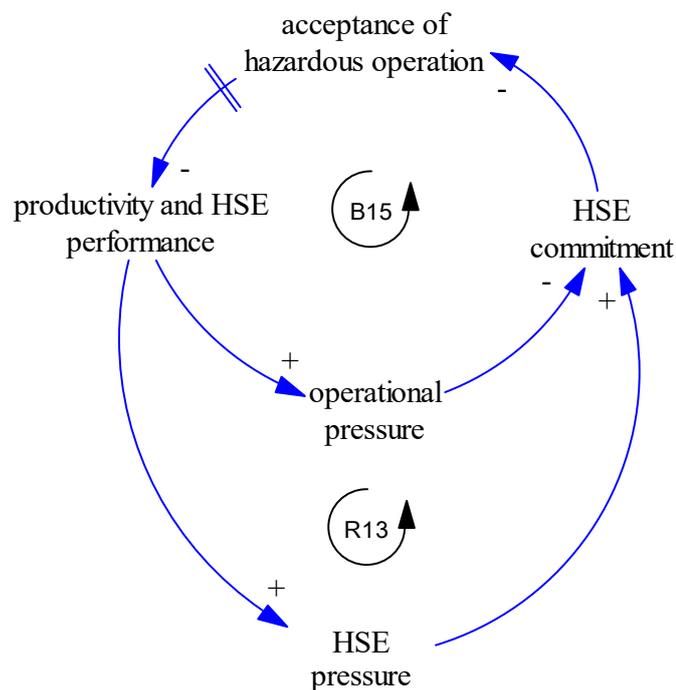


Figure 80: Esperance’s Organisational Culture

8.5 HSE Management System

The major clauses in the OHSAS 18001:2007 (George 2001) were used as the factors for an HSE Management System. These major clauses included Policy, Planning, Implementing, Checking and Review. The sub-clauses under each of these major clauses were used as guiding themes to source for evidence.

8.5.1 Policy and Planning

8.5.1.1 Planning for Hazard Identification, Risk Assessment and Risk Control

Esperance Port Board had established a Risk Management Policy for identifying the various sources of risks, and mitigating them with control measures. The Risk Management Committee would be responsible for regular reporting of progress to the board (Esperance Port Authority 2005a, p.6). Furthermore, according to a submission provided to the committee, the port advised the industry during its heavy metals-handling workshop, 'Beyond the Mine Site,' in December 2006 that it had a zero odour policy (Esperance Port Authority 2007b, p. 2). Had the port diligently applied its own Risk Management Policy by considering the weather conditions, the chemical characteristics of the lead carbonate and its transportation arrangements, it should have identified the risk of dust emission from handling of the product to be high.

The WADEC issued a variation to the Esperance Port Authority's environmental licence to allow it to handle bulk lead concentrate in November 2004. Before shipping the lead concentrate, the port was required to submit a dust management plan. However, the plan provided was an extract from the port's existing Environmental Management Plan, meant for its iron ore operations (Education and Health Standing Committee 2007a, Finding 145). Moreover, the port did not exercise its duty of care to verify the accuracy of the Dangerous Goods classification for the lead concentrate provided by Magellan (Education and Health Standing Committee 2007a, p. 310).

Despite the inaccurate and cursory assessment of the port's facilities, management system and monitoring programs for handling lead by Magellan Metals, the WAEPA deemed Magellan Metals to be compliant. Similar inaccuracies about the port facilities, such as the use of an enclosed conveyor and dust suppression system, and the physical properties of lead were

presented by the port when applying for the licence variation to export lead, and when publicising the information for media release. Rather than this misrepresentation, the inquiry contended that Esperance Port should have been aware of the inadequacies of its facilities (Education and Health Standing Committee 2007a, pp. 48, 49, 105, 118, 120, 121, 123, 165, 168, 178).

The port's knowledge and experience about nickel emissions ought to have provided its management and the board with adequate warnings about the possibility of lead emissions. In particular, the evidence of elevated nickel readings should have triggered a comprehensive risk assessment of its facilities for lead-handling (Education and Health Standing Committee 2007a, pp. 175, 178, 186, 199, 200, 203, 205, 206). This prior knowledge did not prevent the Board of Esperance Port from endorsing the Magellan Lease and Handling Agreement to export lead. Furthermore, a number of policies and recommendations needed to be introduced or changed for the safe handling of lead. This decision was based on the confidence placed on the port that these improvements would be implemented before the shipment of lead expected in July 2005 (Education and Health Standing Committee 2007a, pp. 209, 257-261). One of the directors reiterated the board's commitment to safety by stating that, "the concern of the management and the board was staff occupational health and safety ...The Board committed to a new protection policy, facilities and equipment upgrade. (They) recognised that these improvements would also benefit the employees handling nickel" (Education and Health Standing Committee 2007a, p. 259).

From the correspondences between the General Manager (GM) of Magellan and the port's CEO in March 2005, it was evident that Magellan had considered lead concentrate to be a less hazardous product than nickel. Thus, it accepted that the preventive measures were adequate for the handling of lead concentrate (Education and Health Standing Committee 2007a, p. 311). Also, Magellan's management incorrectly interpreted the Australian Dangerous Goods

Regulations to exclude lead concentrate from the classification of being dangerous goods. The committee was of the view that, had Magellan conducted the appropriate testing of its lead concentrate, it would have correctly determined the classification as a dangerous good class 6.1 from the outset in April 2005 (Toxikos 2007).

8.5.1.2 HSE Management Programs

Finding No. 55 of the inquiry report revealed that both Esperance Port and Magellan Metals did not fulfil their responsibilities in ensuring the effective management of lead exposure in the Esperance area (Education and Health Standing Committee 2007a, p. 166).

According to the Esperance Port's 2005 Annual Report, an Environmental Management Plan covering the areas of dust, noise and odour was integrated into its operations. It was obligated to report to the WAEPA on its progress with implementing various ministerial conditions and commitments (Esperance Port Authority 2005a, p. 24). As part of the requirement for licence variation issued by the then WADOE, Esperance Port submitted a dust management plan for lead, which was an extract of the Environmental Management Plan. It turned out that this plan was the same one being used for management of iron ore. In fact, the WADOH highlighted several deficiencies in the port's dust management plan for lead-handling that could have impacted upon public health (Education and Health Standing Committee 2007a, pp. 277, 280).

As part of the requirement for the amended licence issued by the then WADOE, Magellan was required to prepare a dust management plan for the handling of lead. In the finalised HHEMP in November 2004, Magellan was committed to identifying "key risks relating to the transport operations, and (facilitating) the development of controls and emergency response procedures" (Environment Protection Authority 2000, p. 24). However that formal risk assessment did not occur and it appeared that Magellan had only focused on paper compliance

(Education and Health Standing Committee 2007a, p. 93). Furthermore, Magellan had incorrectly assessed and advised the then Environmental Protection Authority of Western Australia (WAEPA) of the adequacy of the port's facilities (Education and Health Standing Committee 2007f). By conducting only a cursory inspection of the port's facilities, Magellan did not ensure that the dust monitoring system was adequate and effective. Neither did the port act on the recommendations of HSE concerns raised by the workers regarding dust emissions. Contrary to the port's policy and public media release, product was occasionally hosed down the berths. Even though Magellan Metals should have been aware of the deficiencies in the port's reliance on depositional dust monitoring, Magellan Metals depended on the port's dust management plan and assurances of dust control measures for meeting its duty of care, without verifying their effectiveness (Education and Health Standing Committee 2007k, 2 May).

Magellan kept shifting its position on the percentage of moisture content needed for the lead carbonate to contain dust emissions. In the 1999 Environmental Review it stated a moisture content of 8%, then changed it to 12% when it was queried by the WADOH. However, in the Technical Report issued by Ivernia in September 2004, it stated that the product would be dried to less than 7.5% moisture content. This conflicted with the email from Magellan to Esperance Port in March 2005 stating that, at 10% moisture, the ship loading would not create any dust emission issue. Later in April 2005, Magellan informed the port of its decision to change the product into a non-agglomerated form on the basis that it would not affect the moisture content, which was supported by the port and its HSE representative. They further concluded that moisture content at around 9% was effective in minimising dust exposure and spillages (Education and Health Standing Committee 2007a, pp. 101, 111, 211, 212).

In Figure 81, the archetype for “Eroding Goals” or “Drifting Goals” was used to illustrate the gap between actual requirements and actual performance. Shown in the balancing loop (B16, Figure 81), actual requirements refers to the legislative intent, original approval conditions, accurate risk assessment, correct moisture content of lead and adequate dust management plan. In the same figure, balancing loop (B17, Figure 81) represents the actual performance, which includes the flawed interpretation of legislative requirements, non-conformance of approval conditions, inaccurate risk assessment, incorrect moisture content and inadequate dust management plan. When faced with such a gap, organisations could experience external pressures from government departments to take corrective actions or may simply get away with non-compliance. Sometimes, the government departments involved could have been misinformed about actual conditions (e.g. port facilities) and unwittingly accepted the risk assessment results. Other times, regulators did not enforce recommendations (e.g. the WADOH input) to address deficiencies in the dust management plan. Unfortunately, in the case of Esperance Port, enforcement actions came only after the discovery of the mass bird deaths (see delay sign ‘II’ between ‘Gap’ and ‘Enforce corrective actions’). With the remedial actions that occurred after the inquiry, the actual performance of the post-lead event was more aligned to the actual legislative intent and approval conditions (see delay sign ‘II’ between ‘Enforce corrective actions’ and ‘Actual performance’).

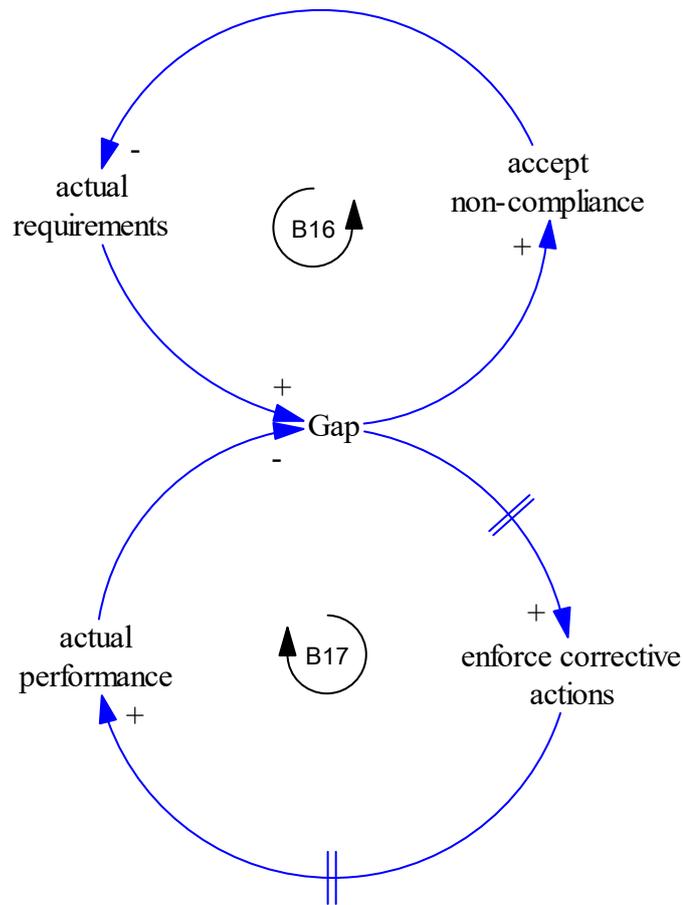


Figure 81: Esperanc's Policy & Planning Factor

8.5.2 Implementation and Operation

8.5.2.1 Structure and HSE Responsibility

The functions of the board of Esperance Port included setting organisational policies, developing strategic business directions, monitoring management's performance and reviewing investment strategies. Besides appointing the CEO, the board reviewed his performance and ensured that regulatory requirements and ethical standards were adhered to, and that risks were sufficiently managed (Esperance Port Authority 2005a, p. 6). Nonetheless, the parliamentary inquiry found that the port's management structure did not reflect the actual trade

volume and complexity of the port's business. For instance, the port handled 84 ships in 1984, but in 2007 that increased to 181 ships (Esperance Port Authority 2007a). As mentioned earlier in Section 8.4.2 on Board Governance, Esperance's board had remained very much the same since the establishment of the port, although additional operational staff were recruited in 2005 to cope with the increased activities (Esperance Port Authority 2005a).

8.5.2.2 Training, Awareness and Competence

Esperance Port recognised the potential harm that lead could do to humans through inhalation or ingestion over a long period. Thus, induction training and education programs were provided to all employees and contractors. Other training programs included "unloading procedures, introduction to cranes, hoists and slings, hatchman training, tag out and isolation procedures, ships mooring procedures, job hazard analysis, nickel sampling, two-way radio communications, stress management, dogging certificate, forklift operation, senior first aid, skid steer loader operation, and respiratory protection" (Esperance Port Authority 2005a, p.26).

8.5.2.3 Consultation and Communication

In order to communicate major operational activities to key stakeholders, customers and residents, Esperance Port developed communication strategies to raise awareness among the community, industry and government, and to share the port's approaches to managing increased activities and new products (Esperance Port Authority 2005a, p.28). However, the experience of the stakeholders on the ground was very different from the publicised communications strategies. The CLD in Figure 82 shows how the lead exposure issues were raised by the residents and the workers through various avenues for resolution.

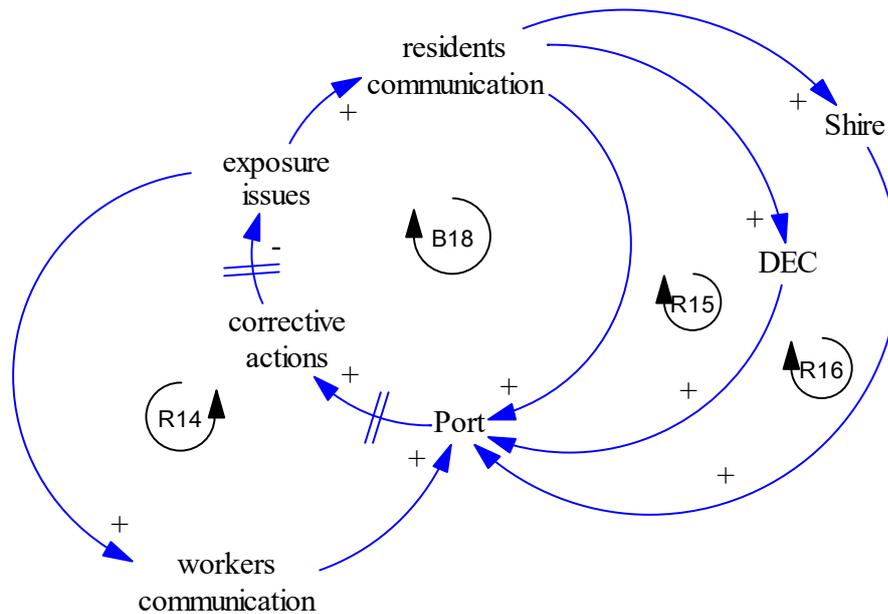


Figure 82: Esperance's Implementation Factor 1

Although there existed a forum – the Port Development Consultative Committee - for liaison with the broader community, there was a lack of legislative requirements to enhance the effectiveness of such a forum to ensure transparency and accountability to the residents. Media and press releases by the port and Magellan cited consultation with the Port Development Consultative Committee, and organisation of the Public Open Day in December 2004 (Esperance Port Authority 2005a, p.28), when in fact not all the most updated information was communicated to the Esperance community. As a result of the misleading information, the publicly available Environmental Assessment Report prepared by the WADOE propagated further disinformation (Department of Environment 2005). Further lack of independent access to dust monitoring results by the community contributed to a breach of trust between the port and the Esperance residents (Education and Health Standing Committee 2007e). Thus, the weak balancing loop (B18, Figure 82) captures this ineffective consultation mechanism, which did not produce prompt corrective actions to address exposure issues as it had for the previous iron ore project.

When complaints from the residents about dust exposure were received by the Shire's Environmental Officers, such information was not shared between the shire and the port, as shown by the dotted reinforcing loop (see R16, Figure 82). This was despite having the president of the shire on the board of Esperance Port. In fact such a dual role created the residents' perception of a conflict of interest, and the perceived need to maintain confidentiality by the shire councillor undermined community confidence in the operations of the shire (Education and Health Standing Committee 2007a, p.68).

Reinforcing loop (R14, Figure 82) shows that similar exposure issues (e.g. raised benthic nickel levels and nickel dust emission) were made known to the port management by the workers. Throughout the handling of the lead, port workers raised concerns about the sustained dust exposure during and after loading of the lead concentrate (Education and Health Standing Committee 2007a, pp.48,49). Unfortunately, workers faced an uphill task in getting management to address these concerns promptly (Education and Health Standing Committee 2007s, 28 June).

Not only did the port receive safety and health concerns from the workers, but the WADEC also received several dust exposure complaints from the residents. These issues were then passed on to the port for responses, as shown in the reinforcing loop (R15, Figure 82), but they hardly resulted in any changes in the way the products were managed. Thus, feedback from residents or workers as an effective tool to improve risk management at the port had been limited. Furthermore, responses from the government had not been consistently based on best-practice (Education and Health Standing Committee 2007a, Finding 179, p.326).

Therefore, despite the existence of a consultation forum between the port and the residents, and the various avenues by which the residents could approach the shire and the WADEC to provide input about the exposure, it did not result in

effective corrective actions to mitigate the exposure to hazardous dust emissions. Similarly, feedback and concerns raised by the workers did not produce greater attention to resolve exposure issues.

8.5.2.4 Operational Controls

From the in-loading to the out-loading of the lead concentrate, various operational controls were used, during the handling process, to mitigate the dust emissions. Some of the main controls included maintaining a certain moisture level within the lead concentrate, selection of appropriate vessels, visual detection of dust emissions and general handling practices. Considerations such as promptness of control implementation, appropriate controls and the right use of these controls were used to determine the effectiveness of control measures. Following are descriptions of various controls used in the handling of lead at Esperance Port.

8.5.2.5 Moisture Control

The parliamentary inquiry found that Esperance Port and Magellan failed to exercise their responsibilities in mitigating the emission of lead dust by ensuring a consistency of moisture content in the product. If the lead concentrate was either too dry (e.g. loading of MV Lemmergracht in October 2006) or too wet (e.g. loading of the Eco Progress on 8 June 2006), then it would impact upon the health of workers and residents. Since Magellan appeared to be more concerned about the concentrate being too wet, it raised the risk of the product becoming more prone to dust emission (Education and Health Standing Committee 2007a, pp.214-216, 225, 226).

Although Magellan had asserted its right, in October 2006, under clause 4.8 of the contract, to deny the port any authority to wet down the lead concentrate, there was a lack of clarity between Magellan and the port as to the party responsible for managing the moisture content of the lead in storage (Education

and Health Standing Committee 2007a, p.217). Nevertheless, Magellan agreed that the port had the legislative obligation to apply dust suppression mist sprays as part of its measures to prevent or minimise emission of visible dust. During the loading operation, coordination between the shipping support officer, the shipper's representative and the cargo supervisor was carried out to ensure that the product did not become too dry or breach the Transportable Moisture Limit (TML) level (Education and Health Standing Committee 2007s, June 28).

8.5.2.6 Dust Management Control

Despite knowledge of the emission of Nickel dust and previous inspection indicating the inadequacy of the facilities in managing heavy metals such as Nickel and Lead, Esperance Port submitted a dust management plan that was similar to that for the iron ore when it applied for variation to its environmental licence for lead-handling. In violation of its own operating procedure, the port had, on occasions, been operating without a vacuum truck to clean up lead spills. Furthermore, the existing control of using a vacuum to clean up had proven to be ineffective when the lead concentrate was moist and stuck to the facilities (Education and Health Standing Committee 2007s, June 28).

Also, concerns about using similar ineffective preventive measures to control lead emission were highlighted by the WADOH to the WADEC in September 2005. The Acting Toxicologist of the WADOH had advised the WADOE that the contamination of the rainwater tanks by highly soluble lead carbonate could cause serious health issues. Consequently, the WADOE recommended further controls (e.g. restricting the duration of dust generating activities; restricting vehicle speed; reducing drop-heights; considering guideline values and monitoring methods, etc.) to be included in the dust management plan for handling of lead carbonate (Education and Health Standing Committee 2007a, Finding 148).

8.5.2.7 Vessel and Out-loading Control

The port allowed MV Lemmergracht, which was earlier identified as one of the vessel types that would be unsuitable for the loader chutes due to its capacity for greater dust emission, to be loaded with lead on 10 December 2006 on a one-off basis (Education and Health Standing Committee 2007s, June 6). Unfortunately, that decision resulted in another major dust emission incident during the loading operation involving the same vessel on 11 and 12 December. Neither was Magellan able to effectively control the moisture content of the lead to be loaded onto the vessel (Education and Health Standing Committee 2007a, pp.225, 226, 234).

Despite the difficulty of using visual means to identify any major dust emission incident during the loading of lead concentrate during the day, the same questionable practice to control dust emission was used during the major emission incident on the night of 11 December 2006. Against advice regarding the health impact from such dust exposure, the port continued to rely on visible dust identification as a form of control during the night loading operation after the previous incident (Education and Health Standing Committee 2007a, pp.225, 229, 247).

8.5.2.8 General Unsafe Practices and Infrastructure

Compounding the safety and health issues were the port's poor handling practices and inadequate infrastructure, which had given rise to the high benthic lead level in the harbour. Although there had been some changes to the port's policies and procedures in response to workforce concerns about the handling of lead concentrate, other unsafe practices and conditions continued to cause hazardous dust emissions. Examples of handling practices included: poor preparation for storms; hosing down of heavy metal spills into the harbour; and not using a vacuum truck to clean up spills. Inadequate infrastructure involved: the dirty water treatment system; the conveyor system; the out-loading system

for heavy metals; and berth bunding (Education and Health Standing Committee 2007a, p.194).

These unsafe practices were not totally unexpected because the March 2002 report on the Esperance Port Nickel Odour Study had recommended spill control measures for the unloading activities but they were not promptly implemented. Despite the availability of better control measures to prevent and minimise contamination, a waste water treatment plant was only installed in June 2007, which was two years after the first lead concentrate shipment. Around the same time, the bunding along the edge of the berth reduced the risk of contamination entering the harbour from the berth. Other critical infrastructure improvements and engineering controls earlier identified to be necessary for minimising contamination were not implemented by November 2006 (Education and Health Standing Committee 2007a, pp.200, 207, 208, 260, 261).

From the above evidence, the following CLD illustrates how the existing and new controls could impact exposure from emissions (see Figure 83). Shown in the weak balancing loop (B19, Figure 83), with lapses in the existing controls, whether it was the inconsistent moisture content, inadequate dust management, incorrect vessel selection, unreliable visual detection of dust emission, inadequate infrastructure, and/or other non-conformance of safety practices, contributed to lead dust emissions. Although identified earlier the need for new or proposed controls (e.g. waste water treatment), they were not promptly implemented. Thus, the balancing loop (B20, Figure 83) was not effective and timely enough to support the current weak balancing loop.

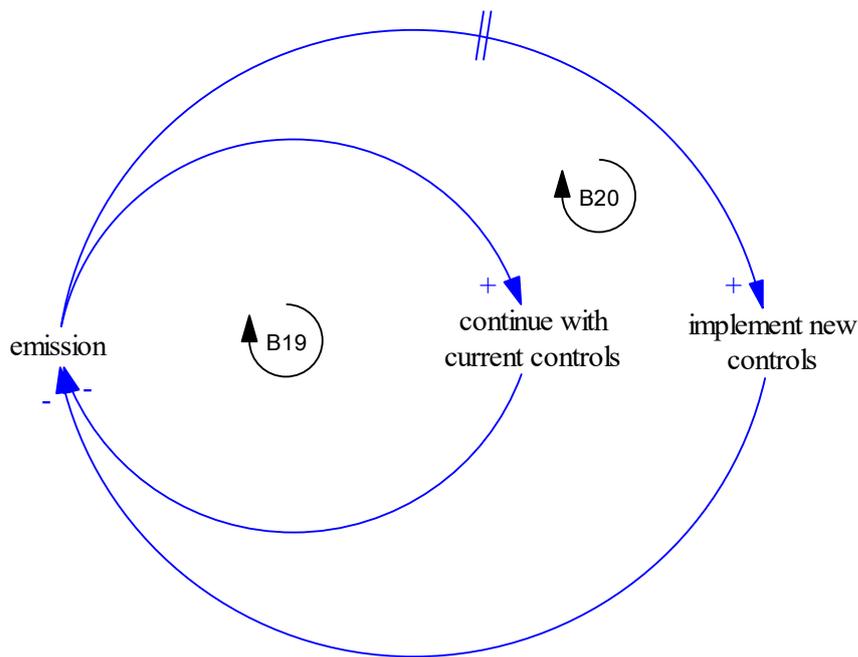


Figure 83: Esperance's Implementation Factor 2

8.5.3 Checking and Review

8.5.3.1 Monitoring and Corrective Actions

Checking focused on the measurement and evaluation of the HSEMS and its performance against legislative requirements and industry standards. The mere existence of an HSEMS was not sufficient to ensure its effectiveness in protecting the health and safety of workers and residents. Dust monitoring, biological monitoring (e.g. mandatory blood testing of port workers), reporting of exposure incidents, and implementation of corrective actions, were useful indicators in appraising the effectiveness of the HSEMS.

Evidence to the committee indicated that the WADEC responded to public complaints concerning the operations of the Esperance Port Authority and pursued strategies to address these. However, these corrective actions were often delayed and, overall, were ineffective in managing the risks highlighted by the complaints (Education and Health Standing Committee 2007a, p.286).

Contrary to the submission provided to the committee stating that Magellan’s workplace practices demonstrated its “acute and ongoing awareness of the dangerous qualities of its lead carbonate” (Education and Health Standing Committee 2007g, p.4), WADOIR Improvement Notices were issued in December 2005, relating to a series of non-compliances, including: lack of atmospheric contaminant sampling; absence of the appointment of a ventilation officer; no appropriate risk assessment of employee exposure to hazardous substances; incomplete registry of hazardous solutions; incorrect donning of PPE; and inadequate implementation of the HHEMP. Other improvement notices were also issued to Esperance Port by the WADOIR and WorkSafe, and the 2005 Esperance Port’s Annual Report mentioned that these were promptly addressed (Esperance Port Authority 2005a, p.27). Thus, the resolution of these improvement notices with better corrective actions should have resulted in improvement of the lead-handling process (see R14, Figure 84).

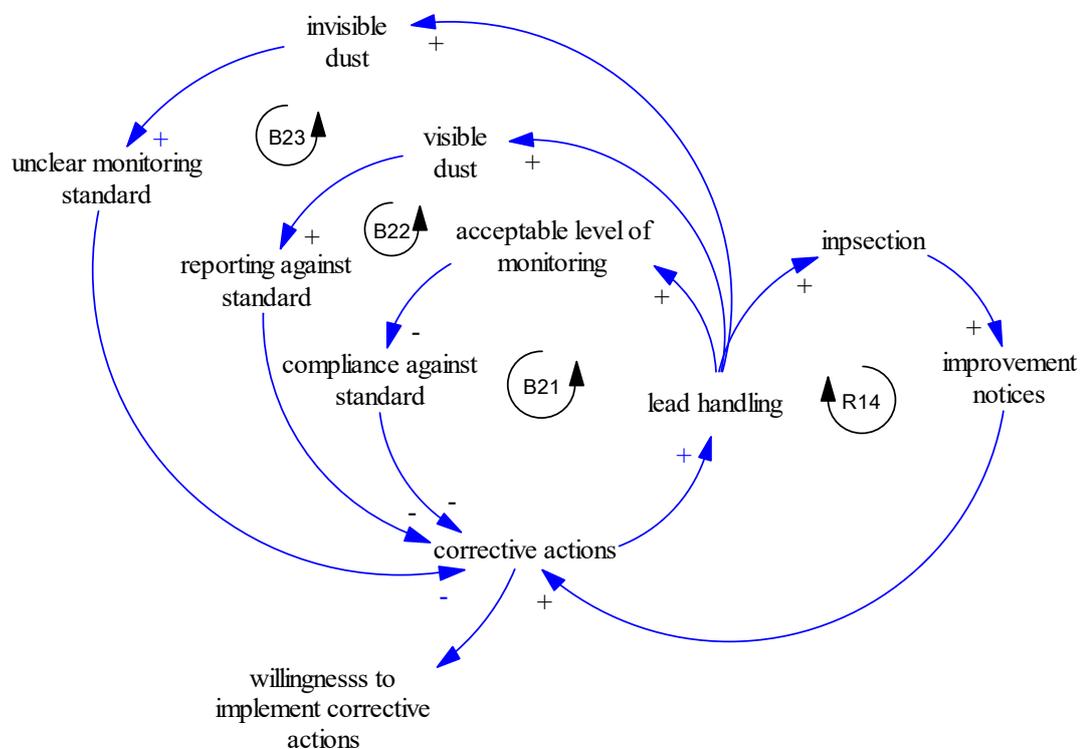


Figure 84: Esperance’s Checking Factor 1

On several occasions, the port's readings exceeded the WorkSafe Australia exposure standard for atmospheric contaminants. The port attributed these higher-than-the-standard readings to the ship-loading activities, which were considered as acceptable short-term exposure to lead, and being controlled by wearing full personal protective equipment. This tolerant attitude was partly due to the induction advice from Magellan Metals that considered any harm caused by the lead concentrate to be related to longer term exposure (Education and Health Standing Committee 2007a, p.251). Also, it was not possible to compare the readings against the National Environmental Protection guideline, because the guideline for lead in ambient air was based on an annual period, which did not necessarily correlate to any short-term exposure standard (Education and Health Standing Committee 2007s, June 5). Balancing loop (B21, Figure 84) depicts the flawed interpretation of the monitoring results, which rendered the compliance guideline irrelevant. Consequently, the port was deprived of the opportunities to implement more effective corrective actions.

Other examples of abnormal monitoring results did not warrant the attention of regulators. For instance, during the period between October 2005 and September 2006, three out of the ten monitored sites indicated very high levels of lead within the port and in residential areas beyond the port's operations, but the WADEC did not include them in the Annual Environmental Monitoring Report since these were voluntarily monitored sites outside the testing requirements (Education and Health Standing Committee 2007a, p.148, 175). Moreover, dust samples were only collected on a quarterly basis within a year and they did not include the summer months when there were strong winds in Esperance town. This resulted in figures that did not paint a true picture of the lead exposure (Education and Health Standing Committee 2007a, p. 148).

While the port had the responsibility of reporting high readings to the WADEC, the committee felt that the annual reporting requirement had contributed to the port's focus on reporting, or 'paper compliance' rather than the effective management of the environmental and health impacts. Not only were the monitoring equipment and processes considered to be outdated, but the incomplete and lagging report did not allow the port an opportunity for prompt response to the findings (Education and Health Standing Committee 2007a, p.166). Such ineffective reporting of dust emissions did little to contribute to better corrective actions (see B22, Figure 84).

As unreliable as the outdated monitoring equipment was, the visual detection of dust emissions did not fare any better. The port focused on visible dust as its 'primary measure' for environmental compliance, which provided a false sense of confidence of its dust control measures. Experience from the monitoring of nickel ship-loading verified that sensitive monitoring equipment could identify the presence of 'invisible' dust, which would not have been detected by inspectors without the use of specialised equipment (Education and Health Standing Committee 2007d), i.e. invisible dust emissions (see B23, Fig. 84) would hardly have produced better corrective actions, unless the outdated monitoring equipment was able to make up for the lack in the visual detection method. However, as mentioned earlier, visible dust emissions (B22, Figure 84) might not necessarily result in reporting and corrective actions.

Apart from the dust monitoring programs, biological monitoring of the workforce was carried out as a primary means of determining the actual exposure and the potential health impacts due to operational spills. However, the inconsistent results of the blood lead levels among the workers raised concern about using such biological monitoring to evaluate the effectiveness of control measures (Education and Health Standing Committee 2007s, June 28). Though the results were well within the Occupational Health and Safety Commission's threshold level of 50 µg/dl, the significant rise in blood lead level within two years should

have prompted the port to further investigate its control measures (Education and Health Standing Committee 2007a, pp. 248, 249). Like dust monitoring, biological monitoring shares the same balancing loop (B19, Figure 84).

In addition to carrying out the environmental and biological monitoring, the port was also required to provide Contamination Monitoring (CONTAM) samples to the Resources Safety Division of the then Department of Consumer and Employment Protection (DOCEP). However, the port did not always meet the quota periods and occupational distributions required by DOCEP. Furthermore, the Education and Health Standing Committee questioned whether the linking of these safety compliance requirements with an incentive scheme for the workforce might have compromised the integrity of the data (Education and Health Standing Committee 2007a, p. 250).

8.5.3.2 Moisture Level and Corrective Actions

There was a strong causal relationship between the lead moisture level and the risk of exposure (Education and Health Standing Committee 2007a, pp. 210, 217) (see Figs. Figure 85a and Figure 85b). Moisture control was achieved by either adding water to increase the moisture level or subjecting the lead to a drying process in order to reduce the moisture level. The following evidence reveals that deviations from pre-determined moisture content were often due to operational considerations rather than its potential impact upon public health.

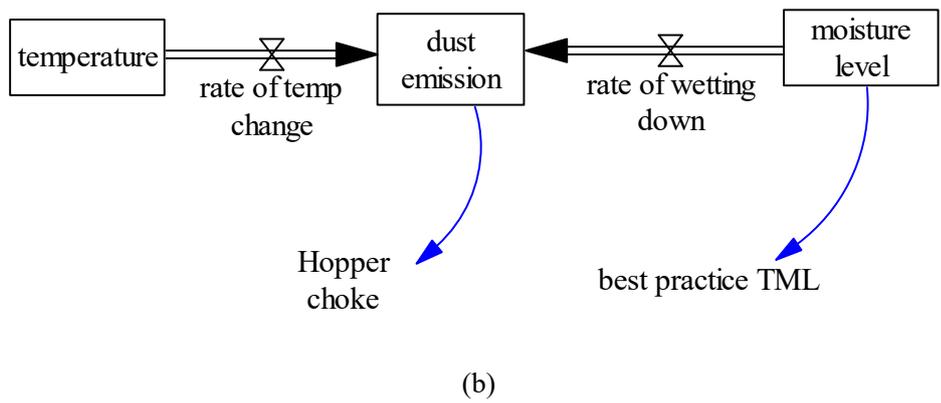
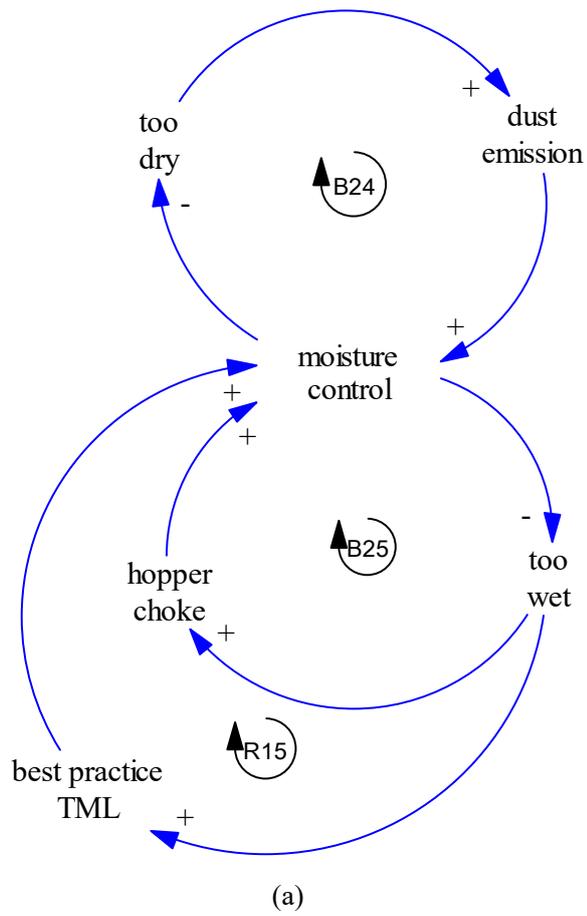


Figure 85: Esperance's Checking Factor 2

In October 2005, the port's workers raised their concern that efforts to reduce the moisture content in order to prevent blockage of the hopper made the risk of dust emission much higher. On the other hand, higher moisture content beyond the Transportable Moisture Limit (TML) could put the safety of the crew and vessel at risk (Education and Health Standing Committee 2007s, June 28). In that same month, the port requested that Magellan control the moisture level at the mine site to between 7% and 9.2% for optimal handling conditions through the port system. Magellan responded with a re-wetting procedure, which unfortunately caused the lead carbonate to be rejected again due to high moisture content. This over-compensation for the lack of moisture had also resulted in some lead exceeding the TML.

Conflict became apparent when the port's environmental consultant and Magellan's representative could not come to a resolution on the enforcement of the moisture level (Education and Health Standing Committee 2007a, pp. 214 - 217). Therefore, balancing loop (B24, Figure 85) illustrates the influencing factors associated with not enough moisture, while balancing loop (B25, Figure 85) and reinforcing loop (R15, Figure 85) depict the influencing factors associated with too much moisture (Figure 85a). Keeping to the same CLD, the three quantifiable stocks can be presented in a SFD are the moisture content, dust content and temperature. The SFD illustrates how the rate of temperature change and rate of wetting down could have impacts on dust emission and moisture level, respectively (Figure 85b).

As a result, the inconsistent nature of the product delivered by Magellan made it difficult for the port to manage it properly (Education and Health Standing Committee 2007s, June 28). Not only was there a lack of clear guidelines for the acceptability of the lead carbonate, there was also no responsible person to manage the moisture content while in storage (Education and Health Standing Committee 2007r). In January 2007, Magellan advised the port that the nature of the drying process and the distance to transport the lead concentrate made it

impossible to deliver a product that would definitely not cause dust emissions (Education and Health Standing Committee 2007a, p. 218).

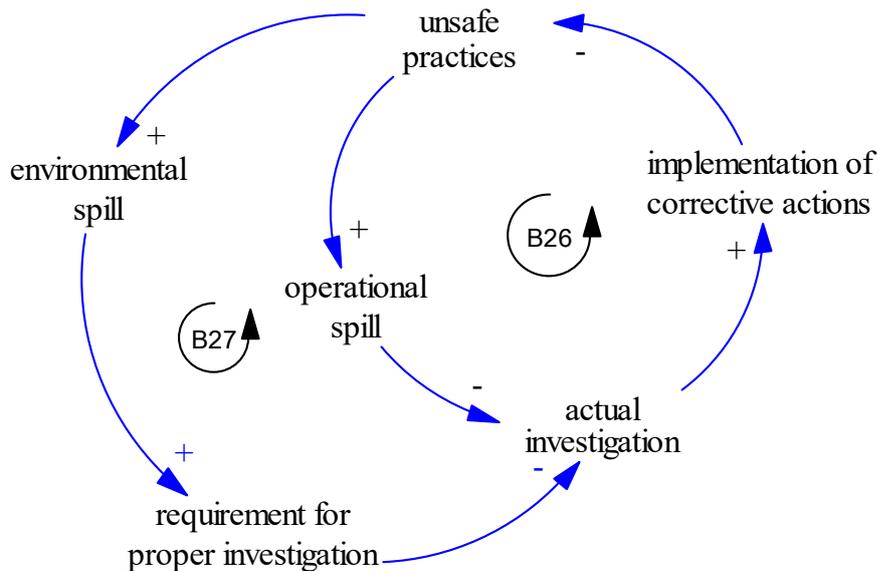
8.5.3.3 Emissions/Spills and Corrective Actions

There were a few major dust incidents during the loading of Magellan's lead concentrate at Esperance Port. The port differentiated between operational and environmental spills, where only the latter would require reporting to the WADEC. Unlike an environmental spill, an operational spill was considered to be an event that could be contained without adverse impact upon the environment. All operational spills were recorded in the 'General Report Sheet' where they could be investigated (Education and Health Standing Committee 2007a, pp. 172, 173). Even though there had been occasions of a significant operational spill and dusting incidents involving MV POS Auckland and MV Lemmergracht, respectively, there was no investigation carried out to prevent their reoccurrences. Neither was there evidence of any assessment of the spill to consider it as being non-reportable to the WADEC (Education and Health Standing Committee 2007a, pp. 192, 193, 225). Despite the night-loading incident involving the MV LEmmergracht in December 2006, Esperance Port continued to rely on the identification of visible dust as a means for controlling dust emissions. Part of the emission was attributed to the inappropriate type of vessel being used, but a similar vessel type continued to be used for loading with lead carbonate in January 2007 (Education and Health Standing Committee 2007a, Findings 114 and 116).

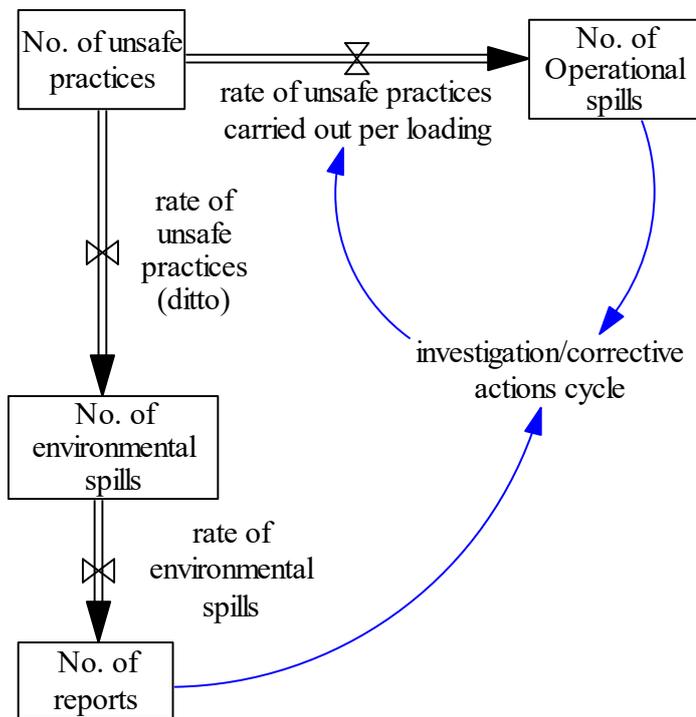
It appeared that there was a lack of reporting culture within the port. For instance, spills resulting from storms and inclement weather were not reported to the WADEC as required under Section 72 of the Environment Protection Act 1986 (Education and Health Standing Committee 2007a, p.187). Also, as stated in Finding No. 85 of the inquiry report, internally recorded spillage of lead into the sea in January 2006 was not reported to the WADEC due to an administrative oversight (Education and Health Standing Committee 2007a,

p.192). For environmental spills that were reported to the WADEC, there was little evidence of investigation being carried out by the department.

In Figure 86a, the weak balancing loop (B26) represents the causal behaviour for operational spills, with inadequate investigation into the causes resulting in the lack of corrective actions to reduce unsafe practices and operational spills. The other balancing loop (B27, Figure 86a) for environmental spills might have a better reporting system, but it did not systematically lead to a proper investigation of their causes. Thus, the rate of unsafe acts that were not corrected by a proper incident investigation process contributed to a higher than otherwise number of preventable emission incidents (Figure 86b).



(a)



(b)

Figure 86: Esperance’s Checking Factor 3

Considerable spillage was evident during the assessment of safe handling of lead concentrate protocols in March 2005. The port’s workers too identified a series of issues regarding the inadequacy of the infrastructure to safely handle lead concentrate (Education and Health Standing Committee 2007k). In May 2005, an environmental consultant recommended corrective actions for addressing these issues (e.g. dirty water treatment plant). Contrary to the port chairman’s media release that no lead from the port had been washed into the ocean, evidence showed that both rain and wash-down water from the berth had contributed to contamination of the marine sediment (Education and Health Standing Committee 2007i).

As in the previous years, there were no significant accidents or incidents in 2004/5. Significant incidents were defined as those causing damage in excess of AUD20,000 to the port's assets, personal injury requiring hospitalisation or fatal accidents (Esperance Port Authority 2005a, p. 17). Consequently, the emphasis on lagging indicators such as lost time injuries did not provide an accurate reflection of the health impact caused by lead exposure. It was not until 2008 that the port started to publish more specific HSE indicators such as Lost Time Injury/Disease Incidence Rate, Lost Time Injury Severity Rate, Lost Time Injury Frequency Rate, Lost Time Injury Duration Rate, Number of Workers Compensation Claims and Number of Employees Participating in Return to Work Programs in its Annual Report (Esperance Port Authority 2008, p.33).

The combination of multiple factors, such as the type of vessel, inadequate infrastructure, weather conditions, moisture content and night-loading, contributed to the major dust emission events. "The committee is convinced that the events that unfolded were foreseeable and in fact were foreseen" (Education and Health Standing Committee 2007a, p.49). Despite the lack of a regulatory framework to comprehensively address lead exposure, the engagement of services provided by independent HSE consultants would have informed the port of the potential impact from undesirable lead exposure. Furthermore, complaints about dust emissions from residents as early as in 2002 did not compel the port to change its monitoring practice.

8.5.3.4 Review

The top management of Esperance Port should have reviewed the HSE Management System to ensure its continuing suitability, adequacy and effectiveness. The review would have addressed the possible need for changes to policy, objectives and other elements of the HSE system, based on audit results, changing circumstances and commitment to continual improvement.

The board was given several opportunities to address environmental and HSE issues yet, each time, they either misjudged the severity of these events or did not pay too much attention to them. Ironically, the board did not even give due attention to the environmental status reports that it requested. Even though the board were aware of the presence of nickel in the water tanks and the series of infrastructure deficiencies highlighted by the workers, they approved the first shipment of lead before resolving these issues. Furthermore, the board mistakenly presumed that all the necessary policy and infrastructure improvements would be implemented before the first lead shipment in July 2005 (Education and Health Standing Committee 2007a, pp.254-260, 263).

It was not until 2005 that the port established a Risk Management Policy and a committee to provide some internal oversight of the risk exposure from port activities (Esperance Port Authority 2005a). However, the board only received the progress report about the need for critical infrastructure improvements more than a year after the lead shipment in 2005 (Education and Health Standing Committee 2007a, pp.261). This lack of review by the board and the consistent number of complaints raised by the residents and workers alluded to the ineffectiveness of the internal risk management control system and policy.

By tracking the number of significant incidents and lagging indicators as the primary safety indicator of its annual HSE performance measure, the port did not accurately reflect the extent of the long-term health and safety issues (Esperance Port Authority 2005a, p.17). As a result, the board was deprived of the means to bring underlying systemic issues to the surface, which could lead to more serious consequences with a bottom line impact upon the organisation.

8.6 Conclusions

At a time when Esperance Port, in Western Australia, was governed by the relatively mature HSE legislation and had access to advanced technology for its operations, it was not able to prevent the lead pollution of the environment. It took the mass deaths of birds to uncover the serious impact on public health that had been caused by the heavy metals-handling in the port. Similar to previous two case studies, Esperance Lead highlighted the inter-relationship of the external and internal organisational factors that impacted business decisions such as the expansion of port handling capacity for Lead and operational activities needed to support the management of the new product (Figure 30).

Evidence from the parliamentary inquiry revealed that these organisational factors contributed to this EIPE. As in earlier two case studies, the CLDs in Esperance Lead showed examples of weak feedback loops, which had allowed organisations to continue with their ineffective practices. Other times, dominant feedback loops could overwhelm weaker feedback loops to produce undesirable outcomes. Systems archetypes also were used to better explain underlying behaviours that contributed to this EIPE.

Examples of external organisational factors were legislation that did not incorporate a health impact assessment (HIA) in the approval process; important recommendations from other government agencies not being considered and implemented; insufficient resources for inspection and enforcement functions; and inadequate licensing provisions in the areas of dust management, monitoring and reporting. Economic factor played a significant role due to the increasing trade activities in the state and growth of the organisations. However, the port facilities were not upgraded to handle heavy metals such as Nickel and Lead. Furthermore, the lack of a formal consultation process for Esperance Port proposal to handle lead had deprived the affected community of valuable updates and input.

Internal organisational factors included the failure of the board to carry out its due diligence in providing necessary oversight for the management of the port's operations. Despite knowledge about previous Nickel emissions, the board focused their decisions on the productivity of the port and did not pay sufficient attention to the health and safety risks faced by the residents and workers. Also, the board had not renewed itself to gain the needed competencies to deal with the increased in trading activities. Other examples relating to the inadequacies in the HSE Management System included: the lack of formal assessment of the port facilities; delay in implementing engineering works to improve the infrastructure for heavy metals-handling; inadequate environmental and biological monitoring; and poor accountability and transparency between the port and its stakeholders, especially the residents of Esperance.

Chapter 9

CASE COMPARISON AND CONTRAST

9.1 Introduction

This chapter, presenting a cross-case comparison and contrast, was guided by the conceptual framework for causation analysis described in Chapter 5 and the themes that emerged from the case studies in Chapters 6, 7 and 8. Findings from these case studies, including the CLDs, provided better insights into the external and internal systemic factors. Each of the external systemic factors - political, legal, economic, technological and social – was analysed and compared to determine the similarities and differences between the three cases.

For the ease of the comparison and contrast, common topics across the three cases within each factor are used as subheadings in the tables. A value judgment to the question - Does this make a difference? - was provided to indicate if these factors made any difference to the prevention of EIPE. Four possible values – “Important” (where factor made a difference across all three cases), “Moderate” (where factor made a difference to two cases), “Minimal” (where factor made a difference to only one case) and “No” (for factor that does not make a difference to any case) - were assigned to these factors. The rationale for these judgements comes from your case studies analysis and is summarised in the sections below.

Similar analyses are carried out for the internal systemic factors. Clauses within each element of the OHSAS18001 Standard (OHSAS Project Group 2007) were used as subheadings within each internal factor. Results from this case comparison and contrast facilitated the development of a qualitative model to achieve the purpose of this research, which was to investigate the

organisational, regulatory and community factors contributing to EIPes and to assess the effectiveness of preventive strategies.

9.2 External Organisational Factors

All EIPe case studies are affected by external organisational factors, such as political, legal, economic, technological and social factors (Tables 9.1 to 9.5). Typically, organisations have lesser control over these factors, compared to the internal systemic factors discussed in Section 9.3.

9.2.1 Political

Both Japan and the US demonstrated symbiotic relationships between the industrial sector and their respective government agencies as a result of similar historical developments. Public policies during the time of the Love Canal case heavily favoured the manufacturing industries, in order to support demand for the world war machinery (Table 9.1). It was such military-driven industrial policies that had shaped and promoted investments, particularly in chemical manufacturing, for both the US and Japan. In the case of Esperance Lead in Australia, the absence of global conflict did not create an overarching policy specifically to support such a national 'war machinery.' Instead, policies in Western Australia were designed to support responsible and sustainable development for the state. That is, proposals were not only considered for their economic merits, but also the social impacts of their implications for the environment, public health, and safety and wellbeing of the people (Government of Western Australia 2017b).

Since the primary objective of the national policies in the US and Japan was to provide the necessary impetus for industrial expansion, government agencies and regulators took a more supportive role in facilitating the growth of manufacturing activities. In the case of Minamata Disease, government and

industry collaborated to ensure that the national interest and productivity were treated as top priorities, and often at the expense of public health and safety. In Western Australia, on the contrary, there was more separation and clearer distinction between the roles of government departments and the industry. This approach ensured that there was lesser likelihood of a possible conflict of interest when regulators were carrying out their legislative functions and responsibilities (Government of Western Australia 2017a).

While political support played a significant role in contributing to the Love Canal and Minamata Disease incidents, there was no evidence from the Esperance Lead inquiry about a possible conflict of interest or political lobbying. Esperance Port's proposal to handle the lead concentrate required deliberation and supervision by the board, even though they might have underestimated the port's ability to handle the lead. To ensure the sustainability of any industrial project that took health, safety and environmental factors into consideration, Esperance Port was required to submit its proposal for assessment by various government agencies and to seek approval from the Minister for the Environment. Thus, there was a due diligence process to ensure that the impact on the environment and public health caused by the lead-handling, if any, would be effectively mitigated by the proposed control measures. Even so, wrong assumptions about Esperance Port's capabilities had resulted in the ministerial approval being given for the lead-handling proposal, with disastrous consequences.

In the case of Esperance, several professionals, such as a toxicologist, inspectors, specialists from various government agencies and external environmental and HSE consultants, were engaged throughout, from the submission of the proposal to its implementation and management. However, in the case of the Love Canal, it was not the industry practice during that time to engage geo-scientists, engineers and health professionals in the planning and design of the waste disposal site. In fact, the actual involvement of the

professionals from the government agencies was restricted to a couple of years before the declaration of the Love Canal as a federal emergency area.

Depending upon the entity that had engaged the scientists and professionals, findings of their studies on the health impact of the Love Canal were politicised to support the different positions or interest groups. Similarly, scientific studies to better understand the causes and impact of Minamata Disease might not be as objective and independent as they were perceived to be. Polluters like Chisso influenced and manipulated the outcome of health impact studies to justify their industrial activities, while collaborative partnerships between government departments and universities in WA were common approaches to scientific studies and public health surveys during the time of Esperance Lead.

Comparatively, national policies and roles of the government agencies and professionals were considered as more significant contributing factor in both Love Canal and Minamata Disease than in the case of Esperance Lead.

Table 9.1: Cross-Case Comparison of External Political Factors

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Political				
National policies	<ul style="list-style-type: none"> • support of manufacturing and war effort 	<ul style="list-style-type: none"> • favour of high growth and support war effort 	<ul style="list-style-type: none"> • considered factors other than economic 	<ul style="list-style-type: none"> • moderate
Government roles	<ul style="list-style-type: none"> • support of industry practices • little due diligence in 	<ul style="list-style-type: none"> • close cooperation with industry • little due diligence in 	<ul style="list-style-type: none"> • separation of roles between government and industry • evidence of a 	<ul style="list-style-type: none"> • moderate

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
	approval process <ul style="list-style-type: none"> limited professional input for HSE during operations, researcher findings were politicised 	approval process <ul style="list-style-type: none"> no evidence of professional input for HSE during operation, partisan input from scientists were sought u Chisso 	due diligence approval process <ul style="list-style-type: none"> evidence of professional input for HSE 	

9.2.2 Legal

Unlike the case for Esperance Port, where there was already a well-developed legal framework for environmental, health and safety protection in the twentieth century, Hooker Chemicals and the School Board in New York (Love Canal) and Chisso (Minamata Disease) were operating in a period where such a legislative framework was immature (Table 9.2). Without comprehensive legislative requirements, enforcement of regulations for manufacturing activities in the Minamata and Love Canal townships were either non-existent or weak.

Before the establishment of any central coordinating agencies at the national level, such as the Japanese Environment Agency, there was a lack of a coherent approach or collaboration among agencies in developing strategies for mitigating the risks of EIPEs. Even the establishment of America’s EPA did not immediately translate into adequate federal enforcement, as it was dependent on individual states, like New York, to manage the legislative requirements.

There was little coordination among government agencies to establish strategies for mitigating the risks of chemical exposure.

Instead of proactively monitoring manufacturing activities for possible adverse health impacts, government agencies in the US and Japan, in the early stages of the HSE legislative enactment in the 60s and 70s, were relatively reactive in addressing any pollution concerns raised by the residents and workers. In the case of Minamata, some government agencies would only consider complaints backed by scientific research. To overcome the lack of resources for government to provide proactive enforcement, regulators primarily relied on industries to self-regulate among themselves.

In contrast, Esperance Port operated at a time when all states and territories, including Western Australia, had already adopted the Robens model of 'self-regulation' and inclusive consultation as their approach to safety and health. Although there were opportunities for improvement in inter-agency coordination within the WA government, regulators and various government departments had better understanding of their roles and responsibilities in comparison with their counterparts in the cases of Love Canal and Minamata. However, this did not always translate into consistent application of the latest industry standards and due diligence, particularly when the regulators approved the Esperance lead-handling proposal.

From the above, it could be seen that the legislative framework and coordination among the regulators played more critical roles to the outcome of the Love Canal and Minamata Disease than in the Esperance Lead. However, the regulators' resources and their ability to carry out enforcement activities had a significant impact across all cases.

Table 9.2: Cross-Case Comparison of External Legal Factors

Cases	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Legal				
Framework	• immature	• immature	• developed	• moderate
Enforcement and monitoring	• weak (state level)	• non-existent	• inadequate	• important
Regulator resources	• inadequate	• inadequate	• inadequate	• important
Coordination	• reactive	• reactive	• satisfactory	• moderate

9.2.3 Economic

Involvement in global events such as the world wars helped to propel the economic growth of the US and Japan and to lower their unemployment rates (Table 9.3). The national and local governments of these nations served as coordinating agencies for stimulus spending and domestically driven investment. As a result, a huge demand for chemicals and, especially, products related to military applications was created by both governments to meet national interests. While the spectacular economic growth in these nations was engineered by domestic policies, economic growth in Western Australia, to a large extent, was more susceptible to external market forces, and WA was dependent on global demand for its resources.

Unlike the Love Canal and Minamata Disease cases, Esperance Lead took place at a time when the Western Australian economy was already developed and it depended heavily on the contributions from the mining sector. In all three

cases, productivity and profit from organisations such as Hooker, Chisso, Magellan and Esperance Port contributed to the economic growth of the cities and states in which they operated. In addition to the valuable tax revenue that the cities received from these organisations, they provided employment opportunities for the residents.

Unprecedented economic growth was not achieved without its associated burdens. It put significant pressure on the ability of the government, industry and society to cope with the changing economic landscape. For instance, prosperity in the City of Niagara led to rising income for the workers and inflation in housing prices. During that 'baby boom' period, the state of New York had to build more schools for a rapidly growing population. While Hooker was enjoying a healthy demand for its products, it needed even more space to dispose of its growing chemical wastes. In the case of Japan, rapid industrialisation allowed Minamata to pursue productivity growth with little regard for the safety and health of its workers, or the protection of the environment. Furthermore, economic prosperity created power dynamics where close business ties between manufacturers and community leaders made it difficult for residents to hold Chisso accountable for their hazardous activities. In Western Australia, the mining boom made it extremely challenging for organisations to retain employees, including those with specialised HSE skills. In particular, government agencies with a limited budget found it difficult to compete with mining companies for skilled labour.

From the above comparison and analysis, rapid economic development and the associated burdens they created had more direct impact to the Love Canal and Minamata Disease than those of the Esperance Lead. Across all three cases, the strong economic demand and influence on the community played important roles contributing to the EIPE.

Table 9.3: Cross-Case Comparison of External Economic Factors

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 - 2007	Does this make a difference?
Economics				
Stage/Phase	<ul style="list-style-type: none"> • post war boom 	<ul style="list-style-type: none"> • period of rebuilding 	<ul style="list-style-type: none"> • mature and healthy support from mining 	<ul style="list-style-type: none"> • moderate
Demand	<ul style="list-style-type: none"> • strong and expansionary phase 	<ul style="list-style-type: none"> • strong and expansionary phase 	<ul style="list-style-type: none"> • strong and steady growth 	<ul style="list-style-type: none"> • important
Contribution	<ul style="list-style-type: none"> • strong contribution to city transformation 	<ul style="list-style-type: none"> • strong contribution to city prosperity 	<ul style="list-style-type: none"> • strong and important source of shire revenue 	<ul style="list-style-type: none"> • important
Burden	<ul style="list-style-type: none"> • little HSE considerations • more waste pollution • rising inflation 	<ul style="list-style-type: none"> • little HSE considerations • more waste pollution 	<ul style="list-style-type: none"> • inadequate HSE considerations • competition for skilled labour 	<ul style="list-style-type: none"> • moderate

9.2.4 Technological

Innovation in technology produced a significant shift in demand, favouring lower cost production methods and particular manufacturing activities (Table 9.4). During the time of Minamata's industrialisation, Japan was moving from a coal-based industry to one that was oil-centred. In the case of the Love Canal, the traditional use of hydroelectric power in the State of New York was replaced by the invention of alternating current, which allowed the transmission of electricity

over longer distances. In the more developed Western Australia, reliance had been on electricity generated by gas-fired power stations and renewable wind farms to support industrial activities.

Favourable national policies and funding allowed companies like Hooker and Chisso to lead in manufacturing innovations. The objective of these organisations was to achieve greater economic performances through the search for greater technological competitiveness. Hooker was able to transfer its technological edge, maintained in military applications, to commercial applications, while Chisso was able to import and adapt foreign technology for its own use. However, emphasis on the application of technology was on manufacturing efficiency and capacity rather than on the enhanced treatment of generated waste. Available methods of more effective treatment of industrial wastes during that time were generally considered to be cost-prohibitive for manufacturers.

Unlike the US and Japan, Western Australia was not one of the major players in chemical manufacturing. Its technological investment was primarily in the mining and resources industry. Instead of the rapid industrialisation experienced in the cases of Love Canal and Minamata, Esperance Port had already entered into twentieth century technology. Rather than revolutionary changes in the port's handling technologies, there were continual improvements or upgrades in infrastructure. While they were adequate for iron ore handling, they were not specifically designed for and applied to nickel and lead handling.

Industry knowledge of hazardous substances and chemicals, in terms of their properties and how they could impact long-term health and be controlled, was not well-developed in the Love Canal and Minamata Disease cases. Consequently, industry knowledge about the hazardous substances and their impact on public health and the environment did not always catch up with advancements in manufacturing technology. Also, inadequate sharing of best

practices among industry players, communities and other key stakeholders, both in the US and Japan, did not help to facilitate better understanding of the public health risks associated with manufacturing activities. However, that was not the case in Esperance, where there was an established understanding of the public health impacts from heavy metals, even though that knowledge was not necessarily translated into consistent application of controls on the ground. Unfortunately, even with reliable knowledge of industry best practices, the more appropriate and advanced technology to monitor dust emissions and to transport hazardous substances had not been utilised for the Esperance lead operations.

From the above information, it could be seen that the evolution of technology for energy supply had some influence on the decisions of organisations such as Minamata to base their manufacturing activities. Better industry knowledge about hazardous substances and application of monitoring technology could have made a difference in the outcome of Love Canal and Minamata Disease. More importantly, the investment and implementation of appropriate manufacturing and waste treatment technology played significant roles in mitigating the risks of all three EIPEs.

Table 9.4: Cross-Case Comparison of External Technological Factors

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Technological				
Power and energy supply	<ul style="list-style-type: none"> electricity replaced hydro-electric power 	<ul style="list-style-type: none"> hydroelectric power replaced coal-powered electricity 	<ul style="list-style-type: none"> mature power generation technology 	<ul style="list-style-type: none"> minimal

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Industry knowledge of hazardous substances	<ul style="list-style-type: none"> limited knowledge, lack of sharing and poor understanding of long-term health impacts 	<ul style="list-style-type: none"> limited and poor understanding of long-term health impacts 	<ul style="list-style-type: none"> well-established and good understanding of long-term health impacts 	<ul style="list-style-type: none"> moderate
Manufacturing technology	<ul style="list-style-type: none"> innovation in manufacturing processes 	<ul style="list-style-type: none"> investment in adapting overseas technology and expanding production capacity 	<ul style="list-style-type: none"> innovation and investment in engineering upgrade of port infrastructure (only for iron ore) 	<ul style="list-style-type: none"> important
Monitoring technology	<ul style="list-style-type: none"> non-existent 	<ul style="list-style-type: none"> non-existent 	<ul style="list-style-type: none"> mature but inappropriate for the operational needs 	<ul style="list-style-type: none"> important
Waste treatment/ emission control technology	<ul style="list-style-type: none"> immature and costly alternatives to dumping 	<ul style="list-style-type: none"> non-existent, lack of investment lack of transfer containment of waste 	<ul style="list-style-type: none"> mature but not applied consistently for all heavy metals poor transfer containment of spill 	<ul style="list-style-type: none"> important

9.2.5 Social

As a result of the heavy industrial growth and increasing urbanisation, the population booms in both cities of Niagara and Minamata put tremendous strain on the local governments to rapidly provide basic amenities to meet societal needs. In contrast, the Shire of Esperance did not face such a population explosion. Most of the infrastructures in the town were already established (Table 9.5).

The general lack of public awareness about the long-term impacts of chemical exposure allowed companies such as Chisso and Hooker to continue their hazardous operations for long periods. As long as the communities benefited from the economic growths of the cities without obvious public health and environmental impacts, there would be little attempt from the companies to share information about the hazardous findings regarding their operations. In the more developed society of Western Australia, there was a comparatively higher level of awareness about the long-term health impacts of chemical exposure among the residents in Esperance.

In contrast to the more egalitarian social structures and individualistic behaviour of residents in the US and Australia, the hierarchical nature of the Japanese society consisted of residents with entrenched traditional beliefs in maintaining strong social cohesion. This belief, combined with the fear that Minamata Disease could be infectious, led to other residents ostracising victims of the disease. Consequently, under-reporting of the incidence of the disease masked the true extent of its impact and suppressed the need to investigate its cause.

Due to Japan's societal demands placed upon its citizens to submit to its nationalistic agenda, the intervention from a structured government and the symbiotic relationship between Chisso and town councils, there was little community engagement on HSE issues. Although residents of the Love Canal

did not subscribe to the same social structure and behaviour, they were similarly absent from public consultation on activities that could impact their health and safety. On the other hand, opportunities for public participation were an integral part of environmental impact assessments and the sound policy development in Western Australia. Since amendments to the Environmental Protection Act 1986 in November 2010, members of the public have had an even greater involvement in proposals that will change the way land is used, and have helped the EPA to decide the level of assessment that should be applied. This feedback has assisted the EPA to make better recommendations to the Minister for Environment, who can use this information to decide whether the project will go ahead, and under what conditions.

From the above comparison, the unique social structure and behaviour played a more relevant role in Japanese society, which affected the prompt discovery and implementation of corrective actions in Minamata Disease. Poor public awareness of the long term impacts of hazardous substances was a factor in both Love Canal and Minamata Disease. Across all the case studies, community engagement played an important role in mitigating the risks of EIPE.

Table 9.5: Cross-Case Comparison of External Social Factors

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Social				
Population	<ul style="list-style-type: none"> • rapid growth and expansion 	<ul style="list-style-type: none"> • high growth from town to city 	<ul style="list-style-type: none"> • stable with little fluctuation 	<ul style="list-style-type: none"> • no
Social structure & behaviour	<ul style="list-style-type: none"> • egalitarian and individualistic 	<ul style="list-style-type: none"> • hierarchical and societal cohesion, support of nation building effort, close alignment with corporate interest 	<ul style="list-style-type: none"> • egalitarian and individualistic 	<ul style="list-style-type: none"> • minimal
Public awareness and expectation	<ul style="list-style-type: none"> • little awareness and interest about chemical risks 	<ul style="list-style-type: none"> • poor awareness with no education on chemical risks 	<ul style="list-style-type: none"> • good awareness about long-term health impacts of hazardous substances 	<ul style="list-style-type: none"> • moderate
Community engagement	<ul style="list-style-type: none"> • lack of consultation, need-to-know basis 	<ul style="list-style-type: none"> • non-existent 	<ul style="list-style-type: none"> • some level of consultation though no consistent for all proposals 	<ul style="list-style-type: none"> • important

9.3 Internal Organisational Factors

The HSE Management System Standard – OHSAS 18001:2007, a systematic management approach to enhancing the safety and health performance of an organisation (OHSAS Project Group 2007), is used as the framework for classifying the internal factors (see Tables 9.6 to 9.8). Major clauses contained in this Standard were used as the subheadings for each of the Internal Systemic Factors.

9.3.1 Policy and Planning

Part of the features of an HSE Management System consists of policy and planning. They are the general plan of intent which guided or influenced decision-making and the systematic arrangements of required resources to achieve the plan. Depending on the available data, not all of the organisations studied had specific information about their HSE policies, goals or board structures (e.g. Hooker and Chisso) and their governance approaches to allow for comparison and analysis (Table 9.6).

It is common practice for organisations in the 21st century such as Esperance Port to make publicly available information regarding their HSE commitment and members of their management team and Board. The Board of Esperance Port had members of the board who were part-time volunteers with limited knowledge about the health and environmental implications posed by the hazardous chemicals. Neither the Board possessed the necessary competencies to carry out their directors' due diligence requirements, nor did they always heed the warnings and advice from within their organisations to ensure that their operations did not pose any risks to the workers, the public and the environment. Inconsistent risk management and 'paper compliance' approaches were dominant themes in both the Love Canal and Esperance.

There was no evidence of an independent board structure in the case of Chisso. Top management was dominated by a small number of principal shareholders who controlled a majority of the company's shares. Among them was the founder of Chisso. Since most of these business decision-makers were also leading engineers and scientists who were keen to invest in new technology, the focus was on enhancing production efficiency and competitiveness. As in the cases of Love Canal and Esperance, Chisso ignored lessons from its operations (e.g. Korean manufacturing experience) to improve its protection for workers' health and safety. 'Production at all costs' would not be an unreasonable description for Chisso's approach to its operations.

Against the backdrop of an immature legislative framework for HSE during the period of Love Canal and Minamata, there was little evidence of Hooker and Chisso's going beyond the prevalent practices of that time. In all three cases, it appeared that the operational needs came before the health and safety of those who were exposed to the industrial activities. Moreover, experience from previous health and safety incidents did not always serve as important lessons for better policy and planning decisions to prevent their reoccurrences. Whatever knowledge they had of the hazardous nature of the chemicals and heavy metals, there was little translation of such understanding into the organisational risk management.

From the above comparison and analysis, evidence about the board structure and senior management's skills in Minamata Disease and Esperance that influenced their decision making, made moderate difference in the prevention of EIPE. More importantly, management commitment, planning for risk management and compliance to legislative and other industry requirements played significant roles in the prevention of EIPE across all three cases.

Table 9.6: Cross-Case Comparison of Internal Policy and Planning Factors

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Policy and Planning				
HSE Policy	<ul style="list-style-type: none"> no evidence 	<ul style="list-style-type: none"> no evidence 	<ul style="list-style-type: none"> presence of HSE policy 	<ul style="list-style-type: none"> no
Board structure and senior management commitment to HSE	<ul style="list-style-type: none"> inadequate 	<ul style="list-style-type: none"> very poor; senior management comprised mainly of engineers 	<ul style="list-style-type: none"> inadequate; part time members with little competency in HSE issues 	<ul style="list-style-type: none"> important
Planning for Risk management – identification, assessment and control	<ul style="list-style-type: none"> some site inspections, general information on wastes before transfer to School Board failure to learn from exposure incidents 	<ul style="list-style-type: none"> non-existent, focus on business considerations (e.g. near sea and cheap labour), ‘production at all costs’ failure to learn from Korean manufacturing experience 	<ul style="list-style-type: none"> superficial inspections, poor risk assessment of infrastructure, submission of iron ore dust management plan for lead, ‘paper compliance’ failure to learn from nickel emissions 	<ul style="list-style-type: none"> important

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Identifying legal and other requirements	<ul style="list-style-type: none"> conformance to the acceptable industry practice at that time 	<ul style="list-style-type: none"> not in compliance to all requirements 	<ul style="list-style-type: none"> not in compliance to all legal requirements 	<ul style="list-style-type: none"> important
HSE objectives, targets and HSE programs	<ul style="list-style-type: none"> no evidence 	<ul style="list-style-type: none"> no evidence 	<ul style="list-style-type: none"> evidence of the use of lagging indicators 	<ul style="list-style-type: none"> minimal

9.3.2 Implementation and Operation

Essentially, the implementation phase of an HSEMS enables organisations to carry out their policies and plans for the management of health and safety. It looks at the allocation of resources, roles and responsibilities for HSE, the mechanism for consultation, and the operational controls used to mitigate the risk of hazardous substance exposure (Table 9.7).

Other than the Safety and Health Representatives (SHRs) and ad hoc engagement of external HSE consultants in Esperance Port, there was little evidence to suggest that there were dedicated health and safety resources and clearly defined HSE responsibilities for all levels of the workforce in the events of these EIPEs. In fact, during the time of the Love Canal case, there was only a handful of chemical manufacturers that had corporate level waste management specialists (CEN 1966).

While there was some consultation with government agencies to find ways to reduce the incidence of skin disease (chloracne) from chemical exposure, there was no evidence to suggest that there was any active engagement with Love Canal residents on HSE issues by Hooker. A similar lack of any consultation mechanism for obtaining feedback and input from workers and residents on HSE issues during production could be seen in the case of Minamata Disease as well.

The inadequate communication was partly due to the general reluctance of organisations to publicise any unfavourable findings. Not only did Chisso not address the discovery of hazardous organic mercury in its production process, but also it carelessly re-directed the waste discharge that allowed the further spread of Minamata Disease. Just like Chisso, Hooker had knowledge about the toxicity of its chemicals, but chose not to share that information with key stakeholders. However, Hooker did provide some health and safety advice on management of the toxic chemicals to the School Board and contractors.

In contrast to the Love Canal and Minamata cases, there were more established consultation mechanisms for stakeholder input in the case of Esperance Lead. Unfortunately, employees' and residents' concerns about chemical exposures were not always given sufficient attention by the management and board of Esperance Port.

Ineffective operational control was a common theme in all three cases. Other than the HSE induction training and specific operational procedures training for workers at Esperance Port, there was no evidence of any structured or formalised training for workers in the Love Canal and Minamata Disease case studies.

Opponents of Hooker argued that the installation of controls was not proportionate to their knowledge of the risk of chemical exposure. Factors contributing to chemical risk exposure in the Love Canal case included equipment with integrity issues, inadequate geological containment, unsafe or non-compliant practices, lack of basic safeguards, and not taking advantage of more effective incineration technology, as well as the lack of management expertise within the School Board, and minimal supervision and regulatory enforcement of contractors' activities.

In the case of Minamata Disease, Chisso addressed the absence of any chemical waste treatment by installing an ineffective treatment system and carelessly redirecting waste to other coastal regions. Compared to employees in Esperance, the workers in Chisso had little rights and were often exploited by irresponsible managers to work long hours, and with exposure to hazardous chemicals at levels beyond what would be considered healthy and safe.

Advancements in technology accorded Esperance Port with more sophisticated controls, but they were not sufficient to minimise the emission of lead to as low as should have been reasonably practicable. Factors contributing to the emission included poor moisture control of the lead concentrate, absence of containment and clean-up procedures after any spill, inadequate sump management and bunding of the wharf, wrong vessel type used for loading, treatment of only visible dust, non-compliance with safe work procedures, an inadequate dust monitoring program, tolerance for short-term lead exposure and delays in carrying out improvement works on the port's infrastructure.

Expectedly, most of the implementation factors of the HSEMS, which directly affected the organisational operations, made important difference in the outcome of all the three EIPE cases.

Table 9.7: Cross-Case Comparison of Internal Implementation and Operation Factors

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Implementation and Operation				
Structure, resource and responsibilities	<ul style="list-style-type: none"> uncommon to have corporate level waste management expertise 	<ul style="list-style-type: none"> no evidence of management roles and responsibilities for HSE 	<ul style="list-style-type: none"> lack of HSE-competent board and dedicated HSE personnel at management level, presence of safety and health representative 	<ul style="list-style-type: none"> important
Training, awareness and competence	<ul style="list-style-type: none"> no evidence of safety training 	<ul style="list-style-type: none"> no evidence of safety training 	<ul style="list-style-type: none"> evidence of safety training 	<ul style="list-style-type: none"> moderate
Consultation on HSE issues with community, government agencies and polluting organisations	<ul style="list-style-type: none"> pre-transfer: no evidence of consultation between Hooker and residents, but some consultation with government agencies, and with the 	<ul style="list-style-type: none"> absence of consultation mechanism, inadequate consultation between Chisso and residents or local government 	<ul style="list-style-type: none"> mechanism in place but not always effective, some level of consultation between organisations, residents and government agencies 	<ul style="list-style-type: none"> important

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Operational controls	<p>School Board on sale of site</p> <ul style="list-style-type: none"> • post-transfer: provision of HSE advice to the School Board, school contractors and city contractors • pre-transfer: poorly maintained equipment, unsafe practices, inconsistent conformance to organisational standards, lack of basic controls, non-use of more effective controls 	<ul style="list-style-type: none"> • inadequate risk management, ineffective waste treatment system, unsafe redirection of waste discharge 	<ul style="list-style-type: none"> • poor product quality control, inadequate control measures, unsafe practices, tolerance for short-term exposure 	<ul style="list-style-type: none"> • important

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Document Control	<ul style="list-style-type: none"> post-transfer: unsafe practices by contractors, inadequate training and education on chemical hazards no information 	<ul style="list-style-type: none"> no information 	<ul style="list-style-type: none"> evidence of document control 	<ul style="list-style-type: none"> minimal

9.3.3 Checking and Review

Checking and review are important elements of an effective HSEMS. They involve the performance measurement and monitoring of the health and safety management system, health surveillance of workers and other affected stakeholders, investigation of incidents and non-conformances, and corrective actions that are taken to prevent reoccurrences (see Table 9.8).

Except for the lagging HSE indicators in Esperance Port's published annual reports, there was no evidence of HSE performance measurement carried out by Hooker and Chisso. Neither was there evidence of proactive site monitoring and health surveillance of affected workers and residents by the same organisations.

In addition to the lodgement of complaints about unknown chemicals entering residential areas in the Love Canal, and reports of abnormal animal behaviours in Minamata, there was a lack of evidence that Hooker, the School Board, the City of Niagara or Chisso had established, implemented and maintained effective systems to monitor the chemicals used in their operations. While Magellan, in the case of Esperance Lead, had submitted its health and environmental management plan, which required environmental contamination monitoring, it did not adhere to the plan. Similarly, both monitoring and review of HSE performance in Esperance Port were less than satisfactory. For instance, major spills were not reported, outdated dust monitoring equipment was used, monitoring of only visible dust occurred, there was tolerance for short-term lead exposure and the frequency of reporting did not meet regulatory requirements.

As in the case of the Love Canal, there were no legislative requirements for Chisso to conduct health surveillance of workers exposed to hazardous chemicals. Nonetheless, the government's test results of high mercury levels being found among residents of Minamata was kept from the public. Similarly, in Esperance Port, there was a failure to address the trend of increasing blood lead levels.

While there might not have been an effective monitoring system, Hooker provided assistance in regard to incidents and complaints about chemical exposures after the property had been transferred to the School Board. It consulted with experts and implemented controls to prevent skin disease from chemical exposure. Nonetheless, Hooker's reactionary approach to addressing these incidents, without proper follow-up or comprehensive investigation, failed to address their underlying causes.

Compared to Love Canal and Minamata, Esperance Lead had a more developed system in place for incident or non-conformance reporting and investigation. There was a process for determining the causes of emission

incidents in Esperance Port, but evidence showed that they were not always required to be investigated, depending on the classification of spills. Furthermore, delays in the implementation of infrastructure improvements or corrective actions, which could have reduced the incidence of lead emissions, resulted in workers being exposed to higher levels of hazardous substances.

In all three cases, there was inadequate information on the internal audit or review of the HSEMS. Nonetheless, diligent implementation of site monitoring, health/biological surveillance, corrective actions and incident and non-conformance investigation were important considerations in mitigating the undesirable consequences of exposure to chemical and heavy metals.

Table 9.8: Cross-Case Comparison of Internal Checking and Review Factors

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Checking and Review				
Performance measurement	<ul style="list-style-type: none"> no information 	<ul style="list-style-type: none"> no information 	<ul style="list-style-type: none"> use of lagging indicators 	<ul style="list-style-type: none"> minimal
Site monitoring	<ul style="list-style-type: none"> no evidence of proactive/on-going monitoring 	<ul style="list-style-type: none"> no evidence of proactive/on-going monitoring 	<ul style="list-style-type: none"> inadequate for both Magellan and Esperance Port 	<ul style="list-style-type: none"> important
Health/Biological surveillance	<ul style="list-style-type: none"> no evidence nor legal requirement 	<ul style="list-style-type: none"> no evidence nor legal requirement 	<ul style="list-style-type: none"> inadequate, failure to address trend of increasing lead levels 	<ul style="list-style-type: none"> important

Cases Factors	Love Canal 1920 – 1978	Minamata Disease 1932 – 1968	Esperance Pollution 2004 – 2007	Does this make a difference?
Corrective actions, incident & non-conformance investigations	<ul style="list-style-type: none"> reactive responses to reported incidents, inadequate internal inspection and investigation 	<ul style="list-style-type: none"> non-existent, refusal to acknowledge reported incidents 	<ul style="list-style-type: none"> system in place, but not always effective 	<ul style="list-style-type: none"> important
Audit of the HSEMS	<ul style="list-style-type: none"> no information 	<ul style="list-style-type: none"> no information 	<ul style="list-style-type: none"> no information 	<ul style="list-style-type: none"> no
Management review of HSE performance and goals	<ul style="list-style-type: none"> no information 	<ul style="list-style-type: none"> no information 	<ul style="list-style-type: none"> presence of management meeting and annual report 	<ul style="list-style-type: none"> minimal

9.4 Conclusion

Findings of the case study comparison and analysis according to the classified external and internal organisational factors had identified similarities and differences among the three cases – Love Canal, Minamata Disease and Esperance Lead. All these cases were impacted, to various extents, by political, legal, economic, social and technological factors. Particularly, favourable national policies and growing economic demand were significant driving factors for Hooker Chemicals, Chisso and Esperance Port to expand their operational activities. Against such dominant reinforcing factors, the counteracting forces of operational controls and feedback had comparatively lesser influence on organisational activities to ensure HSE performance was not compromised.

Often decision makers and management staff placed financial priorities above long term health and safety impacts that contributed to the EIPE. Although Esperance Lead did not share the same geo-political and legislative developments as those of Love Canal and Minamata Disease, Esperance Port was not immune to similar issues such as poor management decisions, inadequate consultation with workers and residents, ineffective hazardous substance controls, insufficient attention given to reported incidents and poor follow up on corrective actions.

Major differences in the external organisational factors were the more comprehensive legislative framework, more advanced production technology and higher public awareness in Esperance Lead compared to the other two EIPE cases. Nonetheless, their effectiveness in preventing the occurrence of EIPE was conditioned on several other factors such as the staffing level within regulatory agencies, clearly defined roles and functions of different government departments, public access to site monitoring data, consultation requirements for proposal variations, and appropriate selection and application of up-to-date technology.

Similarly, all three cases were impacted by the policy, planning, implementation and checking factors in their HSEMS. Due to a combination of external systemic factors, Hooker and Chisso did not have a mature and comprehensive HSEME, compared to those of Esperance Port and Magellan Metals. Nonetheless, there remained a gap between policy/planning and implementation of the HSEMS in the case of Esperance Lead. While there was HSE performance checking in Esperance Port, it was not done effectively enough to provide a platform for continual improvement.

The impact these external and internal systemic factors made to the prevention of EIPE were categorised and tabulated according to the level of importance (see Table 9.9a and 9.9b). Shaded cells against the EIPE cases indicated the factors that made a difference to the EIPE. Their level of impact were represented by the colour scheme: Green – “No” difference, Yellow – “Minimal difference”, “Moderate” difference and “Important” difference. From the summary tables, it could be seen that almost 50% of the external factors and about 56% of the internal factors had important impact on the EIPE. These would then be compared to the findings from the Focus Group discussions in the next Chapter, which identified the common themes and most important factors contributing to EIPE (see Table 10.1 and Table 10.2). Nonetheless, these are not necessarily indicative of the most important factors for ALL EIPE, rather it is a model by which to analyse the EIPE, or potential for EIPE.

Table 9.9: Differences that PLET and HSEMS factors make to EIPE

(a)

External Factors Summary	Love Canal	Minamata	Esperance	OVERALL
Political				
National Policies				
Government roles				
Legal				
Framework				
Enforcement and monitoring				
Regulators’ resources				
Regulators’ coordination				

External Factors Summary	Love Canal	Minamata	Esperance	OVERALL
Economic				
Stage/phase				
Demand				
Contribution				
Burden				
Technological				
Power and energy supply				
Industry knowledge of hazardous substance				
Manufacturing technology				
Monitoring technology				
Waste treatment and emission control				
Social				
community engagement				
Social structure & behaviour				
Public awareness and expectation				
Community engagement				

No difference		Minimal difference		Moderate difference		Important difference	
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Table 9.9: Differences that PLET and HSEMS factors make to EIPE

(b)

Internal Factors Summary	Love Canal	Minamata	Esperance	OVERALL
Policy and Planning				
HSE Policy				Minimal difference
Senior management commitment	Moderate difference	Moderate difference	Moderate difference	Important difference
Planning for risk management	Moderate difference	Moderate difference	Moderate difference	Important difference
Identifying legal and other requirements	Moderate difference	Moderate difference	Moderate difference	Important difference
HSE objectives, targets and HSE programs			Moderate difference	Moderate difference
Implementation and Operation				
Structure, resources and responsibilities	Moderate difference	Moderate difference	Moderate difference	Important difference
Training awareness and competence			Moderate difference	Moderate difference
Consultation with community, government agencies	Moderate difference	Moderate difference	Moderate difference	Important difference
Operational controls	Moderate difference	Moderate difference	Moderate difference	Important difference
Document control				Minimal difference
Review and Checking				
Performance measurement				Minimal difference
Site monitoring	Moderate difference	Moderate difference	Moderate difference	Important difference
Health/Biological surveillance	Moderate difference	Moderate difference	Moderate difference	Important difference
Corrective actions, incident & non-conformance investigations	Moderate difference	Moderate difference	Moderate difference	Important difference
Audit of the HSEMS				Minimal difference
Management review of HSE performance goals			Moderate difference	Moderate difference

No difference	Minimal difference	Moderate difference	Important difference
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Initially, the perceived differences in the national policies, economic growth, legislative framework maturity, technological advancement and society organisation between the case studies due to different historical periods may give the impression that they are fundamentally different. However, the proposed EIPE framework of this research recognises its universal application, based on the understanding that organisations in this world since Love Canal, still operate within purposefully designed PLETS and EHSMS systems. Fundamentally, Chisso, Hooker or Esperance Port was an organised entity of people with a particular purpose, such as a business or government department. These organisations operate in a system where they interact with both the internal and external organisational factors. Therefore, this methodology is a powerful framework for examining EIPEs across geographical locations and historical periods. Potentially, it can be used for current major facilities such as mines, manufacturing plants and other industrial activities in China that run the risk of EIPE with associated public health impact (Li et al. 2014; Wang and Yang 2016; Wang et al. 2017; Wong 2017).

Chapter 10

FOCUS GROUP EVALUATION

10.1 Introduction

Previously in this study, the conceptual framework (Chapter 5) has been applied to three EIPE cases (Chapters 7 to 10), which facilitated a better understanding of the complex causes contributing to EIPEs. To evaluate the conceptual framework and findings of the EIPE case studies, and to gain a better understanding of the contributing factors for the occurrences of EIPEs and how they could be mitigated, a Focus Group study was conducted, consisting of professionals with experience in EIPEs. Although they may not have been exposed to CLD, their facilitated input provided valuable data to enhance the conceptual framework.

A Focus Group is not only ideal for expressing experts' points of view about EIPEs, but it also enables the researcher to observe the process of prioritisation and decision-making in a group setting (Kitzinger and Barbour 2001). Moreover, such collective engagement of stakeholders, or participants involved in similar areas of study, acknowledges the value of a participatory approach in elucidating the mental models from different perspectives (Rouwette, Vennix, and van Mullekom 2002; Andersen et al. 2007a; Black and Andersen 2012; Newell and Proust 2012).

10.2 Focus Group Profile and Activities

The Focus Group was made up of eight participants, which was large enough to provide a diversity of opinions, but small enough to provide opportunities for each member to participate in the discussion. Representatives from different government agencies and industry associations, with experience in managing

industrial events, were selected to participate (see Appendix H). As much as possible, participants from the same organisations were organised in different groups to prevent the possibility of “group think” and to maximise the diverse range of views. The Focus Group methodology was described in more detail in the earlier Chapter 4 on Research Design (see Section 4.5.3.1).

The Focus Group consisted of the following exercises to: help identify key contributing factors linked to EIPEs; provide insight into the interactions among these contributing factors; and discuss possible strategies that could prevent the occurrence of an EIPE and improve its management (see Appendix F).

- Exercise 1: Develop individual influence diagrams;
- Exercise 2: Develop pair-blended influence diagrams;
- Exercise 3: Identify top three external and top three internal contributing factors to an EIPE, in two groups of four; and
- Exercise 4: Discuss the top external and internal factors for each group.

The intent of influence diagrams is more narrowly focused than that of the CLDs. As the name “influence” implies, influence diagrams are about capturing the key factors and the relationships among them. Although, not all participants were familiar with this non-linear approach of representing causal links between factors, and given the available time for carrying out the Focus Group activities, it was a less demanding tool to apply than to explain the more complicated concept of CLD polarity. Further Focus Group sessions could provide more data to convert the influence diagrams into more detailed CLDs.

10.3 Evaluation of EIPE Conceptual Framework

The conceptual framework developed in Chapter 5 combined the internationally accepted HSE Management System, based on the well-established principle of Plan-Do-Check-Act, with the macro business environment survey methodology of PLETS (see Figure 29).

In the first Focus Group exercise, individuals provided their perspectives on key contributing factors to EIPEs and the relationships among them, in an individual influence diagram. After the Focus Group, factors recorded in individual diagrams were sorted into conceptual framework, as shown in Table 10.1 below:

Table 10.1: Individuals' Contributing Factors for EIPEs

External organisational factors				
Political	Legal	Economic	Technological *Industry	Social
political action, political influence, political expectation, government funding and budget aligned with policies	regulatory review, enforcement, effectiveness of regulation, inter-agency agreement, agency response capability (e.g. clean-up expertise, emergency response)	economic impact, economic factors, employment, local jobs	level of technological development, proven technology, investment in industrial sector, industrial associations, best practice, well-established scientific research, scientific information, Industry apathy, industry self-interest	social effects, public awareness, community perception, community expectation, media expectation

Internal organisational factors				
Policy and Planning	Implementation and Operation	Checking and Review	*Safety Culture	
policies and procedures, risk assessment, risk identification, plant and process risk identification, planning, consideration of age of facilities' age, consideration of building specifications, asset value, profitability of project, costs and budgeting	responsibility and accountability, emergency response capability, risk controls, training and education, organisational best practices	organisational monitoring, symptoms of exposure, safety management system improvement, continual improvement	safety or organisational culture	

- Proposed terminologies for the revised conceptual framework.

With the exception of industry related issues and organisational culture, all the external factors presented by the experts could be aligned with the external factors (PLETS) of the conceptual framework (see Table 10.1). The proposed new terminologies (*) were then included in the revised conceptual framework (see Figure 87).

Although industrial innovation is categorised under “Technological,” external factors related specifically to the behaviour of the industry, such as industry self-interest, would be difficult to include in the conceptual framework. Therefore, changing the term from “Technological” to a broader one, such as “Industry”, would allow the inclusion of other non-technological issues affecting an industry’s competitiveness and survival.

Similarly, all the internal factors presented by the experts were compatible with the HSE Management System of the conceptual framework. Using the Standard OSHSAS 18001, the findings from the Focus Group aligned with the HSEMS elements. However, “organisational and safety culture” was an internal factor identified by the Focus Group participants that was not included in the conceptual framework. Culture was not explicitly included in the proposed conceptual framework, because it was initially considered to be an intangible factor and there was little consensus in the current literature regarding its definition (Clarke 2000; DeJoy 2005; Hopkins 2005; Beus et al. 2010; Dekker and Nyce 2014).

Regardless of the existing research, some experts in the Focus Group considered organisational and safety culture to be one of the key contributing factors that could impact an EIPE. Despite the fact that different perceptions of organisational and safety culture may exist, it is important not to ignore the role culture could play in the occurrence of an EIPE.

In this case, safety culture is considered as a subset of the larger organisational culture. Hence, the conceptual framework has been enhanced to include safety culture as one of the contributing factors to an EIPE. As shown in Figure 87, safety culture is the underpinning internal factor that affects every element of the HSE Management System whether it is policy, planning, implementation, checking or management review.

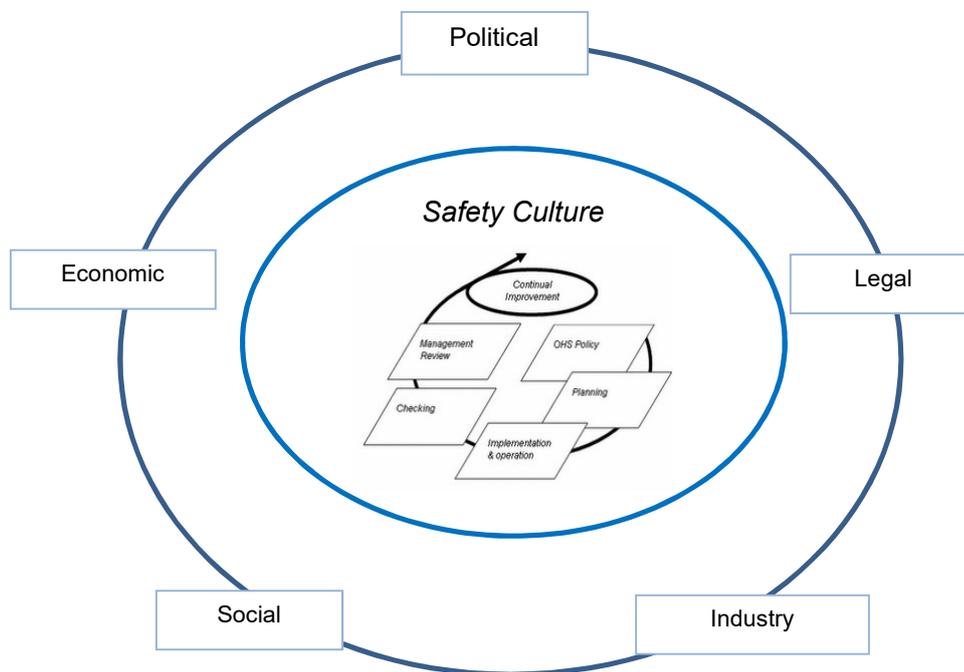


Figure 87: Improved Conceptual Framework

Findings from the individuals regarding the contributing factors to EIPes were ranked by a simple scoring system. Each participant was allocated three scoring colours – red (3 points), yellow (2 points) and blue (1 point) – to identify the top three most important external factors. A participant could only assign one colour for each of his/her three selected factors. This scoring method was used to create a ranking order of the selected factors and to prevent groups of factors sharing the same level of importance.

This process was repeated for the internal contributing factors. Table 10.2 shows the list of external and internal factors arranged in order of their significance, or descending order of the total points. Depending on the group dynamics and individual expertise, the factors from both groups may overlap. However, in this exercise, there was minimal overlapping of factors due to the different perspectives of the stakeholders.

Table 10.2: Consolidated Contributing Factors for EIPes

Leading Factors	Group 1	Group 2	Total
External			
Factor 1 Effectiveness and comprehensiveness of regulation/policy framework, resources, enforcement and monitoring	0	10	10
Factor 2 Application and planning approvals including design EIA, HIA	8	0	8
Factor 3 Political priorities (e.g. economic growth)	0	8	8
Factor 4 Government monitoring and surveillance (compliance and enforcement)	7	0	7
Factor 5 Community perception, expectation, consultation, communication and acceptance	5	0	5
Factor 6 Body of scientific evidence available	0	3	3
Internal			
Factor 1 HSE Management Systems implementation and auditing of systems, preventive maintenance system	9	3	12
Factor 2 Project Lifecycle Planning - safe design: planning design of plant/project/process	0	11	11

Leading Factors	Group 1	Group 2	Total
Factor 3 Management commitment, with clear reporting and accountability, and positive reporting culture, leadership	7	0	7
Factor 4 Continual improvement (system, process)	5	0	5
Factor 5 Level of knowledge/understanding – requirements, criteria, lack of competent people	0	4	4
Factor 6 Leadership (could be included under factor 3)	0	3	3

The top three external contributing factors were:

1. effectiveness and comprehensiveness of regulation/policy framework and its enforcement;
2. application and planning approvals including design EIA and HIA; and
3. political priorities.

Therefore, although regulatory requirements play a significant role in ensuring that organisations understand and carry out their legislative obligations, the enforcement of the relevant acts and regulations by the regulatory authorities is just as important (see EIPE case studies, Figure 34, Figure 53, Figure 66 and Figure 69). Furthermore, experts stated that unless the critical stage of planning and approval was properly established and executed, decisions to authorise an industrial operation could have serious HSE consequences. For instance, the approval of any industrial proposals, especially a large-scale infrastructure expansion, such as the Esperance Port's heavy metal-handling, involves several government agencies and extensive coordination among them (see Figure 68).

Sometimes, political priorities to promote local economies can play a significant role in the approval of projects such as the Love Canal's chemical site in New York (Figure 33), Chisso's production plant in Minamata (Figure 52) and lead handling in Esperance (Figure 68).

From the Focus Group input, these top external contributing factors compared well with the PLEIS factors, identified as either "important" or "moderate" from the case studies (see Table 9.9).

- regulatory enforcement and monitoring
- legal framework
- national policies
- government and professional roles
- government agency coordination

The Focus Group's top three internal factors were:

1. management systems implementation and auditing of systems;
2. lifecycle - safe design: planning design of plant/project/process; and
3. management commitment with clear reporting and accountability, and positive reporting culture and leadership.

This means it is not only critical to have a comprehensive system of managing HSE, but it is also important to periodically audit its effectiveness (Figure 5). Additionally, emphasis on considering safety at the early design and planning stages would help to minimise subsequent operational issues relating to HSE (see EIPE case studies, Figure 39, Figure 57, Figure 58 and Figure 78).

From the Focus Group input, these top internal contributing factors compared well with the HSEMS factors, identified as either "important" or "moderate" from the case studies (see Table 9.9).

- operational controls, site monitoring, health/biological surveillance (management system implementation)
- corrective action, non-compliance, incident investigation (auditing of management system)
- planning for risk management (product lifecycle planning)

Although the concept of continual improvement would have been more familiar with the Focus Group participants, it would not be a common practice in the Love Canal and Minamata Disease case studies, or before the OHSAS18000 and ISO 9000 Standards were introduced.

10.4 Evaluation of the Influence Diagrams

After the construction of individual influence diagrams, pairs were formed to develop pair-blended diagrams (Newell and Proust 2012; Brown et al. 2013). Analysis of pair-blended diagrams was undertaken to determine whether they represented potential archetypes or systemic behaviours. These are discussed in more detail in Chapter 11.

After the Focus Group, minor adjustments were made to the diagrams. Similar contributing factors were combined, and factors were phrased in neutral terms. For instance, if a factor was expressed as 'poor planning' it was rephrased as 'planning quality'. This is purely cosmetic and has no bearing on the meaning of the diagram. The resulting influence diagrams are shown in Figure 88 to Figure 91.

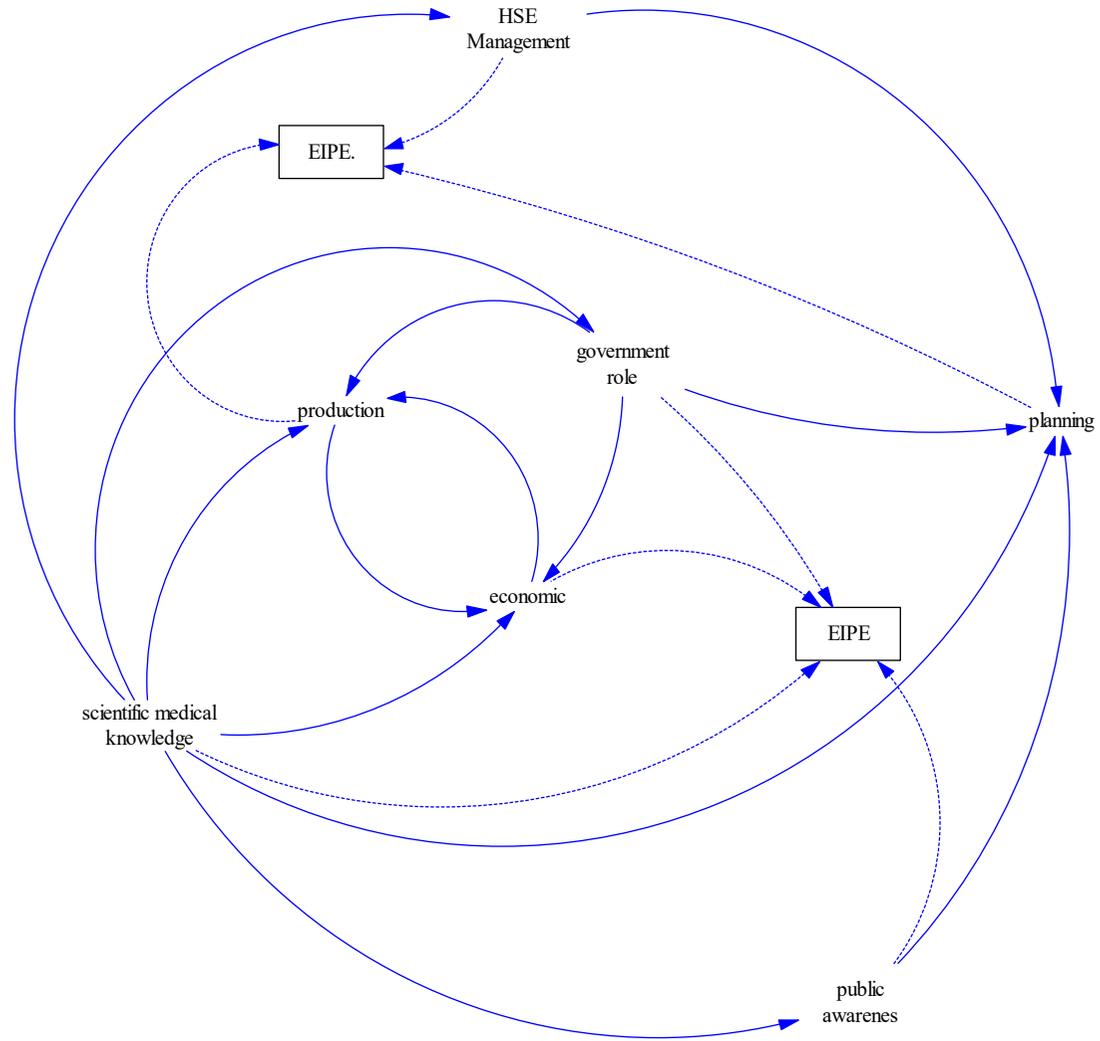


Figure 88: Pair-blended Diagram A

10.4.1 Comments for Pair Blended Diagram A

Figure 88 shows that external factors, such as the government's role, scientific medical knowledge, economics and public awareness, and internal factors, such as HSE management, production and planning, contribute to EIPes. The descriptors for the factors are listed below. Specific PLEIS and HSEMS factors related to the diagram are listed in bold font and included in brackets.

External contributing factors

- Government Role - Regulations, prosecution, monitoring and inspection, approval process for industrial activities
- Scientific Medical Knowledge - Exposure pathway, concentration sources, toxicological effects
- Economic - Viability, local employment
- Public Awareness - community values, risk communication and risk perception
- Production - Technological development, industry best practices

Internal contributing factors

- HSE Management - HSE Management System, management commitment, regulatory compliance, culture and values
- Planning - HSE assessment, cohesive communication, buffer zones, historical conflicts, geographical impact

The approach to HSE depends on the management system, top management's commitment, regulatory compliance and organisational culture and values (**safety culture**). It is influenced by existing scientific knowledge about the negative health impacts caused by poor management of hazardous substances (**industry**).

A key element of an HSE Management System involves the **planning** for an industrial undertaking that may include risk assessment and siting considerations to minimise the risk of exposure to hazardous operations. Other factors that influence the planning phase are regulatory requirements, scientific knowledge and public awareness (**social**). Additionally, existing understanding about the toxicological impact of certain hazardous substances may lead to changes in production methods and public perceptions (**social**).

Government's approval of an industrial proposal (**legal**) affects the **economic** landscape of the area where the manufacturing activity is to be carried out. The decision to support such an industrial investment can be influenced by the existing scientific knowledge about the possible health impacts (**industry**). In addition, the accompanying approval conditions and regulatory requirements can affect both planning considerations and production practices (**implementation and operations**) in order to achieve their compliance.

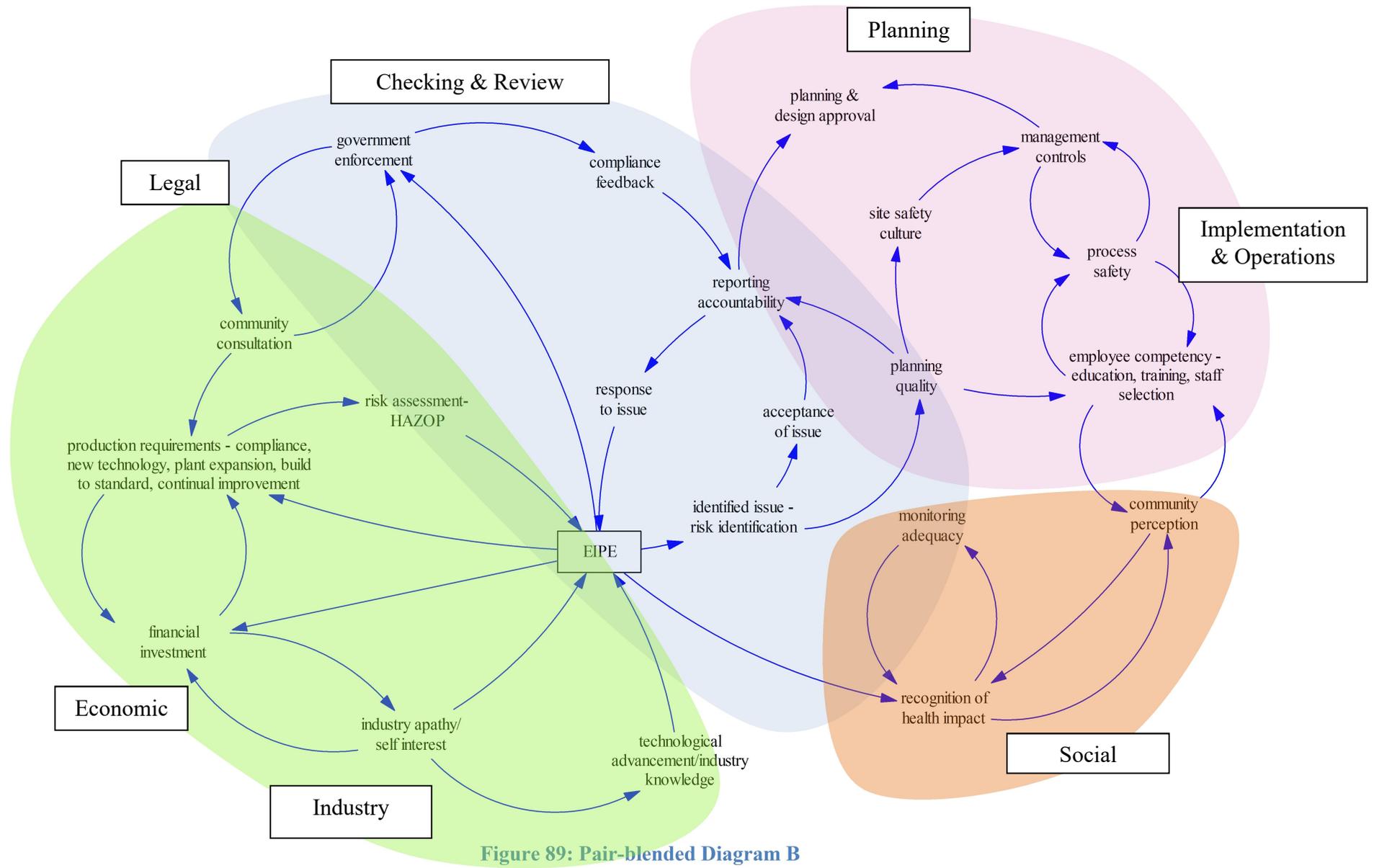


Figure 89: Pair-blended Diagram B

10.4.2 Comments for Pair Blended Diagram B

Figure 89 reveals a categorisation of factors that are closely aligned with the revised conceptual EIPE framework. The internal factors of planning, implementation and operations, and checking and review, and the external factors of industry, economic, social and legal, interact with one another to contribute to EIPEs.

Planning, implementation and operations are influenced by the overall safety culture, which affects the effectiveness of management controls that, in turn, drive safety in the process safety. The integrity of this process safety needs to be sustained by competent employees through education, training and staff selection. **Checking and review** ensure the effectiveness of the internal management system through the feedback cycle: risk identification - acceptance of issue - reporting accountability - response to issue by taking necessary corrective actions. This checking mechanism is commonly triggered by government enforcement activities (**legal**) that provide compliance feedback to organisations. The effectiveness of the environmental and health surveillance programs also forms part of the internal compliance feedback, which plays an important role in the recognition of health impact and in shaping the community's perception (**social**) about the risk of an EIPE.

Industry related factors take into consideration the production requirements such as legislative compliance, build standard, availability of new technology, need for plant expansion and continual improvement. Part of the production planning involves risk assessment such as HAZOP that aims to mitigate the risk of EIPE. These decisions are influenced by feedback from the community, the level of financial investment (**economic**) and lessons learned from EIPE. Also, industry's apathy or interest in preventing EIPEs influences such financial decisions, which can lead to greater technological advancement and better industry knowledge about manufacturing practices.

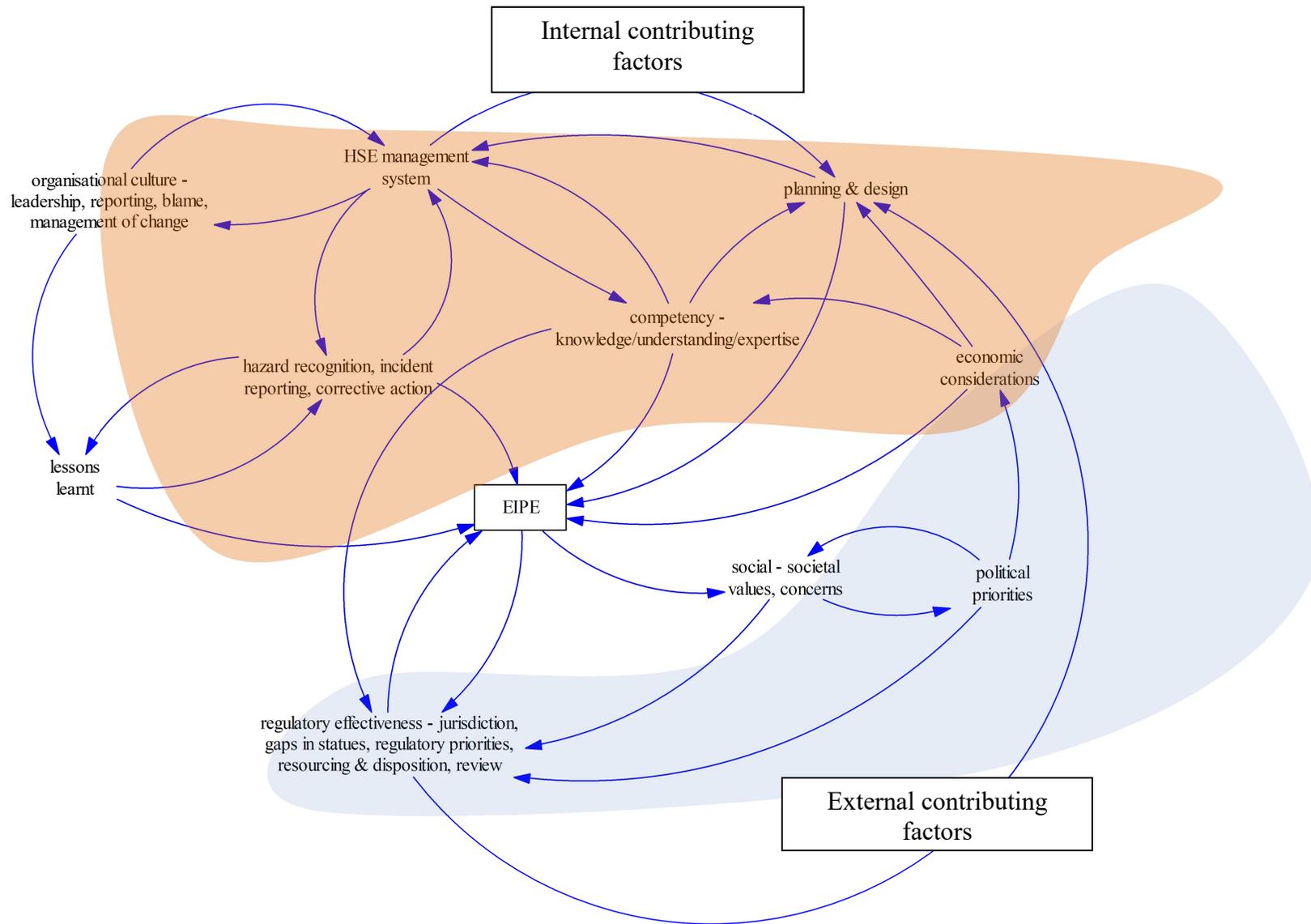


Figure 90: Pair-blended Diagram C

10.4.3 Comments for Pair Blended Diagram C

The factors for Figure 90 fell into two main categories – internal and external contributing factors. Similar to the earlier diagram, these contributing factors aligned well with the conceptual framework for EIPE. Specific PLET and HSEMS factors related to the diagram are listed in bold font and included in brackets.

Internal contributing factors include different elements of the HSE Management System, such as planning and design (**planning**), competency of employees (**implementation and operations**), hazard recognition (**planning**) and organisational culture (**safety culture**), which interact with one another to cause or prevent an EIPE. For instance, a positive reporting culture can result in lessons learnt from the feedback cycle of hazard recognition, incident reporting and corrective actions (**checking and review**). Also, competency of employees affects the quality of planning and effective maintenance of the HSE Management System.

External contributing factors that can interact with one another and with internal contributing factors to cause an EIPE are political priorities, economic considerations, social factors and regulatory effectiveness. For instance, government political priorities (**political**) drive economic decisions (**economic**) such as the investment of more expertise necessary for project planning and regulatory review. Similarly, political priorities create national policies (**political**) that are informed by social values and concerns (**social**), which then feed into subsequent regulatory review to address gaps in statutes, regulatory priorities (**legal**).

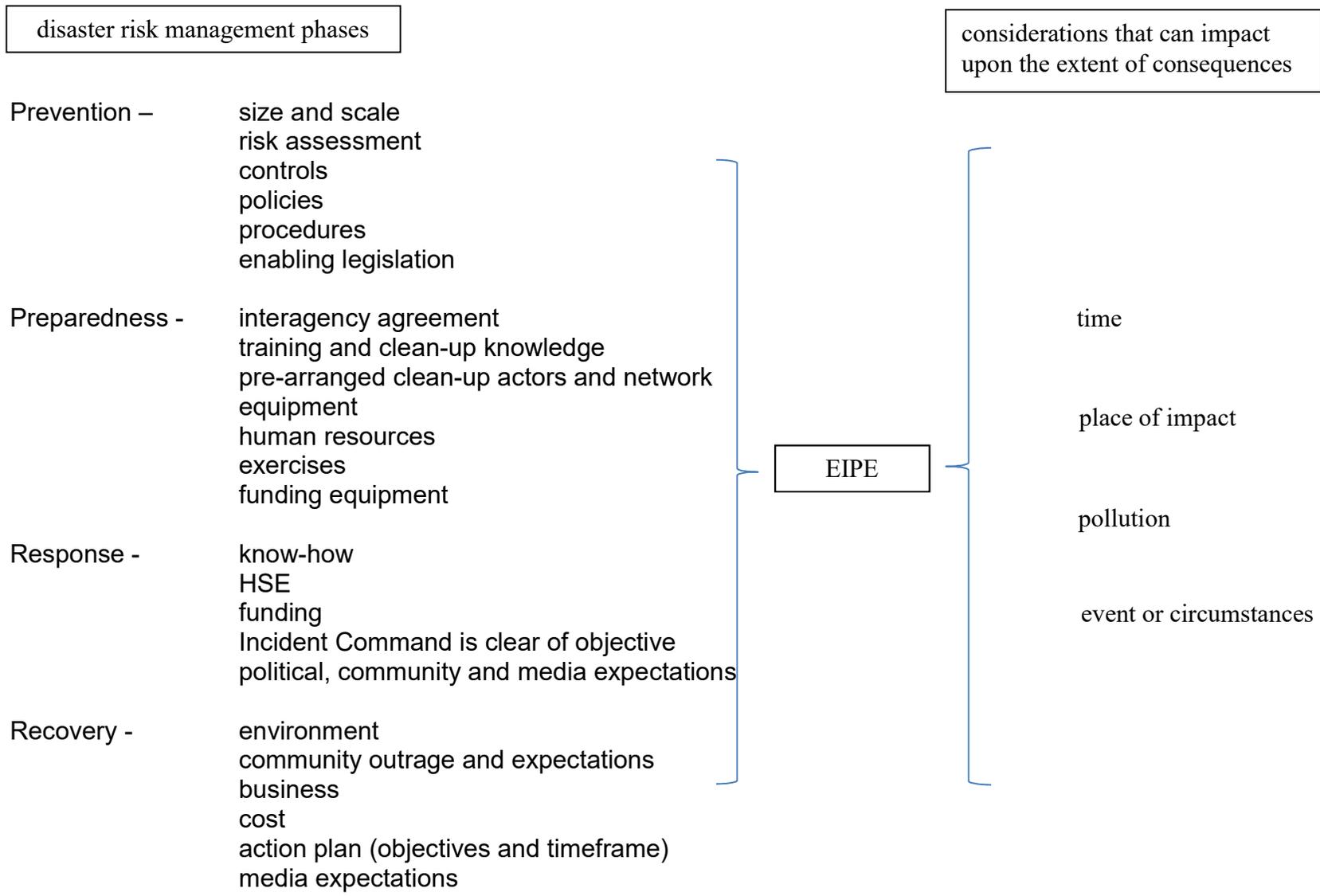


Figure 91: Pair-blended Diagram D

10.4.4 Comments for Pair Blended Diagram D

Unlike the previous influence diagrams, factors identified in Figure 91 were organised into a list by the participants. This is likely to be due to the strong background in disaster management of some participants. Also, it is indicative of the approach commonly taken by organisations when investigating incidents, without necessarily understanding the links and feedback pathways between factors. Consequently, the absence of any connecting links between the factors makes it challenging to identify meaningful feedback loops within the diagram.

10.4.5 Interactions among Contributing Factors

The majority of the experts identified a combination of different external and internal factors that influenced one another in a non-linear fashion. Some examples of these inter-relationships include 'checking' in Figure 89, and 'internal...' or 'external' contributing factors in Figure 90. Similarly, in the EIPE case studies, examples of interacting contributing factors were presented in the CLDs in Chapters 6, 7 and 8.

Feedback loops between contributing factors were a feature of the influence diagrams. For instance, in Figure 88, production takes into consideration financial decisions, whose activity then facilitated business growth and informed production requirement. In Figure 89, HSE issues identified in an industrial activity required the acceptance of lapses in the system, before they were reported to the responsible management for the appropriate response to their resolution. Another example of a feedback loop is the ineffective regulative requirements that contribute to an EIPE, which then requires regulatory review to address any gaps found in the legislation (Figure 90).

Recognition of these feedback loops by the participants supported the feedback loops that were identified during the analysis of the EIPE case studies. All three case studies highlighted feedback loops between factors,

such as economics (Figure 35, Figure 54 and Figure 72), production (Figure 40, Figure 59 and Figure 82) or government (Figure 33, Figure 52 and Figure 69) and EIPE impacts.

10.4.6 Time Delays

Although not explicitly denoted in the paired influence diagrams, time lapses are implicit in several key relationships. For example, there are time intervals between activities with cumulative impacts on other factors, which are not immediately observable. Some of the reasons for these time delays range from the bureaucratic red tape found in government agencies to operational inefficiencies in organisations to progressive capability-building of resources or expertise. Possible time delay embedded within the paired influence diagrams, and the corresponding examples found in the EIPE case studies, are listed in Table 10.3 below.

Table 10.3: Possible Occurrences of Time Lapses in Paired Influence Diagrams and EIPE Cases

Time lapses	Paired A – Fig. 88	Paired B – Fig. 89	Paired C – Fig. 90	Paired D – Fig. 91
Obtaining government approval for an industrial activity	X Figure 68			
From research findings to the acceptance of new scientific medical knowledge that would gradually influence management commitment to prevent newly discovered health impacts	X Figure 36, Figure 55			
From planning to the implementation of actual operational phase	X Figure 57			

Time lapses	Paired A – Fig. 88	Paired B – Fig. 89	Paired C – Fig. 90	Paired D – Fig. 91
From financial investment decision to the commissioning of the enhancement in production technology		X Figure 57, Figure 75		
From monitoring of HSE risk exposure to the verification of cumulative health impacts		X Figure 36, Figure 40, Figure 42		
From acquiring of expertise for the review of legislation to the amendment in regulatory gap			X Figure 34, Figure 53	
Creation of a poor organisational culture or the way things are done in business			X Figure 58, Figure 80	
Growing social concerns from grass root activism to eventual impact of regulatory review			X Figure 34	
Time cited as a general factor that could impact the effectiveness of the PPRR* process				X Figure 91

* *Prevention, Preparedness, Response and Recovery*

10.5 Opportunities for Improvement in EIPE Prevention

The final exercise of the Focus Group required experts to provide input about the most significant contributing factors, including opportunities for improvement, possible implementation barriers and stakeholders' involvement.

Participants in the Focus Group were divided into two groups to discuss one top external factor and one top internal factor from Table 10.2. Results from Appendix G1, Appendix G2, Appendix G3 and Appendix G4 are summarised into current obstacles and issues, and opportunities for improvement in the PLETS - HSEMS conceptual framework (Table 10.4 and Table 10.5).

Table 10.4: PLETS - Current Obstacles and Opportunities for Improvement

	Current obstacles and issues	Opportunities for improvement
Political		
National policies	political priorities that maybe in conflict with HSE needs	
Social		
Community engagement	inadequate community consultation	improved community consultation during EIA and for project sites impacting large residential areas
Legal		
Framework	<ul style="list-style-type: none"> · gaps in policy and legislations – loopholes · different legislation needed to meet several requirements 	<ul style="list-style-type: none"> · improved guidance for planning and operations · uniform legislation for all states and territories · better integration of health risk assessment with EIA process · maintain currency on relevance of legislation
Enforcement and monitoring	<ul style="list-style-type: none"> · lack of competent 'specialist' knowledge for potentially complex and/or high risk applications · time taken to implement opportunities for improvement 	<ul style="list-style-type: none"> · increase technical and scientific knowledge and capacity of those reviewing proposals

	Current obstacles and issues	Opportunities for improvement
Regulator resource	<ul style="list-style-type: none"> · lack of competent ‘specialist’ knowledge for potentially complex and/or high risk applications · difficulty in maintaining technical and corporate knowledge and experience · lack of government resources · time taken to implement opportunities for improvement 	<ul style="list-style-type: none"> · increase technical and scientific knowledge and capacity of those reviewing proposals · industry placement for inspectors under training
Coordination	<ul style="list-style-type: none"> · multiple agencies and stakeholders involved in the planning and approval process · jurisdictional overlap · time taken for lengthy approvals · time taken to implement opportunities for improvement 	<ul style="list-style-type: none"> · clearer lines of approval and more streamlined process · better inter-agency cooperation · better integration of health risk assessment with EIA process

Table 10.5: HSEMS - Current Obstacles and Opportunities for Improvement

	Current obstacles and issues	Opportunities for improvement
Policy and Planning		
Planning for risk management	<ul style="list-style-type: none"> · prohibitive costs found after cost-benefit analysis i.e. not feasible for implementation · fragmented design and contract process 	<ul style="list-style-type: none"> · inclusive and integrated planning process
Implementation and Operations		
Structure, resource and responsibilities	<ul style="list-style-type: none"> · resourcing for HSE roles · lack of time and/or resources · unclear or unreasonably high stakeholder expectations 	<ul style="list-style-type: none"> · engage competent people for the risk assessment and review · systems integration to existing process · user friendly systems and solutions
Operational controls	<ul style="list-style-type: none"> · conflict between policy and action (i.e. safety first until production affected, then short-cuts taken) 	

	Current obstacles and issues	Opportunities for improvement
Checking and Review		
Corrective actions, incident & non-conformance investigations		· review of projects and lessons learnt
Safety Culture		
	· management apathy · poor work culture	· developing positive safety and reporting culture and performance management system · empowering innovation

For the external contributing factors, the emphasis was on establishing political priorities that incorporate HSE requirements, improving community engagement, developing comprehensive legislative framework, strengthening regulatory capabilities, improving regulatory resources and enhancing coordination among government agencies.

For the internal contributing factors, the emphasis was on more integrated risk management approach to planning, providing adequate resources, competent workers and user-friendly system to support the implementation of HSEMS, better alignment of HSE policies and operations, ensuring the review of projects and lessons learned, management commitment to HSE and building a culture conducive to better performance, innovation and safety.

It is clear that there are many areas that need to be addressed to prevent EIPEs. Given more time and resources, the Focus Group could further identify more issues and improvement opportunities for other contributing factors listed in Table 10.2. Nevertheless, findings from the Focus Group align well with the EIPE conceptual framework. Moreover, the wide range of stakeholders that were identified highlights the magnitude of the effort required by a broad spectrum of government, industry and society

representatives. These preventative strategies are considered in the subsequent Chapter 12, as part of the recommendations of this thesis.

10.6 Conclusion

The Focus Group participants were drawn from government, industry and academic professionals and were provided with a shared platform, where valuable insights into the complex and inter-related behaviours affecting an EIPE were explored from a wide range of backgrounds and experiences. This approach to blend different perspectives recognises that interactions among the parts of a complex system cut across disciplinary, industrial and organisational boundaries.

The initial struggles (and in some cases failures) to construct influence diagrams indicated the difficulties that people have in thinking about the behaviour of a system. Different functional responsibilities within organisations, and the tendency to work in silos, reinforce such thinking handicaps. Nevertheless, the participants did undertake the pair-blending exercise, which facilitated shared experiences and identified important feedback loops and possible time lapses. It was evident that their characteristics corroborated the systemic nature of EIPEs. Additionally, several of the current obstacles discussed by the Focus Group were also issues witnessed in the EIPE case studies. Therefore, opportunities for improvement provided valuable into possible strategies for the prevention of EIPE in the subsequent Recommendation (see Chapter 12).

Overall, the Focus Group participants not only identified internal and external contributing factors that made either important or moderate difference to the outcome of the EIPE, but they were also closely aligned with the conceptual framework for an EIPE. Further results and discussion were presented in Chapter 11. It looks at the key themes and contributing factors, EIPE archetypes, leverage points and qualitative models based on the evidence gathered from the Focus Group and EIPE case studies.

Chapter 11

RESULTS AND DISCUSSIONS

11.1 Introduction

Findings from the EIPE case studies (Chapters 6 to 9) and Focus Group (Chapter 10) supported the EIPE conceptual framework by providing a better insight into the complex behaviours of Extended Industrial Pollution Events. An evaluation of the findings from the EIPE case studies will help to identify potential archetypes and leverage points (Section 2.4.5). This evidence will form the basis for the development of qualitative models for EIPEs. The chapter concludes by proposing strategies to mitigate the occurrences of EIPEs.

11.2 Key Contributing Factors and Themes

Data from the Focus Group and the EIPE case studies was analysed and compared. The key contributing factors and themes were identified and categorised into leading external and internal factors (see Table 10.2). Comparing these with the “important” and “moderate” factors that made a difference in EIPE (see Table 9.9) and eliminating those similar factors, the consolidated key factors were presented in each of the internal and external categories (see Table 11.1).

Table 11.1: Consolidated Key Factors from Focus Group and EIPE Cases

Consolidated Factors from Focus Group and EIPE cases	
External Factors	
Political	<ul style="list-style-type: none"> · national policies (GDP growth for the state or nation) · political priorities (focus on trade or growth of identified industry sectors at the expense of HSE)
Legal	<ul style="list-style-type: none"> · legal framework · government roles and functions · regulators' resources and capabilities · government agency coordination and activities (e.g. proposal planning and approval, enforcement and monitoring)
Economic	<ul style="list-style-type: none"> · economic demand and supply · economic contribution and influence; · economic development stage · economic burden (focus on growth over HSE)
Industrial	<ul style="list-style-type: none"> · production technology (efficiency and expansion) · control technology (waste treatment, emission control and monitoring) · industry best practice (e.g. transport and containment of hazardous substances) · industry knowledge of hazardous substances · access to scientific evidence to support best practices.
Social	<ul style="list-style-type: none"> · community engagement or consultation · public awareness and expectation · community acceptance (licence to operate)
Internal Factors	
Policy and Planning	<ul style="list-style-type: none"> · risk management planning · project life cycle planning (safe design, plant, project and process) · identification of legal and other requirements
Implementation and Operations	<ul style="list-style-type: none"> · structure and responsibilities for HSE (e.g. specialists, senior management and board) · consultation on HSE issues · operational controls · training and awareness (knowledge and understanding)
Checking and Review	<ul style="list-style-type: none"> · site monitoring · health/biological surveillance · HSE audit · corrective actions, non-compliance, incident investigation · continual improvement (system, process)
Safety Culture	<ul style="list-style-type: none"> · management commitment · positive reporting culture · leadership

CLD, SFDs and system archetypes are used to provide insight into the underlying issue and for serving as basic structures on which qualitative models can be further developed (Senge 2006). Furthermore, system archetypes enable decision-makers to pinpoint leverage points, which can facilitate the development of preventive strategies appropriate for generic feedback structures found in complex EIPEs (Meadows 1999).

11.2.1 Political

This CLD (Figure 92) builds on the “Limits to Growth” archetype (Kim 2000), where the reinforcing loop (R1) and balancing loop (B1) depict the inter-relationship between growing industry performance due to favourable political priorities and decreasing HSE attention. Also, this CLD shows the influence between the external “Political” factor and the internal HSEMS necessary to raise HSE effort and prevent EIPE incidents.

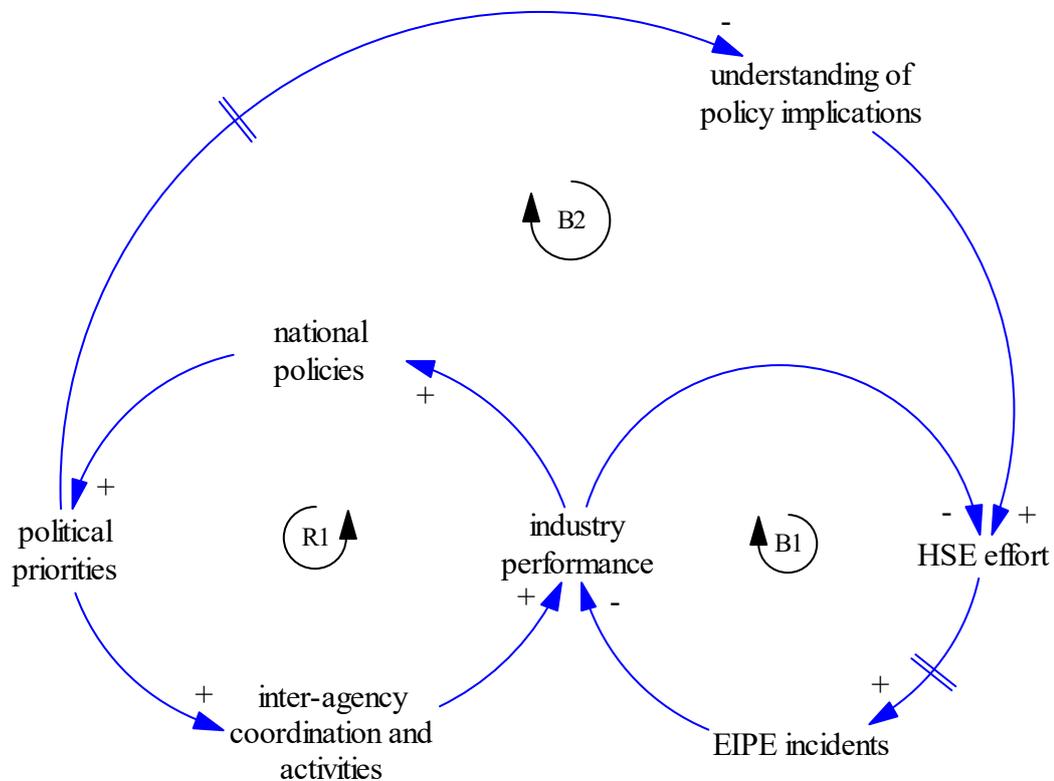


Figure 92: PLEIS - Political

Governmental approvals of proposals or industrial activities are often guided by political importance or priorities, such as the growing chemical industry in Love Canal and Minamata and facilitating the resource trade in Esperance Lead, which are primarily driven by national policies (Government of Western Australia 2017b). Expectedly, inter-government agencies would coordinate their resources to align with the political priorities and to support industry performance. However, such emphasis often comes at the expense of decreasing investment in HSE effort and more EIPE incidents, which impact industry performance (B1). Moreover, the balancing loop (B2) shows that the lag in understanding of the policy implications takes time for an increase in HSE effort, in order to prevent the occurrences of EIPE incidents.

11.2.2 Legal

The CLD archetype of “Eroding Goals” or “Drifting Goals” (Kim 2000) (Figure 93) shows two balancing loops (B3 and B4) trying to close the performance gap between the goal to reduce EIPE incidents and regulatory reform. The regulatory activities necessitate the regulatory interaction with organisations’ HSEMS to prevent EIPE incidents, which reveals the connection between the external and internal contributing factors.

B3 is the balancing loop where legal review leads to changes to the legal framework, regulatory roles and functions (Australian Government 2014). The improved regulatory coordination and activities among government agencies contributes to a reduction in EIPE incidents. As long as the performance gap exists, the desired goal will continue to drive this balancing loop.

At the same time, this performance gap contributes to the long-term investment of regulatory resources and capability by the government agencies to support the desired goal of EIPE incident reduction (B4) (Safe Work Australia 2017). This resource and capability investment can include, but not limited to the hiring and training of competent staff and/or restructuring of government agencies.

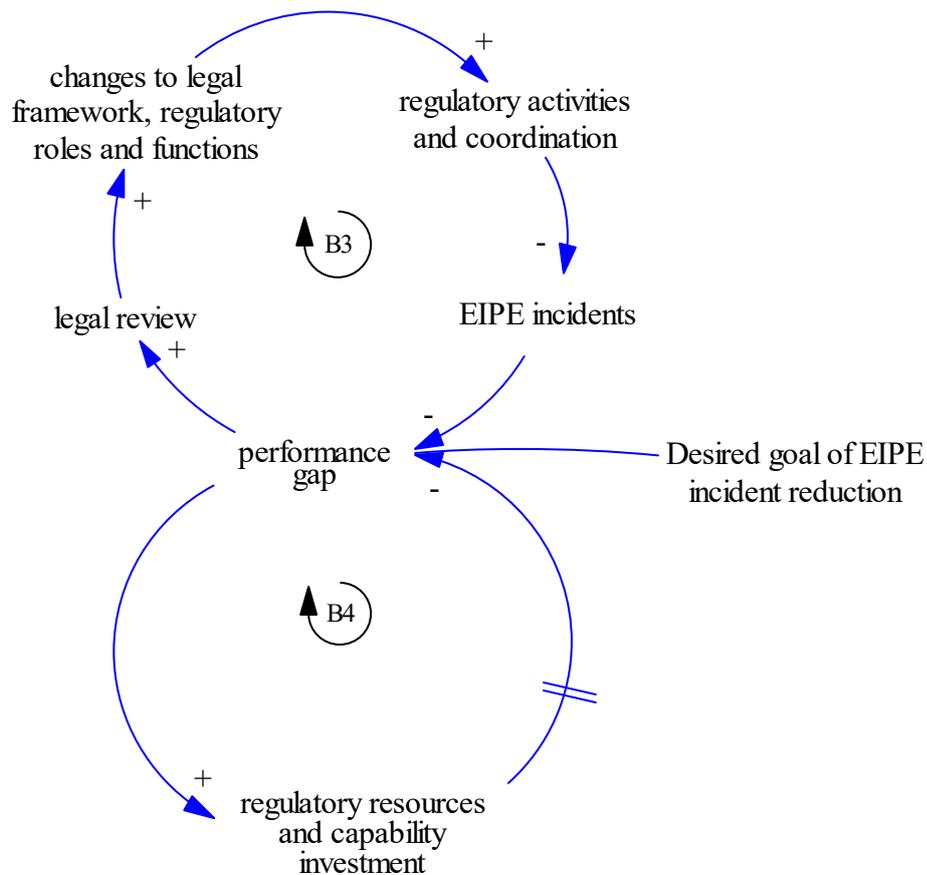


Figure 93: PLEIS - Legal ('Drifting Goals' Archetype)

11.2.3 Economic

An adapted version of the “Limits to Growth” system archetype (Kim 2000) describes a growing industrial activity that increases its economic contribution and influence (R2, Figure 94). Examples related to EIPE cases include the liberal industrial policies that specifically targeted chemical manufacturers in the US and Japan. In Australia, the state and federal governments recognise the important role that the resource industry plays in stimulating the local economy (Roarty 2010). Interaction with the internal contributing factors is through the industrial activity, which requires the integration of HSEMS in any organisation’s operation.

This reinforcing loop is constrained by the demand and supply balancing loop (B5, Figure 94) in response to economic and financial challenges (Warwick 2013). Similarly, the increase in EIPE incidents due to a focus on economy at the expense of HSE can also dampen the demand for more industrial activities, which contribute to the economic burden (European Environment Agency 2014) (B6, Figure 94).

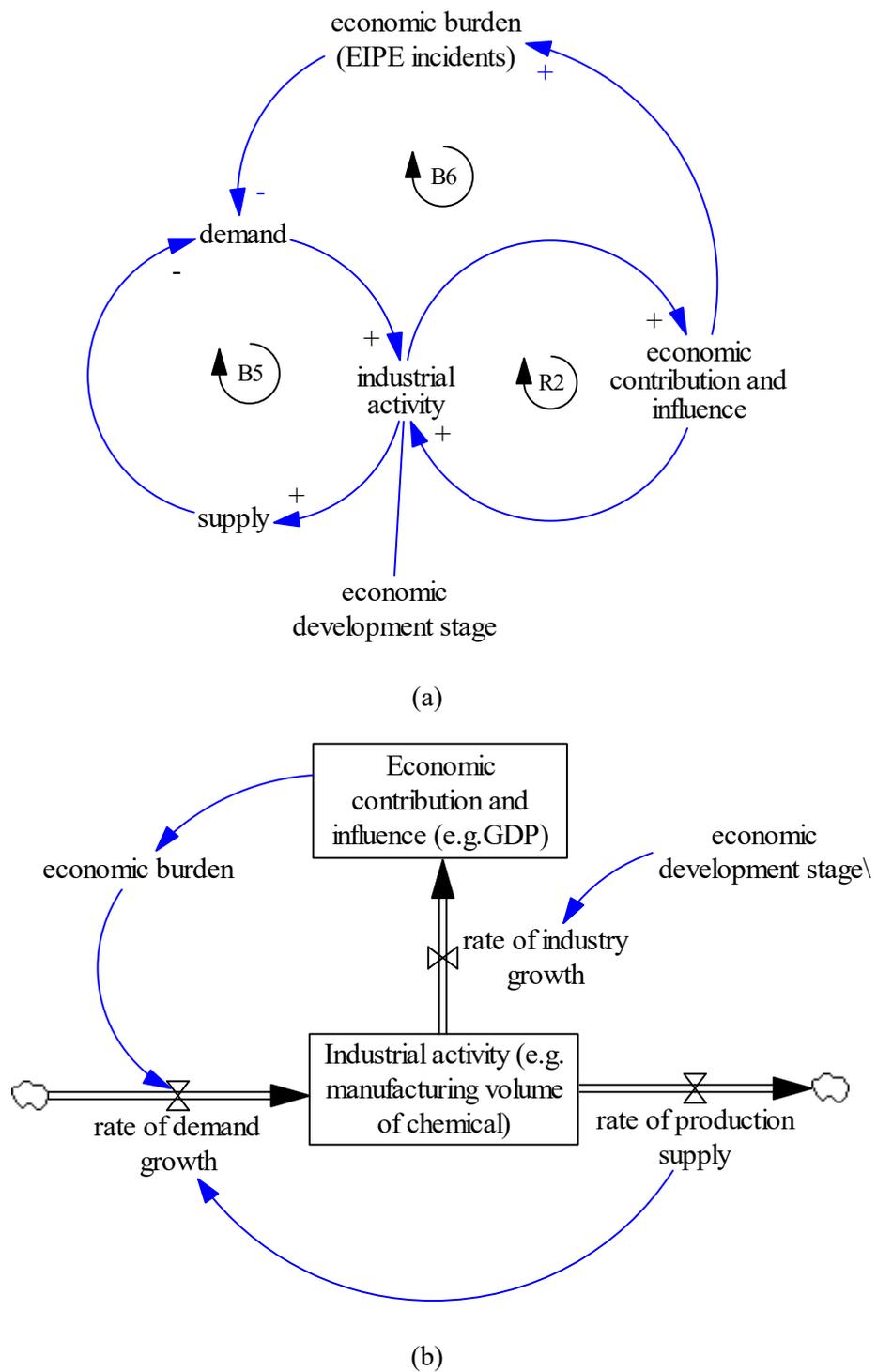


Figure 94: PLEIS - Economic

11.2.4 Industry

An adapted version of the “Limits to Growth” archetype is used for this CLD (Figure 95). Naturally, industry factors interact with internal organisational HSEMS to produce industry best practice and implementation of new technology.

Driven by competition and product demand, emphasis on increasing production performance creates a reinforcing cycle (R5) of leveraging on more advanced technology to achieve better efficiency and capacity (Silva, Styles, and Lages 2017). However, when investment in production technology is not supported by corresponding recognition of the associated long term health and safety risks (e.g. Chisso’s adaptation of foreign technology and Esperance’s design for Iron ore was inadequate for Nickel and Lead handling), HSE can be easily compromised. This focus on only production performance can detract organisations from the need for investment in better control technology (B9). Thus, with access to latest scientific evidence and industry knowledge, HSE can be further enhanced (R4). Increasingly, technological innovation and HSE considerations are considered to be inextricably linked (World Economic Forum 2017).

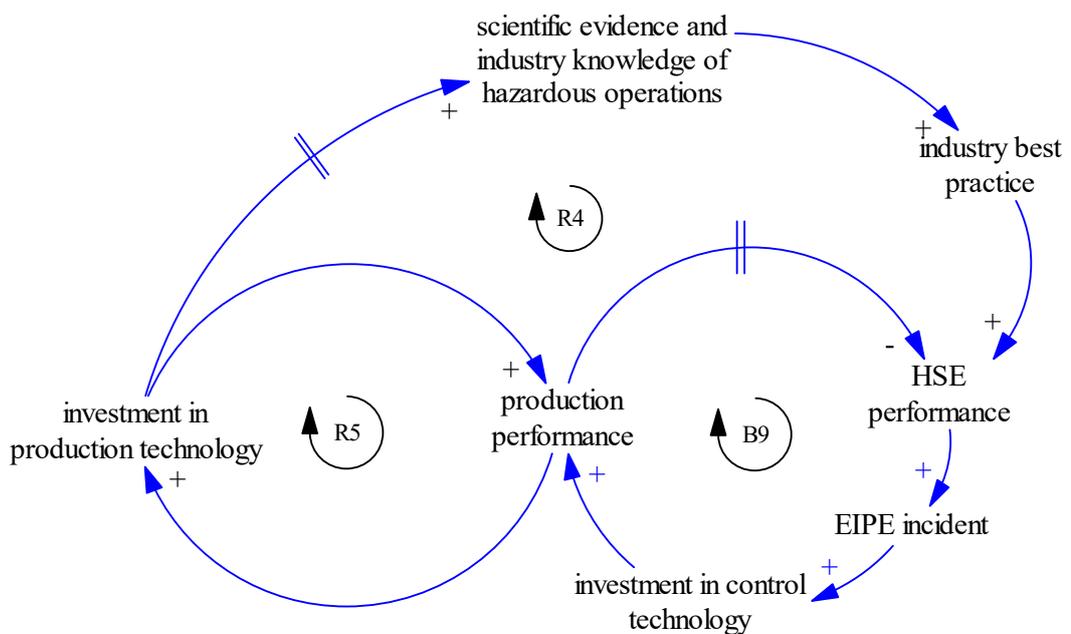


Figure 95: PLEIS - Industry

Although access to scientific findings on hazardous operations can facilitate the development of industry best practices and investment in better control technology, it takes time for industry to accumulate its knowledge regarding the use of more advanced technology (GHD 2009) (B9, Figure 95).

11.2.5 Social

A “Shifting the Burden” system archetype (Kim 2000) is used to depict the inter-relationship of community engagement, public awareness and community acceptance or licence to operate (Figure 96). As in previous external factors, organisational consultation or communication policies, procedures within the HSEMS are required to interact with the community.

Public consultation is critical in addressing community concerns about health and environmental impacts from industrial activities (OECD 2001). Concerns can include incidents, hazardous substance exposure and other industrial related health issues. Minimal engagement with the community may allow organisations to temporarily alleviate some of the issues (B7) and defer the need for more proactive engagement with the affected residents (R3). Such symptomatic solution was a common approach during the early stages of modern economic development, where industrialisation (e.g. Love Canal and Minamata Disease) was accompanied by minimum awareness of the health impacts posed by manufacturing activities.

However, the recurrence of EIPE incidents and non-conformances eventually exposed the falsely perceived licence for organisations such as Chisso and Hooker Chemical to continue with their hazardous operations. This increased awareness has created greater public expectations for organisations and government to prevent the reoccurrence of such incidents (Harvey and Brereton 2014) (B8).

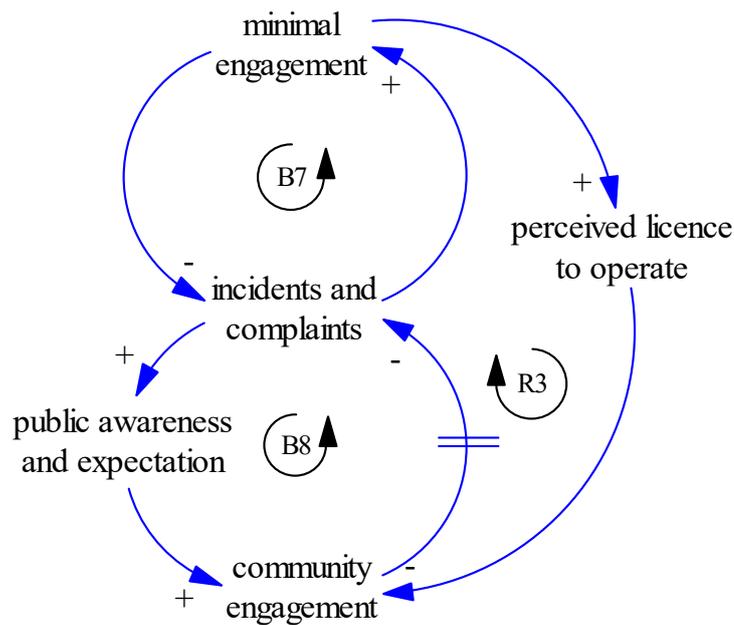


Figure 96: PLEIS - Social ('Shifting the Burden' Archetype)

11.2.6 Policy and Planning

This CLD (Figure 97) is a variation of the “Growth and Underinvestment” archetype (Kim 2000). This archetype presents the need to invest in additional resources to meet current product demand that is driven by national policy and economic factors (B10, R6). This systemic behaviour was evident in all three EIPE case studies where Hooker, Chisso and Esperance Port took different actions to increase business productivity and growth. Besides the external “Political” and “Economy” factors, compliance requirements and investment in production capacity connect with the “Legal” and “Industry” factors as well.

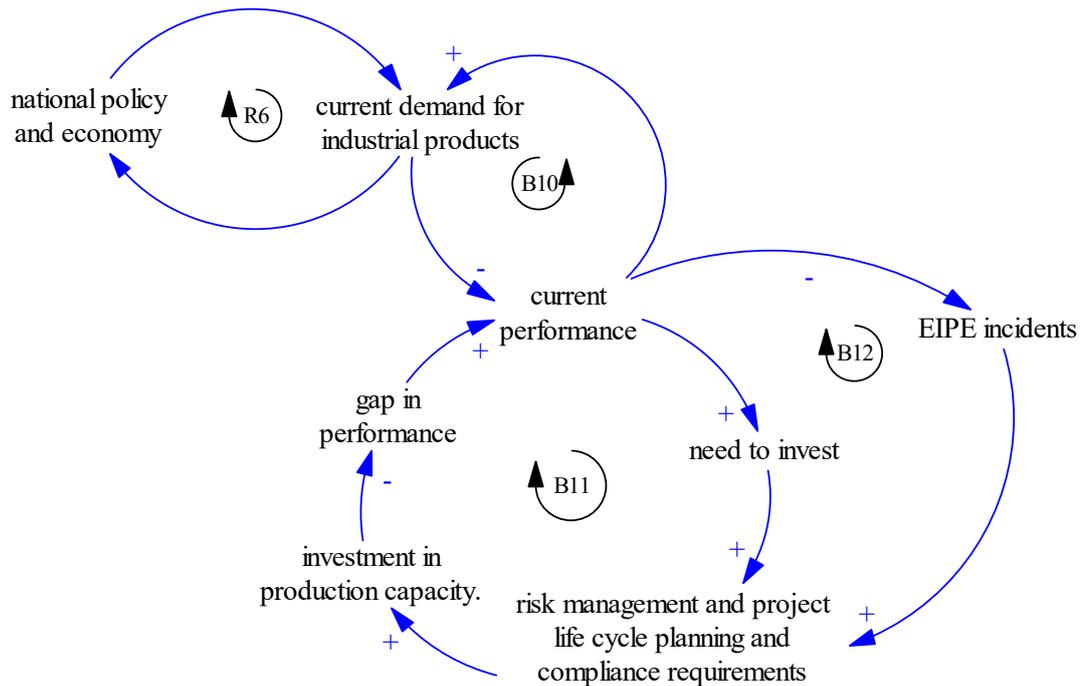


Figure 97: HSEMS - Policy and Planning

Once the business decision is made to increase production performance, whether it is through the improvement of existing engineering process or to acquire new technology, organisations need to incorporate risk management in their project life cycle planning (Szymberski 1997). Naturally, various legal and industry requirements relating to HSE compliance have to be considered as well. The integration of risk management in the early stages of the business decision facilitates the reduction in EIPE incidents, which provide valuable insights to the subsequent risk management planning (National Research Council 2009) (B12).

11.2.7 Implementation and Operation

This CLD (Figure 98) builds on the “Shifting the Burden” system archetype (Kim 2000). Also, proactive consultation and controls (e.g. technological solutions, industry knowledge) can interact with the external factors of “Social” and “Industry.”

Fundamental to any HSE Management System is the systematic and structured approach to managing HSE risks within an organisation (British Standards Institution 2007). However, not all operational controls are equally effective. Those controls that address only the symptoms, such as diverting the industrial waste to another part of the river in Minamata Disease or using inappropriate controls for Lead handling in Esperance Port, of the EIPE incidents are shown in the balancing loop (B13).

According to this archetype, these controls may initially be perceived as effective solutions (R8) for addressing the causes of EIPE incidents when they are actually prolonging the critical need to implement controls that address the root causes (Braun 2002) (B14). Moreover, EIPE case studies showed that decisions to support using the ineffective controls often came from management personnel, who were neither knowledgeable, nor adequately supported by qualified professionals to understand the risk implications of their hazardous operations (B15).

To overcome the implementation of symptomatic controls, proactive consultation with the community, professional associations, research institutions, government agencies and other relevant stakeholders can help to uncover underlying issues contributing to EIPE (Environmental Health Investigations Branch 2001). Such efforts can facilitate the development of better controls for the prevention of EIPE (R7).

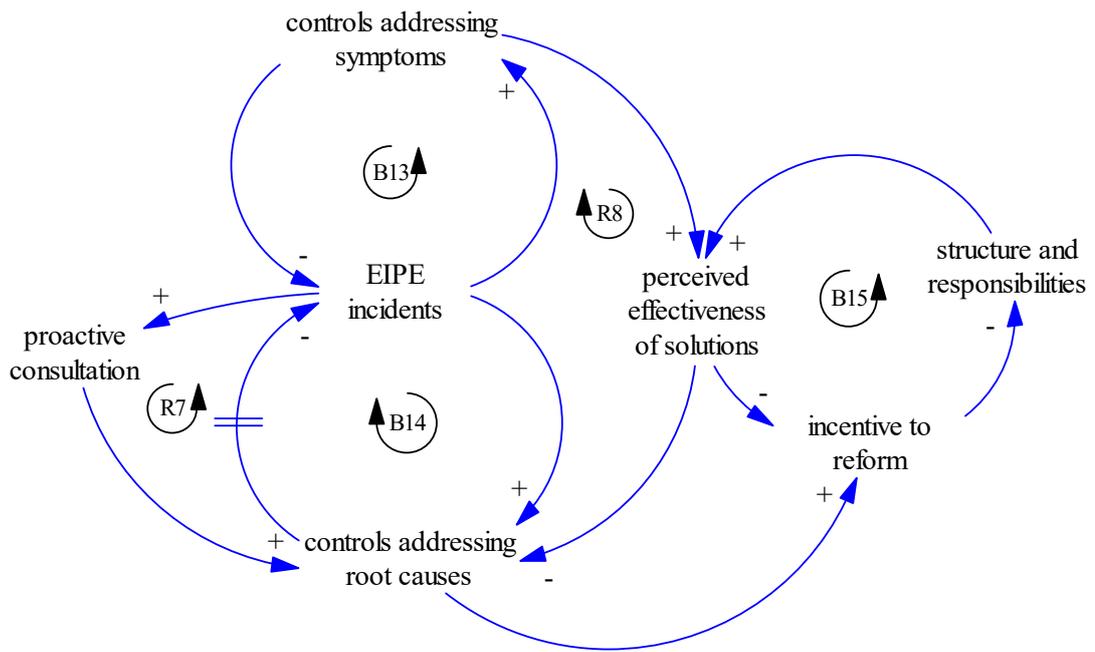


Figure 98: HSEMS - Implementation

11.2.8 Checking and Review

An effective HSEMS requires a process for checking and reviewing its effectiveness. Any gaps or lapses found within the system either through EIPE incidents or HSE audit findings can be addressed by the organisations in two primary approaches described in the “Eroding Goal” or “Drifting Goal” archetype (Kim 2000) (Figure 99). This system archetype highlights the gap between the compliance target and the current HSE performance, which can be resolved by either taking the corrective action loop (B17) or lowering the goal loop (B16). Depending on the nature of the compliance target, whether it is related to legislative requirement of reporting to government agencies or consulting with residents, this internal factor can connect with the external factors of “Legal” and “Social.”

Management of the incidents and non-conformances, such as chemical burns in Love Canal and higher than the permissible level of dust particles in Esperance Lead, requires the reporting and investigation of these events, before the needed corrective actions can be implemented (B17). Instead of

taking the more the resource intensive corrective actions, organisations can be under pressure to lower the compliance target (B16).

Consider the compliance target of “20% reduction in incidences related to chemical spill.” This can be achieved by considering an environmental spill to be a non-reportable operational spill, in order to achieve a closer attainment of the target, as shown in the Esperance Lead case study. Also inappropriate dust monitoring equipment or under-reporting of incidents could provide the false impression of target compliance. This could be due to a lack of knowledge of the impact of chronic exposure to chemicals can be incomplete, but there has been increasing effort to raise public awareness about the long-term health impact from hazardous industrial activities (Kelishadi 2012).

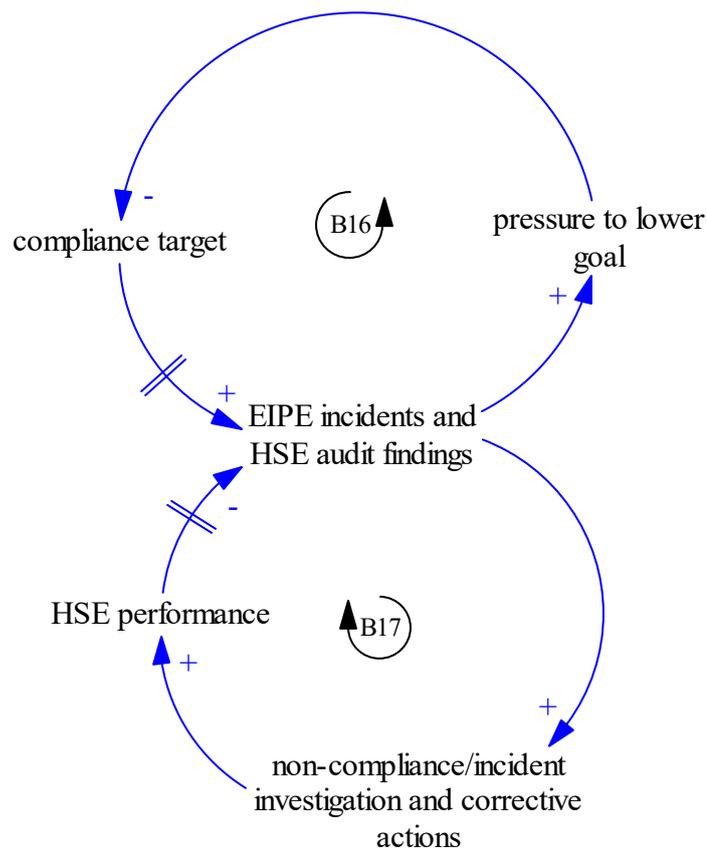


Figure 99: HSEMS - Checking and Review ("Drifting Goal" Archetype)

11.2.9 Safety Culture

Evidence from the EIPE cases and the Focus Group did not reveal a set of universal characteristics for safety culture. As mentioned in Section 10.3, this, together with a lack of uniform assessment criteria, is consistent with findings from studies on organisational behaviour and incident causation. It is difficult to accurately define safety culture, because it is an embodiment of an organisation's shared beliefs, values and practices (Baram and Schoebel 2007; Díaz-Cabrera, Hernández-Fernaud, and Isla-Díaz 2007; Edwards, Davey, and Armstrong 2013a). Nonetheless, safety culture as a broad term that captures factors such as management/HSE commitment, leadership, pro-active engagement with stakeholders, reporting culture and learning culture has emerged from the Focus Group discussion and EIPE cases. For the purpose of this research, safety culture is considered as a subset of the larger organisational culture. Also, safety culture can interact with external factors such as "Legal" for an organisational commitment to legislative compliance, and "Social" for its commitment to a social operating licence.

An adapted "Fixes that Fail" archetype is (Kim 2000) used to describe EIPE incidents and non-conformances, such as the exposure to hazardous substances in Love Canal, Minamata Disease and Esperance Lead, which have occurred on several occasions throughout the organisational activities and yet have never really received effective resolution. Whether it was the Esperance Board not exercising their due diligence when considering the Lead handling proposal, or Hooker Chemical not providing adequate information about the hazardous waste to the School Board, or Chisso's poor engagement with the Minamata's community, lack of a strong safety culture played a role in contributing to the EIPE incidents.

Organisations may implement solutions that seem to yield short term results or continue with the existing operation as long as it does not have an adverse impact to business productivity (B18). Sometimes, organisations may be reluctant to implement more expensive solutions, such as the technologically advanced waste incineration in Love Canal, which can better address

hazardous exposure issues. Yet other times, organisations such as Chisso may exploit existing societal or workplace norms in reinforcing a culture of poor incident reporting. Without resolution to the fundamental problem, the HSEMS eventually breaks down. Often the expansion of the industrial activity magnifies and exposes the ineffectiveness of the existing management approach, which contributes to more incidents and non-conformances (R9). Studies have shown that management commitment plays an important role in ensuring an effective HSEMS and building a strong safety culture (Gallagher, Underhill, and Rimmer 2001; Crutchfield and Roughton 2014).

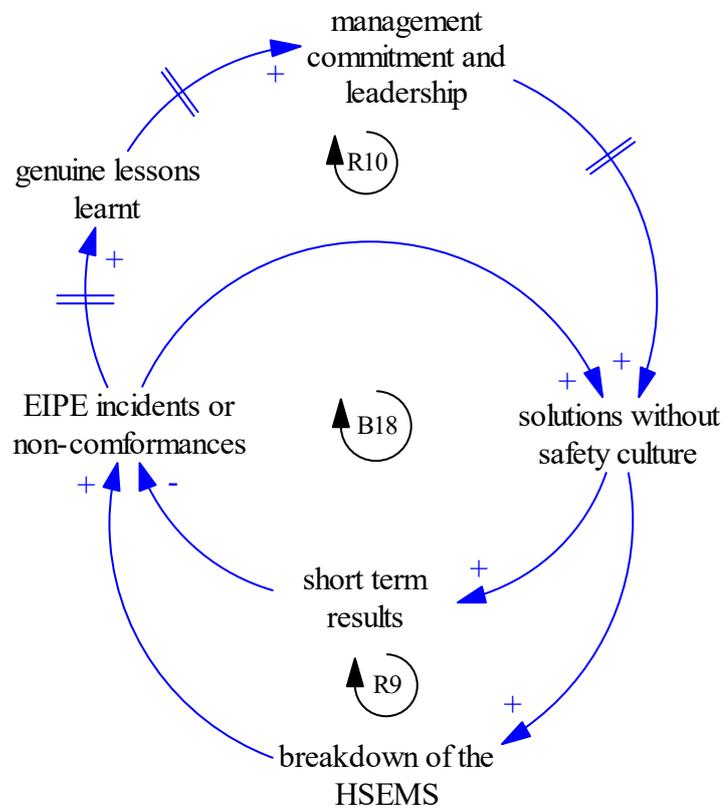


Figure 100: HSEMS - EIPE Safety Culture

The power and influence of change in safety culture is greatest at management level, where visible commitment and leadership to HSE can support organisational solutions in preventing EIPE incidents (Crutchfield and Roughton 2014). Additionally, a strong safety culture can facilitate an atmosphere of trust, which encourages notification of system lapses or “reporting culture” (Reason 1997). Similar to a resilient system that

reorganises and adapts to disturbances, threats and disruptions (Walker et al. 2004; Hollnagel, Woods, and Leveson 2006; Westrum 2006; Hollnagel et al. 2011), a learning culture ensures that corrective actions are implemented on site to address findings of the incident/non-conformance investigation.

11.3 Leverage Points

Using data from the case studies and Focus Group, more comprehensive and holistic strategies for the prevention of EIPes can be developed. Strategies are more effective in addressing systemic behaviours when stakeholders and decision-makers better understand areas in a complex social, political and business environment, where changes could be made to produce more positive outcomes and to prevent policies that could exacerbate the very problems to be resolved in the first place (Sterman 2006). Leverage points provide such opportunities, where a small intervention could mitigate undesirable dynamic behaviours leading to industrial incidents. Meadows (2016) provides a classification of the leverage points, from the weakest to the strongest (Table 11.2).

Table 11.2: Leverage Points Meadows (2016)

Leverage Points	Concept
Numbers	Constants and parameters such as subsidies, taxes and standards
Buffers	The size of stabilising stocks and inventories relative to their flows
Stock and flow structures	Physical systems and the way that they interact
Delays	The lengths of time relative to the rates of system change
Balancing feedback loops	The strength of feedbacks relative to the impacts they are trying to correct
Reinforcing feedback loops	The strength of the gain of driving loops
Information flows	The structure of who does and does not have access to

Leverage Points	Concept
	information
Rules	Policies and laws, including incentives, punishments and constraints
Self-Organisation	The power to add, change or evolve system structure
Goals	The purpose or function of the system
Paradigms	The mindset, out of which the system - its goals, structures, rules, delays and parameters – arises

11.3.1 Numbers

Numbers have the weakest leverage, because they rarely change behaviours and have minimal long-term impacts within a complex system. Consider the stock called ‘number of competent inspectors’. Its increase or decrease is based on the rate of recruitment and the rate of attrition. Adjusting the ‘flow’ rates, or parameters, is only a short-term measure, which does not address the underlying causes of inspector shortage due to overloaded roles and/or talent competition from industry demand. Another common industry practice included instituting a quota system for mandatory reporting of incidents within a specified time period, which does not address the poor reporting culture.

11.3.2 Buffers

A buffer is the accumulation of a stock that is higher than the potential rate of inflow or outflow. Buffers may be able to help a system, but they are often inflexible physical entities that are poor leverage points. Sometimes, they tend to mask the underlying causes of a systemic problem. For instance, increasing the waste disposal capacity or ‘buffer’ by Hooker only temporarily contained the problem of hazardous chemical exposure, which did not consider its long-term treatment. In the case of Minamata Disease, the sea water and river, used by Chisso as buffers to ‘dilute’ the harmful effects of MeHg, only served to delay the inevitable health impact to residents who consumed the contaminated marine life.

11.3.3 Physical Stock and Flow Structures

Plant and equipment such as the Chisso manufacturing plant and Esperance Port facility are examples of physical stocks, and the associated processes are flows. Although these structures can have a significant impact on the manufacturing process, they are considered poor leverage points due to the difficulty in changing them without incurring huge capital costs. These organisations had another opportunity to make their production facilities safer during the expansion or upgrade phase, but they failed to take advantage of it. Therefore, a lack of consideration for safety during the structural design phase (e.g. poor containment design of the conveyor handling system at Esperance Port) can lead to significant operational risks in HSE.

Should the cost of investing in better control technology, as part of the overall HSE management strategy, outweigh the benefits, then government can consider providing financial incentives such as tax breaks for organisations to offset some of the initial capital expenditure. In the long-term, pollution control spending has represented a tiny fraction of the total value of goods produced (US Bureau of the Census 2008). If organisations are aware that there are innovations that can increase productivity while reducing waste, then they will be more likely to implement these innovations. This is another area that the government can support by funding industrial research and development in cleaner technologies. Data from America has shown that the benefits of pollution control investment outweigh the costs of achieving them, by a factor of at least thirty to one (EPA 2011).

11.3.4 Delays

Time delays within complex systems are common features that can distort behaviours among interacting factors (Table 10.3). Intervention strategies designed to reduce the delay between information received (e.g. incident investigation findings) and responses implemented (e.g. recommendations for more effective chemical spill control) can help overcome this. Other interventions designed to reduce delays include: investment in technological

advances in industrial safety controls; and greater partnership between industry and the government health sector in carrying out medical research on cumulative toxicological effects on public health.

To reduce time lapses commonly associated with complex, bureaucratic processes of government agencies, Focus Group participants suggested a more streamlined process for project approval and better inter-agency cooperation in the proposal review process (Appendix G and Table 10.4).

11.3.5 Balancing Feedback Loop

In any complex EIPE, there are multiple feedback loops working in combination to maintain some functional equilibrium among various influencing forces within the system. However, over time, some of the feedback loops could exert more influence than others to produce unintended consequences. Below are some examples of such feedback loops from the EIPE case studies and Focus Group discussion.

The tension between productivity and safety loops (Figure 58, Figure 80) leads to a tendency for organisations in a competitive business environment to focus more on production efficiency than HSE. Thus, to enhance the HSE feedback, there should be a corresponding increased focus on HSE management to ensure that any change in business focus will not lead to a higher risk exposure for workers and stakeholders.

The push to close HSE performance gap between a target and existing situation highlights the need for additional regulatory resources, review of legislative requirements, and investment in more effective controls, risk management planning and corrective actions (Figure 93, Figure 95, Figure 97, Figure 98, Figure 99). Therefore, sufficient budget allocation for critical resources, early recruitment and succession planning for technical expertise and capability-building of competent staff should be part of the EIPE mitigation strategies for both businesses and government.

Another source of valuable feedback that is often overlooked in the face of expediency in policy implementation and business management is the input from residents or communities affected by EIPEs. With growing societal expectations, industry should encourage organisations to consult different stakeholders in their policy development and throughout the entire project cycle (API 2014). Not only will this meet the residents' desire to participate in decisions that affect them, it will also facilitate understanding, promote accountability and trust, and improve decision outcomes (e.g. resident group contributing to better controls for the Esperance Port Iron Ore project) (Figure 96).

Ineffective consultation and unclear expectations among stakeholders are other common system weaknesses mentioned in the EIPE case studies (e.g. Figure 40, Figure 42, Figure 59, Figure 76 and Figure 82) and Focus Group discussion (Table 10.2, External Factor 5 and Appendix G1 and Appendix G4). Additionally, a dysfunctional interaction or an invalid 'licence to operate' that can prevent organisations from achieving their business objectives (IFC 2013). Hence, one of the suggestions from the Focus Group discussion was to enhance consultation during the early project planning stage, especially when it involves proposed activities that could impact a large population base (Appendix G1 and Table 10.4). By adopting a well-structured framework for community engagement, organisations would be able to apply leverage to improve their competitive advantage by managing societal expectations in a better way (EPA 2014; Harvey and Brereton 2014).

11.3.6 Reinforcing Feedback Loop

A reinforcing or positive loop is one in which a behaviour produces a result that influences more of the same behaviour. The relationship between national economic growth and organisational business growth is an example of a reinforcing loop. Instead of allowing an unchecked reinforcing loop to collapse, since no growth can continue forever, strategies could be put in place to weaken it. This can be achieved by introducing another balancing feedback loop to counteract the self-reinforcing cycle.

Notwithstanding some legislative weaknesses in all three EIPE case studies, the corporations involved had to ensure that their industrial activities were carried out in compliance with the respective local HSE laws. Pursuing industrial growth without necessary controls could lead to long-term health impacts (e.g. Figure 33, Figure 38, Figure 52, Figure 94, Figure 95 and Figure 97). Therefore, policy-makers should prevent destructive growth rates by integrating HSE requirements with their political priorities and project approvals (Table 10.4 and Appendix G1).

One practical way to ensure that HSE impacts from a possible EIPE are taken into early consideration is to incorporate Health Impact Assessment (HIA) into the planning decision and approval process. Rather than a single methodology, HIA is an approach that encompasses a combination of procedures, methods and tools by which an industrial development project could be evaluated for its likely health impacts on a population (WHO 2014). This requires multiple government agencies to come together to develop a coherent national policy framework, before implementation of policy decisions at the state and city levels. Internationally, there has been some sharing of best practices in the implementation of HIA as part of policy development and decision-making (National Research Council 2011; WHO 2013).

11.3.7 Integrity of Information Flow

A complex system depends on an array of information to initiate subsequent actions, which, in turn, can affect other inter-related factors. Consequently, a defective or missing feedback can cause the system to malfunction. This is not about enhancing or minimising the strength of feedback, but about delivering information to where it is required. Compared to the inflexible physical stock and flow structures, it is easier and typically less expensive to change information flows.

In the EIPE case studies, there were several examples of missing information flow from the absence of site monitoring in Love Canal and Minamata (Figure 45 and Figure 61) to the unclear dust monitoring requirements or criteria in Esperance Lead (Figure 84). Since the integrity of information flow could not be guaranteed, there was no assurance of implementing the appropriate corrective actions to address the HSE issues. Therefore, organisations need to implement quality assurance framework to maintain confidence in data integrity and accuracy (EPA 2007a; DECCW 2009; EPA 2009; DEHP 2013).

Without information about the severity of the hazardous chemicals, and the technical knowledge to prevent exposure to them, there is little perceived need for action (Figure 95). Therefore, another opportunity for information flow improvement is in the area of more effective transfer of research findings into industrial practices. Well-designed and funded studies are not only sources of technological innovation to improve safety in chemical production, but they also help to increase public and industry awareness about the toxicological impact of certain industrial chemicals (Government 2015; NHMRC 2015).

To harness research as a strategic resource for the prevention of an EIPE, barriers that hinder collaboration between research and industry should be identified and removed. Instead of providing credible information to support business decisions and to educate the public, research findings can be misused as tools for political lobbying. Examples are Chisso's denial that its production caused harmful health impacts and the Love Canal's advocacy groups using self-funded research to disprove the government's findings. Therefore, to maintain the integrity and credibility of information flow, it is critical for research institutions, government agencies and industry to agree on the objectives, process, funding model, resource allocation and management of potential commercial returns of any research conducted (Dodgson. M et al. 2011; Innovation Board AISBL 2012; Dodgson. M, Gann. D, and Phillips. N 2014).

Within organisations, better integration of HSE communication approaches into the overall business processes and system would improve delivery of relevant information. For instance, it would be beneficial to install user-friendly solutions that enable better access to HSE data and a better incident reporting culture (Appendix G1, Appendix G2 and Table 10.5).

11.3.8 Rules of the System

Rules of the system can be a powerful leverage point. They include the relevant Acts, Regulations, Code of Practices and policies, and their associated penalties for non-compliance, which define the scope, boundaries and degree of freedom within a market economy. Health, Safety and Environmental laws are in place to ensure that organisations carry out their legal obligations to protect the health and safety of employees and the public. However, the EIPE case studies have shown that gaps in the legislative framework could contribute to the occurrence of industrial incidents (Figure 93, Sections 6.3.4.1, 7.3.2 and 8.3.2.1).

Regulators and government agencies need to periodically review and amend the legislation to reflect changes in economic forecasts, policy directions, market conditions, technological capabilities and societal expectations. The most effective regulatory and governance frameworks, and a nationally consistent environmental management regime, should include up-to-date standards (e.g. chemical exposure standards) that are aligned to the latest scientific studies and understanding about hazardous exposures (Rosenfeld and Feng 2011).

Since the complexity of most regulatory landscapes is often the result of different stakeholders being involved in layers of inter-governmental arrangements, any amendments to the legislation should seek the engagement of industry, non-government organisations, unions, consumer groups and local communities, before parliamentary approval (SWA 2012a, 2012b; WorkSafe 2014).

11.3.9 Power to Evolve

The resilience of a complex system depends on its ability to self-organise or to change its structure and systemic behaviours. Therefore, a self-organising business, institution or government agency is one that is able to learn from incidents and continually improve, which is also the principle of an effective business management system discussed in Chapter 5. Unfortunately, the PDCA, or Deming, Cycle is perhaps more widely discussed than it is practised.

The chosen EIKE case studies showed that stakeholders did not learn from reported incidents of exposure to hazardous substances so that improved control measures could be implemented to prevent their reoccurrences. Furthermore, the Focus Group highlighted the significance of reviewing and learning from past projects during the organisational planning and design stage (Figure 99, Table 10.5 and Appendix G4).

By sharing lessons learnt from EIKEs through associations such as the Chemical Society of Japan (CSJ 2014), Association of Manufacturing Excellence (AME 2014) and Minerals Council of Australia (MCA 2014a), organisations can strengthen their best practices and mitigate the occurrences of EIKEs. Other collaborative networks to facilitate the interpretation of scientific and technical information, such as the Global Harmonised System for chemical classification and labelling, and the OECD Cooperative Chemicals Assessment Program, can be established for countries at the international level (ILO 2009; UNECE 2014).

11.3.10 Goals of the System

The goal of any system is a strong driver of behaviour and a powerful leverage point. The goal in the business environment is typically to maximise returns to shareholders. From the EIKE case studies, it was shown that underlying factors of hazardous substance management were often tied to the dynamics of a globalised market economy. For instance, the demand for

lead carbonate in Australia, acetaldehyde in Japan and various organic chemicals in the US incentivised organisations to exploit the abundant natural resources in these regions. As a result, organisations were motivated to develop their strategies and implement their operations with the ultimate goal of increasing their profit margins.

If management is rewarded for both financial and safety performances, rather than the organisation's profitability alone, then all the activities would revolve around that new direction and the systemic behaviours generated would certainly be very different from those in the alternative example. Increasingly, safety is often part of the corporate sustainability goal, where organisations not only espouse their vision in terms beyond financial targets, but also embed safety goals into high-level monitoring and reporting (DOW 2016). Globally, there is a growing trend for health, safety and environment performance to be taken into account as part of a company's triple-bottom-line reporting (GRI 2015b).

For projects with risks of substantial public health impact, such as the Love Canal, Esperance Lead or Minamata Disease, the local approving authorities should consider increasing the weight of public health considerations compared to economic criteria. Increasingly, government agencies are investing in more integrated development, where the wider economic, social and environmental implications of policy decisions are considered (UN 2009; Infrastructure Australia 2010; RET 2011; MCA 2014b; NACFAM 2014; Organization of American States 2014). Beyond the domestic scope, government agencies in various countries can coordinate their activities to implement regional and global initiatives that have a consistent policy approach for mitigating HSE impacts from potential EIPEs (ICCM 2012; IFCS 2014; SAICM 2014).

However, sometimes powerful business lobby groups can put pressure on governments to fast track the approval process for a project, without carrying out due diligence to fully understand the HSE implications from the proposed industrial activities. Indeed, the Focus Group highlighted political priorities,

such as the export push for locally manufactured chemicals, as one of the most significant contributing factors that could affect HSE considerations.

11.3.11 Mindset for the System

According to Meadow, mindset or paradigm is the most powerful leverage point, because it influences all other leverage points mentioned earlier, or lower down the system (Meadows 2008). Behind the structure and goals of a system is usually a fixed mental attitude that predisposes a person's response in driving certain actions. Oftentimes, a person may not be aware of the powerful impact his/her mindset has on his/her behaviour (Senge 2006). Collectively, a community of shared beliefs is known as the society's paradigm, which is the genesis of most systems (Meadows 1999). A paradigm shift can, therefore, occur by changing assumptions that lead to different directions in systemic behaviour.

The dominant mindset of the chemical industry used to be that natural resources exist for organisations to exploit, with little consideration for workers' and communities' health and safety. Nonetheless, with the high profile EIPEs such as Love Canal and Minimata Disease, a change took place in the societal mindset toward harmful industrial operations. This created pressure on organisations to invest in technology and strategies and to implement better legislation and enforcement, which could mitigate the occurrences of such incidents with impacts upon public health and the environment.

Within an organisation, the change in cultural mindset to improve safety seems so promising, yet so elusive. Transforming deeply embedded organisational values, assumptions, behaviours and attitudes requires a long time. In the Focus Group discussion, experts referred to management commitment and safety culture as one of the significant contributing factors to EIPEs (Table 10.2, Internal Factor 3). From the Esperance case study, it was evident that employees of Esperance Port reported exposure incidents during the handling of heavy metals, but they were often not followed up by

management, who could have put in place measures to improve the situation. Such disparity between management's and employees' commitments to safety is common, even among organisations with developed HSE Management Systems. Specifically, 37% of CEOs and board directors did not believe HSE should be an agenda item for board meetings, and 14% of CEOs and board directors expressed that HSE was not an integral part of corporate governance within their organisations (AIM 2011).

Given that top management sets the tone and culture of HSE commitment, it is important that they take ownership of HSE governance and performance. Also, HSE should be discussed at a strategic level and be well-integrated into corporate strategies (Lo 2012). Essentially, positive HSE performance and the ability to mitigate EIPEs depend on organisational commitment from the top (Mearns and Yule 2008).

11.4 Qualitative EIPE Models

The key contributing factors, themes and archetypes became the basis for the development of the external and internal qualitative models. These models are examples of the many ways in which archetypes and CLDs can interact with one another to form a more holistic picture of a larger complex system. As much as possible, factors and naming conventions used in previous CLDs and archetypes were preserved, with only minor changes to prevent duplication of variables.

11.4.1 External Qualitative Model

External contributing factors - "Political," "Legal," "Economic," "Industry" and "Social" - are connected by various balancing and reinforcing loops sharing a common EIPE impact (Figure 101). Each contributing factor consists of a combination of causal diagrams and system archetypes discussed in detail earlier (see Section 11.2.1). Connections between the archetypes and CLDs have been added to provide a more comprehensive model. These external factors interact with the internal factors (Figure 30), represented by the downward arrow to "HSEMS."

The reinforcing growth of national policies and industry performance (R1) is limited by the balancing loop of HSE performance (B1). Unfortunately, implementation of the national policies is not always accompanied with good understanding of their implications to HSE performance (B10). The effectiveness of the legal review and inter-government coordination, which is a consequent of the national policies, impacts the extent of the government's performance gap (B2). Poor coordination among government agencies can delay the approval of industrial projects. Bureaucracy and efficiency rarely go together, especially when there is duplication of roles and functions among some government agencies. In contrast, the clarity of government roles and functions increases regulatory performance. Hence, the quality of inter-governmental coordination directly influences the delivery and outcome of regulatory activities (DIIS 2016; NICNAS 2016).

The scope and demand of the regulatory activities can also place pressure on the inspectors when carrying out their enforcement activities. To address this performance gap, investment in critical resource is needed to support effective regulatory activities (B3) and engagement with the community (B4).

Additionally, minimal engagement with the community is necessary to reduce incidents (B6) and to provide industry with the licence to operate its activities (R2). Indeed, effective stakeholder engagement helps to increase community understanding and support for the organisation's goals and government policies, and to improve transparency and accountability, while also building confidence on proposed initiatives to reduce EIPEs (Bremmer and Hanna 2009; Harvey and Brereton 2014).

The industry activity, driven by the market supply and demand of products (B7), reinforces its positive contribution to the economy (R3). Similarly, industry determines the appropriate level of investment in production technology according to the supply-demand cycle of the market (B8). Naturally, investment in production technology has a corresponding improvement in production performance (R4). Although this is a simplistic

representation of a more complicated economy at work, it highlights the importance of the connection between economics and industrial activities (China Business News 2011; Reuters 2014; Morawietz et al. 2015).

As could be seen from the EIPE case studies, an increase in production performance was often achieved at the expense of decreasing HSE performance. Therefore, there needs to be a similar investment in control technology and increase in industry knowledge from lessons learned, in order to prevent EIPE (R5).

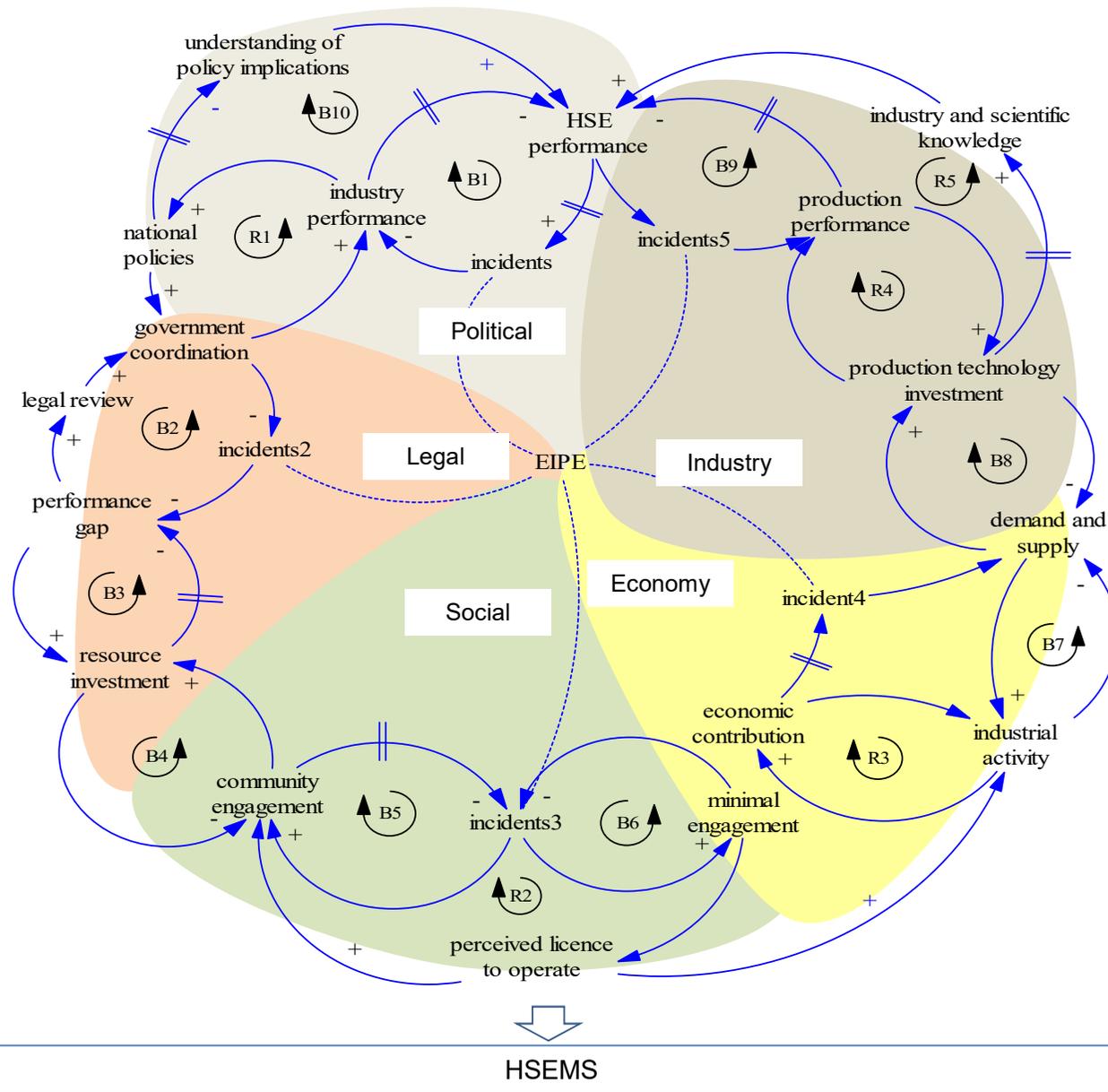


Figure 101: EIPE External Qualitative Model

11.4.2 Internal Qualitative Model

The internal qualitative model (Figure 102) consists of the HSEMS factors of “Policy and Planning,” “Implementation and Operations” “Checking and Review” and “Safety Culture.” These internal factors interact with the external factors (Figure 30), represented by the upward arrow to “PLEIS.” As with the external qualitative model, key contributing factors and themes that were identified from the EIPE case studies and Focus Group discussion were used to develop causal diagrams and system archetypes (Sections 11.2.6 and 11.2.9).

Three major archetypes - “Growth and Investment,” (R1, B1, B5) “Shifting the Burden” (B7, B8, R4) and “Eroding Goals” (B2, B3) – corresponding to the key HSEMS factors form the basis of this model. Other balancing loops (B4, B6, B9) and reinforcing loops (R2, R3) are included to connect these archetypes into a more holistic model.

Organisational decisions to expand production and improve business productivity require the integration of risk management into the planning process (B5). With early risk management consideration for production investment, likelihood of EIPE incidents will reduce and lessons learned from them through proactive consultation will feed into the subsequent risk management planning (B4, B6). Furthermore, a positive safety culture ensures that there is management commitment to identifying obstacles to incident prevention and to extract valuable lessons from them (Probst and Graso 2013; Russell Vastveit, Boin, and Njå 2015).

Similar cycle of continual improvement and lesson learned supports the implementation of effective controls (R2) and corrective actions (R3) in the “Implementation and Operations” and “Checking and Review” of the HSEMS. This organisational behaviour is influenced by both the HSE performance and consequences of any EIPE, because of the fear of adverse business impacts such as regulatory penalties and/or reputational damage.

Essentially, the transfer of diligent investigation findings into corrective actions should also lead to better safety performance and prevention of EIPE (Love, Goh, and Smallwood 2012).

Besides the impact safety culture has on “Policy and Planning” and “Implementation and Operations,” of the HSEMS, safety culture also influences the structure and responsibilities of the workers and “the way things are done” in the organisation (B9). Visible leadership and management commitment are important behavioural components, which set the tone for the safety culture of an organisation (Crutchfield and Roughton 2014). Indeed, safety culture is an important leverage point that influences the successful outcome of business and safety performance (Hesketh 2012; Rollenhagen 2013).

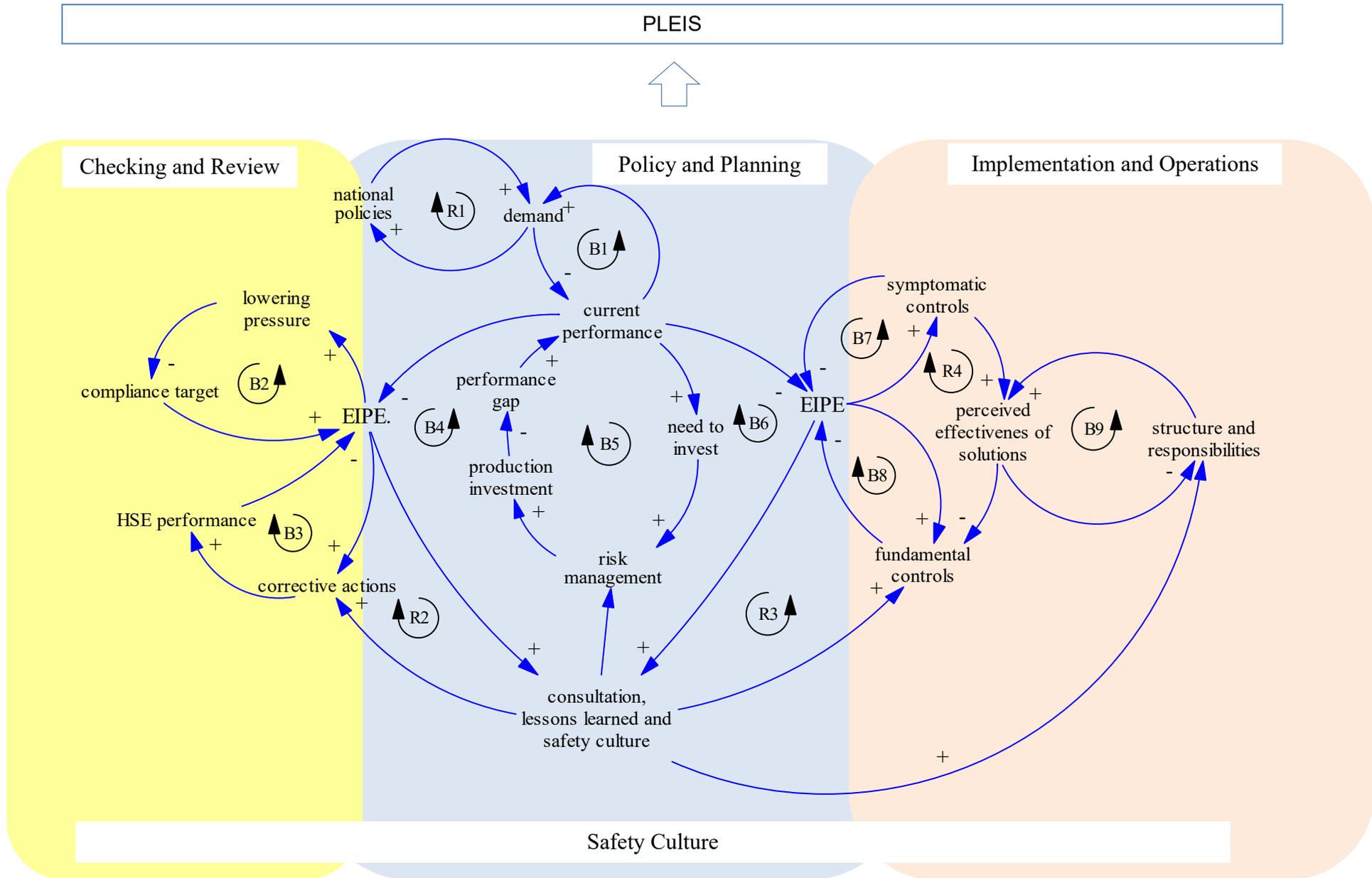


Figure 102: EIKE Internal Qualitative Model

11.5 Conclusions

Analysis of the data from the Focus Group and the EIPE case studies showed that the key contributing factors and themes aligned well with the enhanced conceptual framework where the “Industry” factor included scientific knowledge, industry best practices and technology used for industrial activities. Added to the HSEMS was the “Safety Culture” factor, which considered organisational characteristics that support an effective HSEMS.

CLDs used in the analysis have shown to be valuable diagrammatic tools in visualising the inter-relationships between these external and internal contributing factors, which would have been extremely challenging to replicate using linear causation models. Also, key system archetypes are able to provide further insight into the common characteristics of the underlying issue found in EIPE. These insights enable decision-makers to pinpoint leverage points, which could facilitate the development of preventive strategies appropriate for generic feedback structures found in complex EIPEs.

The dynamic forces of growth were evident in the reinforcing loops of “Limits to Growth” archetypes found in the “Political,” “Economy,” “Industry,” and “Policy and Planning” factors. Working against these vicious cycles were counteracting forces found in the balancing loops of the system archetypes such as “Eroding Goals,” “Shifting the Burden” and “Fixes that Fail.”.

Dominant reinforcing loops supported by national policies that favoured aggressive industrial growth, often incentivised organisations to focus on production expansion at the expense of HSE performance. Several reasons could be attributed to the ineffective or defective balancing loops designed to constrain such reinforcing loops. They included focus on production over HSE, using ineffective controls, lowering of the HSE compliance target, not

learning from lessons, lack of management commitment and other contributing factors that eventually eroded the performance of HSE.

These archetypes and CLDs can be combined to provide more holistic qualitative models, which show that EIPEs are results of several inter-connecting balancing and reinforcing loops. Therefore, strategies to preventing these incidents require the examination of EIPEs from the systemic perspective, rather than the individual components such as workers, equipment or procedures. While fundamental control solutions may require more investment of resources and time, they are often more effective in addressing the underlying issues contributing to the EIPE. Furthermore, effective HSEMS cannot be sustained without management commitment. In fact, a mindset geared toward building a strong safety culture is one of the most powerful leverage points, which ensures organisations do not pursue business strategies at the expense of HSE performance.

Chapter 12

RECOMMENDATIONS

One of the most important objectives of this research was to develop strategies to prevent the occurrences of EIPEs. The review of the existing understanding of incident causation in Chapters 1 to 4, the application of the conceptual framework for EIPE case studies in Chapters 5 to 8. The case study comparison in Chapter 9 and the evaluation of the systems approach Focus Group in Chapter 10 provided better insights into the underlying EIPE structures and behaviours. More significantly, they resulted in a series of systems archetypes depicting key aspects of system behaviour as related to the internal and external factors of EIPE. This analysis, reported in Chapter 11, enabled the identification of leverage points which form the basis of the final recommendations in this chapter.

The following recommendations will help to mitigate systemic behaviours and structures that could lead to an EIPE. They are listed in order from the global level to the organisational level. Also, leverage points are identified as the subheadings for these recommendations.

12.1 Global Level

- *Changing the “Rules of the Game” - develop global partnerships with key market stakeholders in driving sustainable development.*

EIPE case studies showed that organisational activities did not operate in a vacuum, but were affected by global market forces and demand for industrial products (see “Limits to Growth” archetype, Figure 94). An initiative proposed by the United Nations and funded by the European Commission is encouraging the investment community to take a wider and longer look at the key drivers of industrial and economic change. Due to the changing landscape in our understanding of fiduciary duty, Principles for Responsible Investment (PRI) recognises the need to approach investment beyond

merely economic considerations and acknowledges that the “generation of sustainable returns is dependent on stable, well-functioning and well governed social, environmental and economic systems” (UNEP 2015; UNPRI 2015).

This approach targets two of the most effective leverage points. The alignment of the societal and investment values changes the paradigm of the investment aim. By altering the ‘rules of the game,’ government agencies, industries, communities and other key stakeholders will have to develop strategies to adapt to market forces that are no longer determined by only financial outcomes, as seen in the “Growth and Underinvestment” archetype.

- *Increasing the “Integrity of Information Flow” - enhance global collaboration in the development of common principles, standards, procedures and policy guidance.*

There have been several developments at the global level to share best practices and to develop a common framework for the prevention of industrial incidents. For instance, the United Nations Environment Programme (UNEP) established an international initiative called “A Flexible Framework for Addressing Chemical Accident Prevention and Preparedness”, which aims to help countries develop and implement effective programs for the prevention of industrial incidents (see “Limits to Growth” archetype, Figure 95) (UNEP 2015). Besides providing critical guidance, more case studies or success stories need to be developed, so that other nations will be encouraged to adopt a similar roadmap for the prevention of industrial incidents (ADPC 2013).

Another United Nations (UN) initiative is the development of the Globally Harmonised System (GHS) of classification and labelling of chemicals to promote the communication of consistent information about hazardous substances (UNECE 2015). This also provides a basis for harmonisation of regulations on hazardous substances at national and state levels within various countries. GHS implementation is an on-going global partnership between governments, businesses and communities to facilitate transitions to

GHS-based systems. Key to the success of this internationally adopted standard is the development and enforcement of national legislations to make GHS a local requirement. Furthermore, a whole-of-government approach should be taken to support the implementation of GHS, especially when it affects policy development, program management and service delivery across multiple government agencies.

Besides specific global standards for chemicals, an independent group of international organisations has developed the Global Reporting Initiative (GRI). This is a standardised reporting framework to promote public reporting by organisations of their economic, social and environmental impacts. This is to create a common language for organisations and stakeholders, so as to facilitate greater transparency and accountability in regard to industrial activities (GRI 2015a). Although organisations still face challenges in uniting stakeholders who have different views on how this GRI should be implemented, sustainability reporting holds the potential to becoming a mainstream business practice (EY 2014).

There is a trend towards standardisation of principles, standards and guidance for industrial activities, in order to facilitate the sharing of best practices and to promote better comparability of industry performance globally.

12.2 National Level

- *Changing the “Rules of the Game” - develop a coherent national framework, policies and guidelines for the prevention of EIPEs.*

The EIPE case studies and the Focus Group identified the importance of a comprehensive and up-to-date legislative framework in preventing EIPE occurrences. The ILO’s Occupational Safety and Health Convention, 1981 (No. 155), the Occupational Health Services Convention, 1985 (No.161) and the Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187) provide a framework for countries to develop and implement

their national policies, regulatory programs and supporting services (ILO 2015). While these Conventions may not be enforceable at the international level, many different countries report to the secretariat about their progress in adopting them.

Government can positively influence HSE through a regulatory framework that is flexible, responsive and adaptive to the changing nature of job roles and work environments. This can be achieved through periodic review of the existing legislation, policies and regulatory practices, which can be tiered, complicated and ineffective (see “Eroding Goals” archetype, Figure 93). Recent harmonisation of the Work Health and Safety Act is an example of the approach taken by the Australian Federal Government to engage stakeholders from all states and territories to ensure that the review process is effective, constructive, transparent and accountable (Safe Work Australia 2013). Additionally, integration of HIAs into the regulatory framework ensures that economic growth assessments for the viability of projects take into account their public health impacts.

- *Prioritising “Goals of the System” and minimising “Delays” - coordinate resources-planning and capacity-building for the implementation of national policies and regulatory activities and to support the goals of EIPE prevention.*

EIPE prevention needs to be among the national priorities for countries with a heavy presence in hazardous chemical manufacturing. National policies and programs relating to economic, environmental and social development should be supported by evidence-based research and coordinated by federal governments to maximise research resources (“Political,” “Legal” and “Industry” factors). For instance, sufficient funding could be allocated to the Australian Research Council (ARC) for EIPE prevention research, which can then facilitate greater collaboration between academia and industry. Such research should lead to practical results in enhancing industrial risk control and preventing EIPEs. More significantly, the research outcome aligns with

the ARC's aim of delivering cultural, economic, social and environmental benefits to the Australian population (ARC 2015).

The EIPE case studies and Focus Group discussion highlighted that efforts to tackle EIPE problems at national levels are often fragmented due to uncoordinated regulatory activities and unclear roles among government agencies (see "Eroding Goals" archetype, Figure 93). Consequently, the resulting delays and lack of coherence undermine efficient management to achieve better regulatory outcome. To overcome unproductive processes and unnecessary hindrances that can become part of the contributing factors to an EIPE, governments could adopt the Regulator Performance Framework, where one of the KPIs stated the need for a streamlined and coordinated approach to compliance and monitoring (Australian Government 2014). This framework requires regulators to examine their operations and the compliance burden they create when administering regulations.

The existence of legislation and regulations is not sufficient in itself; government must find ways to ensure that organisations meet their legislative obligations. Unfortunately, governments, especially those from developing nations, often lack the capacity and capability to inspect, audit and review organisations' industrial activities for whole project life spans (WEF 2011). Therefore, it is important to implement effective enforcement programs that proportionately prioritise resources for higher risk activities. More critically, these programs should be supported by competent staff who are adequately incentivised to remain employed with the regulator for a reasonable period, in order to protect the talent pool from industry competition (see "Drifting Goals" archetype, Figure 93). For example, government agencies need a strategic human resource recruitment and succession plan that effectively maintains an adequate level of staff competency.

In recognition of the challenges that some organisations may face in raising sufficient capital to implement the latest and safest technologies, governments may need to adjust their political priorities by using financial tools such as grants, tax allowances, R&D funding and other business

incentives to increase HSE effort within the industry (see “Limits to Growth” archetype, Figure 92 and Figure 95).

12.3 Industry Level

- *Strengthening the “Power to Evolve” and “Feedback Loops” - establish platforms for industries to share best practices and exchange of ideas and innovations in EIPE prevention.*

Mature establishment of an industry typically leads to the creation of associations, such as the Manufacturers Chemist Association (MCA) in the US, the Chemical Industry Association in Japan, or the Association of Mining and Exploration Companies in Australia, which represent organisations with common interests and operating activities. By including academic researchers as part of the steering committees in these industry forums, there can be more effective transfer of latest research findings to practical industry applications (MIRI 2015). The increase in an industry’s ability to learn positively contributes to wider acceptance of best practices, such as safety in design, will enhance HSE performance and strengthen organisations’ ability to be more resilient against unsafe practices (see “Limits to Growth” archetype, Figure 95). Additionally, industry associations can be advocates in promoting initiatives such as Responsible Care that aligns with societal expectations (ICCA 2015).

- *Strengthening “Feedback Loops” - explore ways to increase industry-community engagement in order to deliver a socio-economic-environmental cohesion outcome.*

Mismatches between expectations and reality exist when the affected public are not consulted enough or early enough in the planning and development stages of any industrial operation. Local communities are often not adequately consulted by industry stakeholders, who are keen to fast track project approvals. It is critical to involve community representatives, not only after an EIPE incident, but also throughout the project lifecycle (see “Shifting the Burden” archetype, Figure 96). This will lead to a better understanding of

the respective needs and objectives of industry and the community, as well as the value an industry can deliver to the society. Recommendations contained in the public engagement strategy proposed by the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) serve as a good reference point (Bremmer and Hanna 2009).

12.4 Organisational Level

- *Reviewing “Goals of the System” - integrate HSE into organisational governance systems and strategic business planning processes.*

Beyond meeting economic goals when investing in business productivity, organisations need to consider the associated HSE risks early in their strategic decision making process (see the adapted “Growth and Underinvestment” archetype, Figure 97). With the changing regulatory landscape focusing on directors’ due diligence, there is a growing awareness that HSE has to be viewed as a key corporate governance issue (Safe Work Australia 2011, 2013). In addition, the critical relationship between governance practices and investment decisions requires a high level of HSE engagement to promote investor confidence. To achieve this, top management should be cognizant of the long-term HSE implications of their strategic business decisions, because the strategic focus and planning process of any organisation should not be focused solely on the maximum return for shareholders (Lo 2012).

- *Ensuring effective “Feedback Loops” - apply effective operational controls using internationally established risk management approaches.*

The application of the EIPE risk management process (risk identification, assessment and control) should be consistent across an organisation to ensure the objectivity and reliability of results. However, organisations need to recognise that there are possible reinforcing forces, which can delay the implementation of more effective controls addressing the underlying causes of EIPE (see “Shifting the Burden” archetype, Figure 98). To achieve a better risk management performance, organisations can adhere to the International

Risk Management Standard (International Organization for Standardization 2009). It facilitates the integration of a risk management framework within an organisation's overall strategic and operational policies and practices, and takes into consideration internal and external relationships, accountabilities, resources, processes and activities.

- *Ensuring the “Integrity of Information Flow” and “Power to Evolve” - apply lessons learned from incidents, near misses and other non-conformances that could lead to an EIPE.*

While most organisations may have incident-reporting and investigation processes in place, they do not always produce the desired learning outcome. Common barriers to ineffective learning from incidents can include access to inaccurate monitoring data, complacency towards unsafe activities and lack of management support (see “Drifting Goal” archetype, Figure 99). To ensure the integrity of information flow, organisations need to implement quality assurance framework to maintain confidence in data integrity and accuracy (EPA 2007a; DECCW 2009; EPA 2009; DEHP 2013).

Instead of reactively responding to incidents, organisations should emulate the characteristics of a High Reliability Organisation (HRO), which habitually looks out for possible failures and proactively installs measures to address them (Branford and Hopkins 2009; Weick and Sutcliffe 2015). This requires organisations to operate as adaptive systems that continually review and make changes in order to remain sensitive to possible failures (R2 and R3, Figure 102). This resilient system should be underpinned by an even more effective leverage point – a mindset change from being focused on incident avoidance to building a resilient culture against perfunctory solutions that can lead to the eventual breakdown of the HSEMS (R10, Figure 100).

- *Changing “Mindset for the System” - build a sustainable safety culture that supports and reinforces an effective HSEMS.*

As the mindset shapes behaviours in a complex system, safety culture drives workplace behaviours in an organisation. Without a strong safety culture, the

best HSEMS in the world are unlikely to be resilient against production-vs-safety tension, non-conformances and EIPE incidents (see adapted “Fixes that Fail” archetype, Figure 100). To promote a sustainable safety culture, safety needs to be part of the core organisational values, where it is not compromised by competing among other business priorities (G. et al. 2013). However, building such a culture takes time and it requires the commitment of the highest level of an organisation.

Visible leadership reflects the commitment of senior management through actions such as strategic planning and financial investment in HSE. Since ‘bad news’ rarely travels up the corporate ladder, management’s involvement in safety initiatives can help to verify the accuracy of reported safety performance. Contrary to a culture of paper compliance, where organisations are susceptible to altering their reporting criteria to reflect a ‘manufactured’ safety performance, a genuine commitment from management is anchored in credible actions (Crutchfield and Roughton 2014). Such management leadership in safety should also translate into consistent support for necessary resource investment, site safety enforcement and compliance. This way, employees are more likely to report incidents, knowing that their actions will not lead to an investigation looking for someone to blame.

12.5 Societal Level

- *Strengthening “Feedback Loops” - facilitate community engagement, awareness and education with key stakeholders.*

In addition to an industry’s wide-ranging consultation with community representatives or interest groups, other stakeholders such as government agencies, unions, allied health service groups and professional institutions should be involved in the planning and implementation of an industrial proposal (see “Shifting the Burden” archetype, Figure 96). Also, mentioned in the earlier Section on organisational lessons learned, this proactive consultation produces better controls and corrective actions for addressing the underlying EIPE issues.

Challenges of facilitating an effective community engagement process are multifaceted. Therefore, stakeholders need to tailor their consultation mechanism or communication strategies by taking into consideration the economic factors, demographic profiles, social values, cultural norms, expectations and awareness of those involved in an EIPE. Although legislation such as the Emergency Planning and Community Right-to-Know Act (EPA 2015) enforces the right of the public to have access to critical information regarding hazardous operations, stakeholders ought to engage the community with the knowledge that it would produce better policy decisions, more effective control measures and increased confidence in a well-defined partnership. Moreover, with the understanding that stakeholders share the same desire in preventing an EIPE, government, organisational and civil society monitoring of industrial activities should be viewed as mutually enforcing and beneficial, rather than isolated or conflicting activities.

To overcome the lack of knowledge about the cumulative health risks of exposure to harmful chemicals, policy-makers and key stakeholders (e.g. UN, regulators, federal and local government agencies, educational institutions, industrial organisations, trade associations, healthcare professionals and HSE advisors) can apply a combination of the following strategies:

- Provide awareness training to residents in the communities affected.
- Make information about the effects of hazardous chemicals on humans and the environment publicly available. (e.g. GHS)
- Require manufacturers to provide basic information for all chemicals used in their products to a centralised government authority (e.g. Community Right-to-Know Act).

Therefore, policy responses should not only aim to provide an avenue for community reporting of EIPE incidents, but they should also dedicate more time to the education and training of residents to be able to identify exposure risks that could lead to long-term health impacts.

12.6 Strategic Planning Guide

Complementing the above-mentioned strategies for prevention of EIPE, a business planning tool, based on the conceptual framework is developed to assist organisations. This guide has been designed by taking into consideration both the external PLEIS and internal HSEMS factors as shown in Table 12.1. It can be used to facilitate the discussion of possible HSE implications arising from certain business decisions and strategies by carrying out the following:

Step 1: Management identify those PLEIS factors that can either impact or support business performance and competitiveness.

Step 2: Organisational strategies are developed to mitigate possible threats arising from PLEIS influence or to take advantage of opportunities presented by these external factors.

Step 3: Through consultation with all the business units, organisations consider how these strategies can affect the internal factors and more specifically HSE performance.

Generally, investment in HSE programs has been a reactive response to incidents that caused serious injury, death or widespread public health impact. However, findings from the EIPE case studies and Focus Group have shown that organisations cannot afford to “wait” for incidents to happen. Instead, management should consider how their selected business decisions and strategies can potentially impact HSE performance.

Since the external forces of PLEIS influence key business strategies, which in turn affect the development, implementation and continual improvement of the HSEMS, this planning guide can assist the EIPE prevention effort by bringing forward operational issues at the strategic planning stage. This way, management can proactively incorporate HSE into their high-level business decision making process.

Table 12.1: PLEIS & HSEMS Planning Guide

	External Factors				
Business Decisions	Political	Legal	Economic	Industry	Social
External influences and possible business impacts	<p>Step 1: List the PLEIS factors that can influence business performance.</p> <p>e.g.</p> <ul style="list-style-type: none"> changes in fiscal policies such as higher business taxes (political, economic) changes in migration law resulting in shortage of needed skills to support business activities (legal, social) 				
Strategic thrusts and key initiatives	<p>Step 2: List key organisational strategies informed by the above PLEIS factors.</p> <p>e.g.</p> <ul style="list-style-type: none"> implement cost-cutting measures such as stretching production equipment mileage, lesser periodic maintenance, lower investment in HSE outsource production activities to lower cost locations 				
Internal Factors	<p>Step 3: Consider how the above external factors and business decisions can impact these internal factors.</p>				
Safety Culture	<p>e.g.</p> <ul style="list-style-type: none"> lack of management commitment in HSE investment potentially sending the wrong message that bottom-line will be achieved at the expense of HSE 				
Policy & Planning	<p>e.g.</p> <ul style="list-style-type: none"> HSE policy becomes a meaningless guidance for HSE production and business planning changes may not adequately consider HSE risks and legal requirements 				

Implementation and Operations	e.g. <ul style="list-style-type: none">• cutting back in dedicated roles for HSE and pushing line supervisors responsible for production quota to be also accountable for HSE performance• inadequate consultation on HSE issues seen as hindrance to a productivity focused culture or due to language barrier• potential increase in equipment issues due to a lack of periodic maintenance that can impact HSE
Checking and Review	e.g. <ul style="list-style-type: none">• lack of HSE performance monitoring• decrease in reporting of HSE incidents, lack of follow up their investigations and valuable lessons are not learned• deteriorating HSE condition is not reported to management as part of the HSEMS review

12.6 Conclusion

Since issues surrounding industrial incidents are complex, a systems approach is necessary to understand the inter-related behaviours among contributing factors in EIPEs. The conceptual framework and qualitative models have shown that EIPEs are outputs of a complex system.

The inter-related, contributing factors extend beyond internal factors such as policy and planning, implementation and operations, and checking and review that organisations have more influence over. Hence, government, community and industry need to work together to develop coherent policies and programs in preventing EIPEs. Globally, governments can partner with one another to develop universal standards to facilitate the sharing of information and achievement of better HSE performance.

While EIPE archetypes alert organisations to potential consequences arising from common patterns found in complex systems, leverage points highlight areas for effective intervention. Collectively, identifying system archetypes and leverage points enables the implementation of effective strategies for EIPE prevention. Additionally, business planning tools such as the PEIS-HSEMS guide can be used to not only help guide strategic decision-making, but it can also anticipate potential problems arising from strategies, which may compromise HSE and contribute to EIPE.

The above recommendations are critical in preventing EIPEs. Development and implementation of these recommendations will take time. However, an important outcome of this research was the recognition that an EIPE can cause extensive and irreversible harm to people and the environment. If traditional approaches to investigating the causes of industrial incidents are used, then preventive strategies for EIPEs are likely to be narrowly focused and ineffective. Given that the use of hazardous chemicals in the workplace is becoming more complex and widespread, (e.g. nano-engineered materials) the increased risk of EIPE occurrences cannot be ignored.

Chapter 13

Contributions, Limitations and Future Works

13.1 Introduction

This research has sought to examine the systemic factors resulting in EIPEs and to develop possible preventive strategies to avoid their reoccurrence. Findings from the EIPE case studies and Focus Group have shown that inter-related and non-linear factors, such as balancing and reinforcing loops, were at play in these complex systems. These contributing factors not only occurred within the organisational management system, but also within the wider governmental, industrial and social systems.

Regarding the specific objectives (Section 1.3), this research: (1) identified key systemic factors contributing to industrial incidents; (2) developed an EIPE conceptual framework that represented the interaction of both internal and external systemic factors; (3) evaluated the systemic approach using a Focus Group of experts and developed EIPE qualitative models; and (4) developed a series of preventive strategies for EIPEs.

13.2 Contributions

In light of the gaps found in existing literature (see Section 3.2), this section provides a summary of the contributions made by this thesis.

13.2.1 Study of the Complex Causation of EIPEs

Much of the current safety research has been devoted to industrial pollution events with the sudden release of uncontrollable energy causing considerable health, safety and environmental impacts. However, there were limited studies on EIPEs where there had been protracted community and

environmental exposures to harmful substances or harmful energy levels. Therefore, this research not only facilitates a better understanding of incident causation through an identifiable representation of real world EIPEs, it also builds on current literature in examining the complex and dynamic causation of EIPEs. More importantly, it provides the basis for implementing more effective preventive strategies to avoid their reoccurrence.

13.2.2 Integration of Conceptual Framework

A significant contribution in this thesis is the methodology to facilitate the qualitative modelling of EIPEs. This methodology incorporates a conceptual framework from a multi-disciplinary approach by combining strategic business planning (Political, Legal, Economic, Industry and Social) and HSE management (Policy and Planning, Implementation and Operation, Checking and Review, and Safety Culture). More importantly, by positioning HSE as a vital component of business management, it supplements the general absence of HSE research in mainstream management literature. Furthermore, its wider perspective in examining incidents diverges from the more traditional behavioural-focused or human-centric causation analysis, which is no longer compatible with recent studies on complex systems.

13.2.3 Application of a Systems Approach to EIPEs

Generally, there is a lack of research into the causes of EIPEs by use of a systems approach. The strength of this approach is in its versatility of application across disciplines and ability to better understand systems behaviour. Often, studies have focused on the aftermath of incidents or the health and environmental impacts immediately upon their discoveries. Therefore, adding to the body of knowledge and understanding of industrial incidents are the studies of three high-profile EIPE cases (Love Canal, Minamata Disease and Esperance Lead). These detailed case studies used the systems approach, including the application of the EIPE conceptual model and the use of SD tools.

13.2.4 Focus Group Evaluation

Understanding of complex behaviours involved in EIPEs does not necessarily increase with the use of computer simulations based on questionable model parameters. Therefore, the Focus Group of experts undertook specially designed activities to evaluate the systems approach to EIPEs. Such a collaborative approach to evaluation provided an excellent platform for the sharing of insights and input from professionals with relevant industry experience in EIPE. Findings from the Focus Group, in the areas of key contributing factors and themes, archetypes, leverage points and opportunities for improvement, corroborated the evidence from the EIPE case studies.

13.2.5 EIPE Qualitative Models

This research provided a structured and systematic approach to developing qualitative models for EIPEs. The conceptual framework from Chapters 5 to 9, combined with the examination and findings of the complex EIPE behaviours in Chapters 10 to 12 of the research, enabled the development of both internal and external qualitative models for EIPEs.

Similar to EIPE systems approach, some of the more advanced models such as Leveson's STAMP and Rasmussen's AcciMap recognise the complex sociotechnical in which organisations operate. However, AcciMap (Rasmussen's risk management framework) portrays the static interaction between levels in organisational system in a hierarchical and linear manner, rather than the increasing "+" or decreasing "-" feedback loop and the non-hierarchical type of interaction presented in these EIPE qualitative models (Branford and Hopkins 2009). Based on similar hierarchical approach to investigating socio-technical system, STAMP suggests that the inter-related parts in a complex system are kept in a dynamic equilibrium or non-incident state by a series of intended controls at different levels. Consequently, to develop a functional control structure, there is a need to have a precise understanding of the process model and their associated control actions,

which could require substantial technical resource and expertise (Qureshi 2008). Rather than focusing only on control failures, EIPE systems approach encourages a collaborative approach to qualitative modelling, in order to uncover issues such as management commitment or priority, which may not be easily understood in term of the flaws in the control system.

In short, the developed EIPE qualitative models portray both the representation and the communication of significant characteristics about dynamic behaviours found in complex systems. They provide a global view of the complex inter-relationships within EIPEs, prompting new ideas and questions about the underlying systems approach, encouraging examinations of old incident causation concepts and theories, drawing attention to multiple realities otherwise not considered and providing possible directions for future works.

13.2.6 Recommendations for EIPEs

The development of public policies is a complex process that involves the dynamic inter-relationships of multiple interests and cross-disciplinary fields. These include economics, sociology, political economics, policy analysis, government administration, management and operations. Therefore, this research contributes to the broad approach of evidence-based development of public policy by highlighting the various factors that can influence policy-making and policy outputs.

Results from the EIPE case studies and the Focus Group provided the basis for the development of recommendations or preventive strategies at the global, national, industry, organisational and societal levels.

13.3 Limitations

All research has limitations, and this study is no exception. Although this research has achieved its aim and objectives, the limitations are discussed in the following sections.

13.3.1 Quantity of Case Studies

Unlike well-researched, high-profile industrial pollution events of a more sudden nature, occurrences of EIPEs are not as readily studied and they do not usually contain sufficiently rich organisational data for a comprehensive analysis of their complex systems. As a result, only a handful of cases met the definition of an EIPE and also had sufficient data to be considered for this research, even though it is recommended by some studies to study more than four cases in order to generate a theory and make generalisations (Eisenhardt 1989a; Gibbert, Ruigrok, and Wicki 2008). However, this study is not about statistical generalisation, which would have been difficult given the rarity of EIPEs. In this study, the EIPE cases are not sampling units, but theory-related analytical generalisations; thus, it is possible to have only one or more cases.

13.3.2 Data Collection Techniques

Common data collection techniques, such as questionnaires and qualitative interviews, would have had limited effectiveness because most of the key personnel involved in these EIPEs, or the associated organisations, had ceased to exist. Also, due to implications surrounding reputational damage and liability lawsuits, it would be rare for organisations to share sensitive company information about the occurrence of such an event. Therefore, the research had to rely mainly on government inquiries and other publicly available information sources. Even then, evidence presented in a trial could have been a few decades after the occurrence of events (e.g. 1979 case of State of New York and USA vs. Hooker Chemicals) and the original authors of documents were not always available to be cross-examined to ascertain their correct interpretation. Despite these limitations, government-sanctioned

inquiries and reports permitted a more rigorous investigation process and comprehensive findings than other forms of data gathering techniques. Complementing the above-mentioned data collection techniques was the valuable input from the Focus Group.

13.3.3 Coverage of Contributing Factors

Much as it is the intention of the developed qualitative models to reflect the real world environment, it is not possible to cover all contributing factors of the EIPes. Some even question the predictive value of incident investigation since a dynamic and complex system would be unlikely to produce another similar occurrence (Dekker 2011). Also, the number of identified factors in the three nominated case studies is dependent on the available data published for these events. To a certain extent, this affects the comparative analysis of common factors across multiple cases. Furthermore, the chosen EIPes occurred in a variety of institutional and societal contexts, in developed or developing nations, which makes cross-case comparison and generalisation more difficult. Although the global context in which governments and organisations operate in the 21st century is very different from the international trade environment of decades ago, past industrial incidents (e.g. Piper Alpha, Esso Longford, BP Texas Refinery and Union Carbide Bhopal) still provide valuable lessons that have affected the way in which HSE is managed today.

Safety culture was not a well-understood concept during the period of the Love Canal or Minamata Disease incidents and, even today, there is little consensus as to what constitutes a safety culture. Part of the challenge in establishing a universal understanding about safety culture is how closely its attributes are linked with those of organisational culture, behavioural-based safety, top management commitment and other intangible variables (Hopkins 2002; Richter and Koch 2004; Hopkins 2005; Díaz-Cabrera, Hernández-Fernaud, and Isla-Díaz 2007; Silbey 2009; Edwards, Davey, and Armstrong 2013b; Rollenhagen 2013; Crutchfield and Roughton 2014). Consequently, there was insufficient data (e.g. culture surveys, workers attitudes,

organisational values and beliefs) and a lack of uniform criteria to capture information relating to safety culture in the EIPE cases. Despite the lack of agreement on the definition of safety culture, this research acknowledged that it plays an integral role in maintaining an effective HSEMS, as shown by its inclusion in the revised conceptual framework.

13.3.4 Focus Group Evaluation

The Focus Group was a useful method to evaluate complex behaviours in an EIPE. Also, it provided further confidence in the EIPE conceptual framework. However, there were certain challenges in organising the Focus Group.

Challenges in forming this Focus Group included recruitment of the 'right' experts with relevant EIPE experience, the great geographical distance (e.g. Esperance) preventing regional experts from participating in the Focus Group held in the Perth metropolitan area and the reluctance of those who were not comfortable in using case studies that might implicate their organisations. Therefore, it was not feasible to attract a large pool of experts. Neither, was it practical to have a large Focus Group because the aim was to maintain a manageable and focused discussion. To overcome possible sensitivities regarding specific EIPE cases, the Focus Group activities were deliberately designed using a generic definition of an EIPE as the context.

The Focus Group showed that some amount of training and practice were necessary to apply the system tools effectively. Also, time constraints in the Focus Group limited refinement of the paired-influence diagrams, and/or discussion about identified factors other than the most significant internal and external factors.

13.3.5 General Systems Approach

It was evident that complex behaviours and other system characteristics in EIPEs could not be reduced to a simple statistical analysis. Instead, models were used to provide insight into the causes of EIPEs. However, all models

are simplifications of reality. No model can perfectly explain all the characteristics of a complex system. As a common aphorism in statistics expresses it: “essentially, all models are wrong, but some are useful” (Box and Draper 1987, p.424).

Other system tools, such as CLDs and SFDs, were needed to elicit mental pictures relating to EIPEs. Although, a SFD could represent changes in quantifiable contributing factors over time (e.g. organisational profit), it would be difficult to illustrate variants in the quality of an intangible factor (e.g. effectiveness of risk assessment). Furthermore, causal loop models “are also never final, but always provisional,” which are subject to continual improvement as our understanding of EIPE improves (Sterman 2000, p.166). As with all specialised tools, system tools do require some practice in order to harness their true potential.

13.4 Future Works

This section discusses areas of future research that were identified as having great potential to gain further insights into EIPEs and to enhance mitigation strategies against their occurrences. Based on the findings of this research, recommended future research includes:

1. Follow up on the recommendations from key stakeholders to enhance the various levels of preventive strategies for EIPE occurrences (see Chapter 12). Development of country specific strategies should take the unique political, economic, regulatory, social and industrial environment into account.
2. Build on this research by studying other more recent EIPE cases. By applying the conceptual framework and qualitative models to a greater number of EIPE cases, preferably across different geographical continents, it will provide further opportunities to expand and generalise the underlying theories. However, researchers need to be aware of the challenges such as the ability to share information freely, overcome

cultural and language barriers and maintain political sensitivities of each nation where the EIPE originates.

3. Explore ways to apply common qualitative techniques such as questionnaires and surveys to gather data on recent EIPE cases. Due to possible legal and reputational implications, researchers will need to overcome the barrier of collecting primary evidence from stakeholders directly involved in the EIPE. Especially, access to specific HSE data such as leading and lagging indicators that could help researchers to better analyse and understand the extent of impact external factors and business decisions have on HSE performance.
4. Conduct more Focus Group sessions on EIPEs, with a larger pool of experts drawn not only from within Australia, but also from overseas. Preferably, pre-requisite training and education in the use of System Dynamics tools should be provided to the participants before the Focus Group. This will reduce the amount of time needed to guide participants in the basics of SD during the Focus Group. As much as possible, more time should be provided for the improvement of paired-influence diagrams and the discussion of strategy implications for other key contributing factors. This way, experts can revisit their pair-blended diagrams to verify the initial assumptions and update them as new understanding is reached. Additionally, other evaluation methods such as Delphi Studies could be considered for the amendment and refinement of the EIPE models.
5. Research into ways of determining the forces or strengths of different reinforcing and balancing loops in CLD. A set of criteria can be developed to measure the various levels of dominance feedback loops are imposing on each other. Also, longitudinal studies can be an appropriate methodology to assess possible changes in the feedback loops in relation to changes in organisational strategies. This way, more insight can be derived from comparing the competing dynamics within complex systems.

6. Further research can focus on specific contributing factors and the development of new archetypes. For instance, national policy-makers may be interested in studying how the decreasing influence of government over its national economy, due to growing global economic forces, is contributing to EIPEs. Such insights into the inter-relationships between national and global economies will enable governments to design policies that minimise the long-term public health and environment impacts from EIPEs. Moreover, through more Focus Group sessions, knowledge and understanding of the participants will increase with the verification of existing archetypes and sharing of learning between organisations.
7. Although safety culture was identified as one of the contributing factors to an EIPE, empirical studies of the relationship between safety culture and safety performance are limited (Hopkins 2006; Goh et al. 2012). Therefore, further study into the complex system of organisational culture should be carried out, which should include the elements of competing interests within organisations, risk perceptions and the willingness to learn from incidents (including near misses), as well as how they impact on safety performance.
8. Despite the similarity between EIPEs and IPEs in terms of the external organisational influences and internal HSEMS, the extent of the impacts of these contributing factors is not clear. Thus, a comparison of the qualitative models for both IPEs and EIPEs will enable a closer examination of the differences between the dynamic behaviours of EIPEs and IPEs.

13.5 Conclusions

This thesis has led to an increased understanding of the systemic factors contributing to EIPEs and the development of strategies to prevent their reoccurrence. These strategies were based on four central objectives.

The first objective was to identify key systemic factors contributing to industrial incidents. Each EIPE possesses the characteristics of a complex system, which requires an examination of its causation from a wider context that is beyond its immediate operating environment. This study identified contributing factors in a complex EIPE, which consisted of both internal and external organisational factors, interacting with one another in a non-linear and non-explicit manner.

The second objective was to develop and apply a conceptual framework that represents the complex interaction of these contributing factors in EIPEs. This study developed a conceptual framework that integrated the key principles of strategic business planning and an organisational management system. The conceptual framework was effective in organising a large volume of data from the three EIPE case studies. Additionally, it provided a coherent structure for data analysis using system tools such as CLDs and SFDs.

The third objective was to evaluate the conceptual framework and key EIPE findings using a Focus Group approach. Industry and academic experts developed internal and external contributing factors that closely aligned with the conceptual framework for an EIPE. Identification of key themes and contributing factors, and the analysis of feedback loops, delays and other system characteristics, determined that a combination of external forces and organisational decisions could often undermine existing controls designed to prevent the occurrence of an EIPE. The complex interaction of these contributing factors would not have been identified using the traditional linear approach to investigating industrial incidents.

The fourth objective was to formulate a series of preventive strategies for EIPEs. The identification of system archetypes and an assessment of the relative strengths of leverage points enabled a better understanding of the behaviour of EIPEs. Also, an organisational planning tool was recommended to facilitate the discussion of possible HSE implications arising from certain business decisions and strategies. To take into account the wider systemic factors, beyond the issues found within the organisations, the proposed recommendations provide policy and decision-makers with a holistic approach to addressing EIPE prevention at the global, national, industrial and organisational levels.

In summary, this research has comprehensively covered the above aspects and satisfied all its objectives. It has added value to the body of knowledge, specifically in the area of a systems approach to examining the causes of EIPEs. Additionally, this research has made recommendations to academics, government agencies and industry practitioners for future expansion and understanding of EIPE prevention.

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Appendix A: Extended Industrial Pollution Events

Selected EIPEs in Chronological Order

Incident	Location	Hazardous Substances	Occurrence Period	Triggered Investigation	Transmission Pathway	Community Size	Health Impact
Port Pirie (Maynard, Franks, and Malcolm 2005; Zoe 2006)	Adelaide, South Australia	Lead contamination	1887 1980s more than 100 years of metal smelting activity	1984: discovered that 98% of young children exceeded the safe blood lead level	airborne deposition of lead-contaminated dust	2,200 houses	increased blood lead levels
Minamata Disease (Ui 1992; Peterson; Takizawa 2000; Ministry of the Environment Government of Japan 2002; Funabashi 2006; McCurry 2006)	Kumamoto prefecture, Japan	27 tons mercury compounds	1932 - 1968	1950: witnessed strange behaviour of cats, birds dropped from the sky; 1956: four patients were hospitalised	ingestion of marine pollution (contaminated fish and shellfish) via bioaccumulation	3,000 residents (farmers and fishermen); 900 died	degeneration of nervous system, numbness in limbs and lips, slurred speech, constricted vision, serious brain damage, involuntary movements

Selected EIPes in Chronological Order

Incident	Location	Hazardous Substances	Occurrence Period	Triggered Investigation	Transmission Pathway	Community Size	Health Impact
Love Canal (Herdman 1978; Eckardt 1979a; Environmental Protection Agency 1979; Love Canal Homeowners Association Inc 1980; Niagara Gazette 1980; New York State Department of Health 1994)	New York, USA	20k ton of 248 assorted chemicals; 82 different chemical compounds at the landfill, of which one is a known human carcinogen and 11 are known or presumed animal carcinogens	1930 - 1960s	1976: Niagara Gazette reported presence of chemical seeping into homes	exposure to surface soils off-site, potential for exposures to contamination in surface water, sediments, and airborne soil particulates	homes immediately adjacent to the landfill: 97 families composed of 230 adults and 134 children	miscarriages, mental retardation, birth defects, congenital malformations in children, liver dysfunction, high blood mercury levels, epilepsy, asthma, urinary tract infections, low white blood cell counts
Hinkley vs Pacific Gas and Electric (Environmental Health Investigations Branch 2001; Los Angeles Times 2006)	California, USA	Hexavalent Chromium 6	1951 - 1969	December 7, 1987: company informed state of chromium, although PG&E knew since 1965	leaks from compressor plant polluted the groundwater	at least 1,000 residents in several Mojave Desert towns	cancer deaths and birth defects

Selected EIPes in Chronological Order

Incident	Location	Hazardous Substances	Occurrence Period	Triggered Investigation	Transmission Pathway	Community Size	Health Impact
Pelham Bay Landfill (New York State Department of Health 2000)	New York, USA	domestic waste	1963 - 1978	1980s: concerns raised by community	inhaling polluted air from the landfill; eating finfish and hardshell fish from Eastchester Bay; swimming and other recreational uses of Eastchester Bay; inhaling, ingesting and dermally contacting contaminated leachate/groundwater and soil; soil/gas migration of contaminants into the basements of nearby homes; contamination of potable water from leaks or breaks in the municipal water mains; flooding of nearby basements with contaminated water which originated from the landfill; and release of landfill gases and dust during remediation and construction of PBL	1990 Census: NYS DOH estimated 26,954 people living within one mile of the PBL	childhood leukemia, autism, sclerosis

Selected EIPes in Chronological Order

Incident	Location	Hazardous Substances	Occurrence Period	Triggered Investigation	Transmission Pathway	Community Size	Health Impact
Times Beach (Leistner 1985; Environmental Protection Agency 1987; Environmental Protection Agency 1990; Johnson 1992; Department of Environment and Conservation 2007)	Missouri, USA	265,354 tons of soil and other dioxin-contaminated material	1972 - 1976	1974: CDC identified dioxin-contaminated soil as cause of death for animals; Nov 1982: a reporter highlighted pollution issue	atmospheric transport and transformation; surface run-off carrying suppressants and/or breakdown products; uptake of dust suppressants by plants; ingestion of dust suppressant constituents by animals; ingestion of exposed animals; infiltration conveying suppressants to vadose zone and groundwater table; occupational contact by applicators; potential impacts on soil microbial ecology; transport of suppressant particulates by wind erosion to unintended areas; off-site run-off of dust suppressant and carrier solvent; consumption of contaminated groundwater; downwind drift of spray off-site during application; ingestion of dust suppressant constituents by humans	2,800 residents were permanently relocated	toxicity to humans during and after application

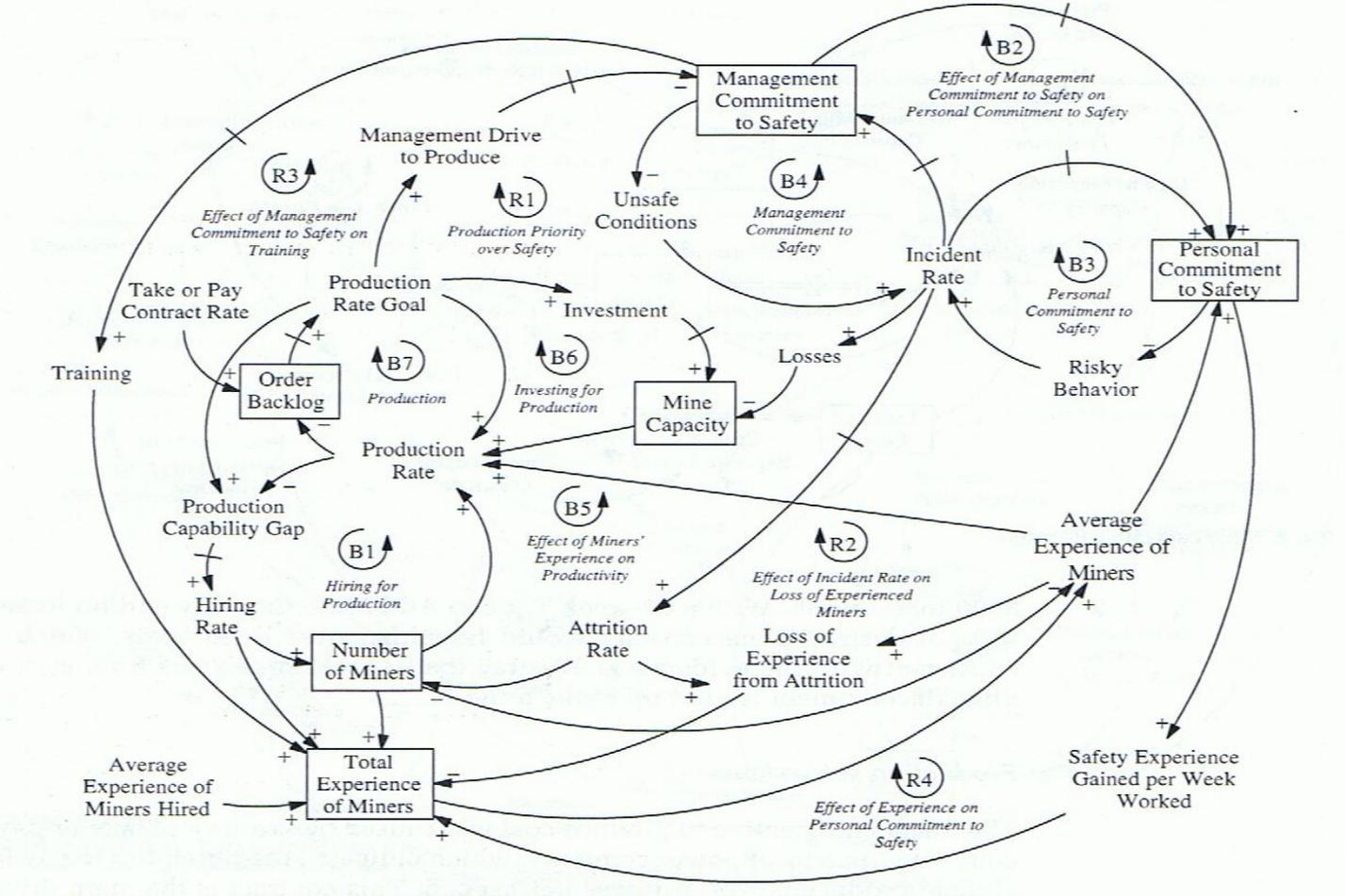
Selected EIPEs in Chronological Order

Incident	Location	Hazardous Substances	Occurrence Period	Triggered Investigation	Transmission Pathway	Community Size	Health Impact
Esperance Lead Pollution (Education and Health Standing Committee 2007a; Clarke 2008; ABC News 2009; Guest 2009)	Esperance, Western Australia	Lead and nickel pollution	2005 - 2007 (18 months)	discovered bird deaths in Dec 2006, same month DEC notified Department of Health and Esperance Shire	inhalation of, and contact with, airborne lead-contaminated dust; rainwater tank contamination; soil, water body and marine sediment contamination	pollution of Esperance Shire; 9,536 residents	elevated blood levels, 25% of sampled children < 5 had blood levels equal to, or in excess of, 5ug/dl

Appendix B: System Descriptions

- ANSI/EIA-632-1999: "An aggregation of end products and enabling products to achieve a given purpose" (American National Standards Institute/Electronic Industries Association 1999).
- IEEE 1220-2005: "A set or arrangement of elements and processes that are related and whose behavior satisfies customer/operational needs and provides for life cycle sustainment of the products" (Homer and Oliva 2001).
- ISO/IEC 15288:2008: "A combination of interacting elements organized to achieve one or more stated purposes" (Thompson and Tebbens 2008)
- NASA: "(1) The combination of elements that function together to produce the capability to meet a need. The elements include all hardware, software, equipment, facilities, personnel, processes, and procedures needed for this purpose. (2) The end product (which performs operational functions) and enabling products (which provide life-cycle support services to the operational end products) that make up a system." (NASA 2007)
- INCOSE: "A system is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. The results include system level qualities, properties, characteristics, functions, behavior and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected" (AICD 2010).

Appendix C: Example of a Causal Model



Causal Structure of Westray Mine Disaster (Cooke 2003)

Appendix E: Focus Group Information and Pre-Reading

1. Introduction

The prevention of Extended Industrial Pollution Events (EIPE) is a complex issue with implications for government, organisations and society. This Focus Group aims to capture the knowledge and perspectives of different stakeholders to gain a better understanding of the contributing factors leading to undesirable outcomes of EIPEs and how they can be mitigated.

The aims of the Focus Group are to:

- Identify key contributing factors linked to EIPE.
- Provide insight into the interaction between these contributing factors.
- Discuss possible strategies that can prevent the occurrence of EIPE and improve management of EIPE.

This Focus Group is divided into two components: Information and Pre-Reading and a Workshop. In order to provide the relevant context and foundation knowledge for the workshop, a description of an EIPE and a list of examples are provided to individual participant two weeks before the workshop. Some references of the EIPEs will also be provided to the participants for them to do some pre-reading, so that they can be better prepared for the workshop.

2. Background

This research has identified two major categories of contributing factors for EIPE:

- External: Political, Legal, Economic, Social, Technological and Social (PLETS) and
- Internal: HSE Management System (HSEMS)

Both the external and internal factors interact with one another and contribute to health impact (see figure 1.0).

In addition to evaluate the findings from the research, this Focus Group will enable experts and industry practitioners to provide valuable input into the contributing factors and preventive strategies. It forms part of the larger research into the analysis of causal factors of industrial incidents using a systems approach. Data from the Focus Group will facilitate comparison and analysis between findings from the research and those gathered from the participants.

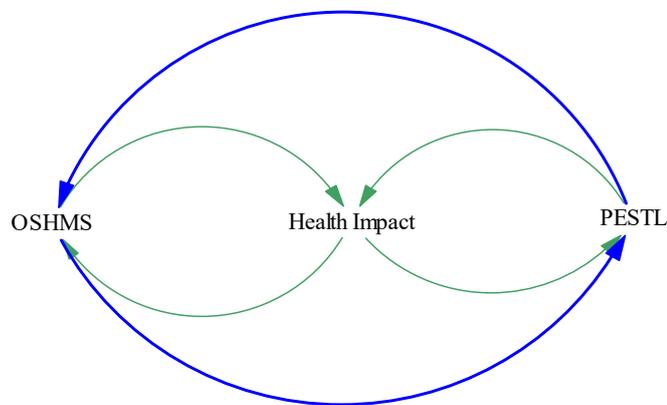


Fig 1.0 Contributing Factors and Their Relationships to Health Impact

2.1 Characteristics of EIPE

EIPEs have the following characteristics:

- Sources of pollution – the point source of emission can be traced to specific industrial activities such as a manufacturing facility. In contrast, non-point sources involve pollution activities that are not possible to confine such as household emissions.
- Pollution management - EIPEs cause protracted community and environmental exposures to harmful substances (e.g. toxic waste) from industrial sources due to the failure of controls to prevent them.

- Impact of pollution - exposures that have significant community impact beyond the perimeter of the immediate industrial operation. At least two or more members of the public are exposed to harmful substances.
- Role of regulator and government agencies - comprehensive investigation of the national regulatory framework and effectiveness of enforcement actions.
- Role of organisation - comprehensive investigation of management actions and other organisational factors (e.g. production over safety).
- Role of community - comprehensive investigation of community engagement and informal safety, health and environmental compliance pressure from the community.

2.2 Examples of EIPE

Participants may be familiar with other EIPE beside those listed here:

- Love Canal (U.S.), Minamata Disease (Japan), Port Pirie (Australia)

2.3 Useful links:

Love Canal

- <http://www.onlineethics.org/cms/9721.aspx>
- <http://www.onlineethics.org/cms/6534.aspx>
- <http://reason.com/archives/1981/02/01/love-canal>

Minamata Disease

- <http://www.env.go.jp/en/chemi/hs/minamata2002/>
- <http://www1.umn.edu/ships/ethics/minamata.htm>
- http://archive.unu.edu/unupress/unupbooks/uu35ie/uu35ie0c.htm#chapter4_Minamata_Disease

Port Pirie

- http://www.ecosmagazine.com/?act=view_file&file_id=EC07p27.pdf
- <http://ro.uow.edu.au/cgi/viewcontent.cgi?article=1366&context=medpapers>
- <http://www.health.sa.gov.au/pehs/PDF-files/ptpirie-future-focus-06.pdf>

Appendix F: Focus Group Activities

Workshop Plan

11 May 2015

Time	Content	Process
0845	Arrival, Coffee. Name Tags. Table lists.	All
0855	Quick Introduction (in table groups).	All participants
0900	Presentation. Brief background, some key evidence, key points. Workshop aims. Influence diagrams.	Facilitator
0915	Exercise 1. Develop individual influence diagrams. (15)	Individual x 8
0930	Exercise 2. Pair-blended influence diagrams. (20)	Pair work x 4
0950	Morning Tea. Place pair-blended diagrams on tables.	
1000	Exercise 3. Each group to identify top 3 external factors and top 3 internal factors contributing to EIPE. (20)	Group x 2
1010	Make a table list of key external and internal factors (combine similar factors). Individuals at table to score factors. Red 3; Yellow 2; Green 1. Collate results.	Table score Top 3 external factors Top 3 internal factors
1020	Groups report back to the facilitator for total scoring. (10)	Facilitator
1030	Collate the scores and select top 6 contributing external factors and top 6 contributing internal factors.	Facilitator
1035	Exercise 4. Each group is assigned top 3 external factors and top 3 internal factors for discussion. (15/factor) each group 3 factors	Facilitator
	Discuss opportunities for prevention of EIPE.	Group work
	Discuss about obstacles that can hinder their effective implementation.	Group work
	Discuss about stakeholders and their possible roles in the above.	Group work
1140	Plenary to summarise group discussion.	Facilitator

Exercise 1: Individual Influence Diagram (15mins)

Aim: Collect individuals' perspectives/expertise about key contributing factors and relationships among them. What are the factors that influence EIPEs?

- Factors can be both internal and external
- Input factors > EIPE > output factors
- 2 or 3 factors
- Re-iterate rules about stock (increase/decrease) and flows (actions or processes). Not just added together – more feedbacks.
- 'Actions are in the arrows'

Material – two sheets of A3 paper for each of the 8 participants (16 sheets).

Label the individual paper at the top right hand corner.

Leave key instructions and an example of influence diagrams up on screen.

Exercise 2: Pair-blended Influence Diagrams (20mins)

Aim: Get people to begin to understand other factors and perspectives of the issue.

Materials: 2 sheets of flip chart paper for each of the 4 pairs (8 sheets flip chart paper).

Label the group paper at the top right hand corner.

Again, keep instructions on screen.

Morning Tea - leave the pair-blended influence diagrams on the table for viewing.

Exercise 3: Identify Key Contributing Factors

Aim: Identify the important internal and external factors driving EIPEs.

- a) Label "Table 3A" and "Table 3B" at the top right hand corner of sheets for each group.
- b) Each group to identify all external factors contributing to EIPEs in Table Ex 3A.
- c) Each participant in a group to place a score of Red=3, Yellow=2, Blue=1 (one set of colours for external) for the top 3 most important factors. Each participant can only assign one colour for each of the 3 selected factors. I.e. No multiple colour assignment for one factor.
- d) Each group add the scores and highlight the top 3 factors for the group.
- e) Repeat the above for internal factors in Table Ex 3B.
- f) Material: Provide Table Ex 3A and Table Ex 3B for each group.
- g) Colour stickers: 2 x Red, 2 x Yellow, 2 x Green for each participant.

Exercise 3A: Identify Key External Contributing Factors

Group 1 / Group 2 (10mins)

	Key Factors (in no particular order)	Dots	Total
1			
2			
3			
4			
5			
6			

List key factors (up to 6) identified at your table. Each group to assign scores:

Most Important: 3 points = **RED**

2nd most important: 2 points = **YELLOW**

3rd most important: 1 point = **GREEN**

Add up scores and identify top 3 external factors.

Exercise 3B: Identify Key Internal Contributing Factors

Group 1 / Group 2 (10mins)

	Key Factors (in no particular order)	Dots	Total
1			
2			
3			
4			
5			
6			

List key factors (up to 6) identified at your table. Each group to assign scores:

Most Important: 3 points = **RED**

2nd most important: 2 points = **YELLOW**

3rd most important: 1 point = **GREEN**

Add up scores and identify top 3 internal factors.

Exercise 3C: Collation of Results

- a) Enter the results directly into the computer with Table Ex 3C and project it on the screen for all to see.
- b) Group 1 – report top 3 external factors and scores.
- c) Group 2 – report top 3 external factors and scores.
- d) Group 1 – report top 3 internal factors and scores.
- e) Group 2 – report top 3 internal factors and scores.
- f) Add the total scores.
- g) Highlight the combined top 3 external and internal factors.

Material: Table 3C projected on screen.

Exercise 3C: Collation of Results

(5 mins)

Contributing Factors	Group 1	Group 2	Total
External			
Internal			

Exercise 4: Discussion of Key Contributing Factors

(50 mins)

- a) Each group is assigned 1 top external factor and 1 top internal factor for discussion. Each group should focus on its assigned factor, but other factors in the list will be connected.
- b) Opportunities – how to implement?
- c) Barriers – how to overcome?
- d) Stakeholders – how are they involved?

Critical policy/sector interactions - complementary or conflicting

Material: Table 4 projected on screen.

Exercise 4: Discussion of Key Contributing Factors

Group 1/ Group2 (15 mins)

Top External Factor	
Opportunities	Stakeholders
Obstacles	

Exercise 4: Discussion of Key Contributing Factors

Group 1/ Group2 (15 mins)

Top Internal Factor	
Opportunities	Stakeholders
Obstacles	

Appendix G: Focus Group Findings

Appendix G1: Group 1 Top External Factors

External Factor - Application and planning approvals: design, EIA, HRA	
<p>Opportunities</p> <ul style="list-style-type: none"> • Better integration of health risk assessment with EIA process • Increase technical and scientific knowledge and capacity of those reviewing proposals • Clearer lines of approval and more streamlined process • Improved community consultation during EIA and for project sites impacting large residential areas • Improved guidance regarding separation distances and buffer zones 	<p>Stakeholders</p> <p>Department of Environment Regulation</p> <p>Department of Mines and Petroleum</p> <p>Department of Health</p> <p>Department of Planning</p> <p>Department of Parks and Wildlife</p> <p>Community</p> <p>Industry bodies</p> <p>Local government authorities</p> <p>Professional bodies</p> <p>Neighbouring industries</p> <p>Heritage</p> <p>Designers and engineers</p> <p>Environmental/ special interest groups</p> <p>Cabinet and Treasury</p> <p>Media</p>
<p>Obstacles</p> <ul style="list-style-type: none"> • Time taken to implement opportunities for improvement • Time taken for approvals – not streamlined • Lack of competent ‘specialist’ knowledge for potentially complex and/or high risk applications • The number of agencies and stakeholders involved in the process 	

<ul style="list-style-type: none"> • The different legislation involved – needing to meet several requirements • Gaps in policy and legislations – loopholes 	
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Appendix G2: Group 1 Top Internal Factors

Internal Factor – Systems and auditability of systems (HSEMS, EHMS, Preventive Maintenance)	
<p>Opportunities</p> <ul style="list-style-type: none"> • Using right people for the risk assessment and review – many need consultants/engineers • Systems integration to existing process • User friendly systems • Using simple solutions • Developing positive safety and reporting culture and performance management system 	<p>Stakeholders</p> <p>OHS personnel</p> <p>Management – senior unions</p> <p>Environmental professionals</p> <p>Workers</p> <p>Engineers and planners</p> <p>Fair Work Australia</p> <p>Builders and construction groups</p> <p>Designers</p>
<p>Obstacles</p> <ul style="list-style-type: none"> • Prohibitive costs found after cost-benefit analysis i.e. not feasible for implementation • Management apathy • Resourcing for service-based job roles i.e. safety, environment 	<p>Process safety engineers</p> <p>Construction safety personnel</p> <p>HR staff</p> <p>Consultants</p>

<ul style="list-style-type: none"> • Poor work culture • Conflicting policy, action (i.e. safety first until production affected, then short-cuts taken) 	
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Appendix G3: Group 2 Top External Factors

External Factor – Ineffective Regulation	
<p>Opportunities</p> <ul style="list-style-type: none"> • Uniform legislation for all states and territories e.g. WHS* model Act • Maintain currency on relevance of legislation • Better inter-agency cooperation • Industry placements for inspectors under training 	<p>Stakeholders</p> <p>National and State authorities</p> <p>Government</p> <p>Regulators</p>
<p>Obstacles</p> <ul style="list-style-type: none"> • Jurisdictional overlap • Political priorities • Lack of resources • (Difficulty in) maintaining technical and corporate knowledge and experience 	

* Work Health and Safety

Appendix G4: Group 2 Top Internal Factors

Internal Factor – Organisational Planning and Design	
<p>Opportunities</p> <ul style="list-style-type: none"> • Inclusive and integrated planning process • Review of projects and lessons learnt • Empowering innovation 	<p>Stakeholders</p> <p>Representatives from all departments</p> <p>Project management</p> <p>Management team</p>
<p>Obstacles</p> <ul style="list-style-type: none"> • Fragmented design and contract process • (Lack of) time and resources • (Unclear/High) stakeholder expectations 	

Appendix H: Focus Group Participants

Focus Group Participants		
No.	Organisations	Participants
1	Curtin University (Fellow and Distinguished Professor)	Observer
2	Curtin University (Fellow and Distinguished Professor)	Facilitator - PhD candidate
3	World Health Organisation (Collaborating Centre in Environmental Health Impact)	Strategic Advisor and Emeritus Professor of Environment and Occupational Health
4	Department of Water and Environmental Regulation	Manager in emergency response and management
5	Department of Health (Host)	Regional Manager
6	Department of Health (Host)	Safety and Health Coordinator
7	Department of Fire and Emergency Services	Principal Scientific Officer
8	Kwinana Industry Council	Council Member and Representative
9	Department of Transport	Manager Maritime Environmental Emergency Response
10	Industry OHS Specialist	OHS Specialist