

# **A Systems Analysis of Preventative Measures and Attributes of a Resilient Enterprise**

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**A Systems Analysis of Preventative Measures and Attributes  
of a Resilient Enterprise**

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## **ABBREVIATIONS**

ABM	Agent Based Modeling
ACE	US Army Corps of Engineers
AM	ArcelorMittal London
AML	ArcelorMittal Liberia (subsidiary)
CHES	Coupled Human-Environment System
CLD	Causal Loop Diagram
CR&S	Corporate Responsibility and Sustainability
DES	Discrete Event Simulation
DRR&M	Disaster Risk Reduction and Management
EID	Emerging Infectious Disease
EMT	Emergency Management Team
EVD	Ebola virus disease
FGD	Focus Groups Discussion
FTE	Full Time Employee
GAR	Global Assessment Report (UNISDR)
GDP	Gross domestic product
GEMT	Global Emergency Management Team
GMB	Group Model Building session
IDIs	In-Depth Interviews
IDRAM	Infectious Disease Risk Assessment and Management
LAMCO	Liberian-Swedish-American Mining Company
LICs	Lower Income Countries
MCEER	Multidisciplinary Centre for Earthquake Engineering Research
MDA	Mineral Development Agreement
NES	Non-Essential Staff
PATM	Professional, Administrative and Technical Management
PHEIC	Public Health Emergency of International Concern
SA	Systems Analysis
SD	System Dynamics
SNA	Social Network Analysis
ST	Systems Thinking
UNISDR	United Nation's Office for Disaster Risk Reduction
UNMEER	UN Mission for Emergency Ebola Response
WHO	World Health Organization

## **DECLARATION**

This thesis is submitted under the University of Salford rules and regulations for the award of a MPhil degree by research.

The researcher declares that no portion of the work referred to in this thesis has been submitted in support of an application for another degree of qualification of this, or any other university or institution of learning.

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## **ABSTRACT**

The Ebola Virus Disease (EVD) outbreak of 2014 had a considerable socioeconomic impact on the affected West African countries. The extractive sector plays a key role in these economies in providing employment opportunities, tax revenue and contributions to gross domestic product (GDP) with some mining firms having to suspend operations and even shutdown during the epidemic. The study looks at a case study of a mining firm that continued operating during the period despite other firms stopping production. Recent literature has suggested a larger role for the private sector in addressing disaster risk reduction and economic resilience has a strong contribution to the resilience of the overall community.

The study has followed a systems thinking approach to understand the impact of the EVD outbreak on the firm. The study used qualitative methods to understand the sequence of events and channels of impact of the outbreak on the firm, as perceived by its employees and contractors. A total of 16 in-depth interviews, 2 focus group discussions, 2 group model building sessions and a final validation workshop were conducted to identify what key employees understood as impacts on the firm and if the attributes of a resilient enterprise were present in the case firm. Informed by the qualitative analysis and the quantitative data provided by the firm, the study estimated the actual cost of the preventative measures (both internal and external) that the firm had adopted during the outbreak period. Additionally, the study has also developed a conceptual simulation model of senior management's perceptions (mental model) of operational resilience of a mining firm in the face of shocks such as the 2014 EVD outbreak.

The research identified the presence of systems for early detection, redundancy in human resource use and to some extent supply chains, flexibility in management and a corporate culture that took new emerging threats to its operations seriously. This resulted in the firm taking well thought out preventative measures that contributed to its resilience and resulted in continued operations. The economic cost of the preventative measures as incurred by the firm was estimated to be between \$10.58-11.11 million. The magnitude of actual costs incurred by the firm largely conforms to the perceived costs impact identified by the respondents in the qualitative study. A breakdown of the costs indicated that most of the money was spent on measures within the firm's compound, or "in fence", in the built environment rather than outside its perimeter, or "out of fence", on the community which indicates a response based approach rather than a pro-active approach to the disaster.

## **CHAPTER 1      Introduction**

Since the beginning of the millennium, more than 2.3 billion people have been directly affected by natural disasters with research showing that total damages may have been vastly underreported – by almost 50 percent – for an estimated total economic impact of \$ 2.5 trillion over the period 2000-2013. The United Nation’s Global Assessment Report (GAR) (2013) indicates that a large portion of those losses has been accrued by the private sector (UNISDR, 2013). The United Nation’s Office for Disaster Risk Reduction (UNISDR) has strongly recommended that the private sector should play a larger role in Disaster Risk Reduction and Management (DRR&M). The GAR cites a number of studies that make a business case for investment in preventative and mitigation measures (UNISDR, 2013, Ingirige et al., 2015). The effective allocation of limited resources for disaster mitigation, particularly in the post-2008 recession economic environment, is to a large extent dependent on decision makers having a better understanding of the impacts of hazard events. Due to complex processes like changing demographics, urbanization and climate change, natural disasters are increasingly affecting human societies making understanding impacts difficult (Guha-sapir et al., 2011). Over the years, disaster researchers have adopted various paradigms in trying to understand how hazards and disasters impact society, organizations and individuals with the recent consensus in the field on adopting a complexity science approach to understanding disasters (Simonovic, 2011, Smith, 2015). The complexity paradigm incorporates hazards and disasters within local processes and the larger global phenomenon (Smith, 2015). This requires scientists to understand impacts from a “systems of systems” view and not only of individual components – allowing us to study the feedback between individual components of a system and how the system behaves as a whole (Simonovic, 2011, Ramalingam, 2013). This approach is particularly useful at looking at decision making within an organization to understand how it was affected and what measures were taken for disaster risk reduction and mitigation (Mabry et al., 2008, Ramalingam et al., 2008, Hovmand, 2014, Inam et al., 2015).

In an ever more connected world, organizations are facing more diverse and ever-changing crisis and emergencies with even greater frequency than before that challenge the economic and social stability of the communities they are based in (Lee et al., 2013). These communities depend on organizations to plan for, respond to and recover from these events and disruptions. If these organizations are not prepared and resilient, then the community itself is not resilient to face the diverse threats from the increasingly turbulent environment (Dalziell and McManus, 2004). As stated above, the largest impact of disasters is on the private sector, and this loss is not only from physical

damages but also the impact of disruptions to supply chains, distribution networks, and finance streams (UNISDR, 2013, Ingirige et al., 2015). The ability of a community to respond to and recover from a disaster is strongly correlated to its economic capacity before the disaster event (Rose and Krausmann, 2013). Economic resilience plays an important role at all four stages of the disaster cycle – Preparedness, Response, Recovery and Mitigation (Rose, 2009). Therefore, the Resilient Enterprise is an important component of community resilience. Business organizations need to play a greater, more proactive role in mitigation, preparedness, response and recovery in the face of a diverse set of disaster events that could potentially disrupt their operations (Sheffi, 2007, Rose and Krausmann, 2013, Sheffi, 2015b).

For them to play a greater role, there is a need to understand these disaster impacts and how they affect private sector firms. Hence, more case studies are required looking at disaster impacts at the firm level to understand how individual firms faced crises so that lessons can be drawn from their experiences of those types of disruptions. Natural disasters, pandemics, economic recession, civil unrest, equipment failure and human error can all pose considerable threats to the continuity of an organization's operations. Thus, it is crucial to understand how each disaster event's disruption profiles might be similar to or different from each other to plan accordingly (Sheffi and Rice Jr., 2005). One of the main threats to organizational resilience that have not been covered enough in the literature is High Impact, Low Probability disruptions which are very difficult to prepare and plan for making it hard to justify large investments in advance for mitigation (Sheffi, 2015b). For large multinational firms spread over many locations and countries, being resilient is not just a theoretical concept but a strategic reality which needs to be understood if the firm is expected to succeed (Dalziell and McManus, 2004, Fiksel, 2015).

This study looks at a recent natural disaster in 2014, the Ebola Viral Disease (EVD) epidemic in West Africa, which can be classified as a High Impact, Low probability event for large private sector firms in the area (Sheffi, 2007). The research focuses on a mining firm in Liberia as a key case of a resilient enterprise that continued operations and production throughout the period (Fry, 2014). The research study looks at the literature on disaster impact research, nature of epidemics and organizational resilience. The case study considers if some of the factors identified there like systems for early detection, redundancy in supply chains, flexibility in management and the right corporate culture were present or not in the case study (Dalziell and McManus, 2004, Sheffi, 2007, Fiksel, 2016). The study also documents the experience of the firm during the period, using complexity methods that combine tools from the sociological school of disaster studies (Stallings, 2002, Phillips, 2014b) and systems analysis (Simonovic, 2011). Systems analysis is considered as a suitable method

to understand how the case study firm maintained operations and production while other firms were unable to do so during the tense period.

## **1.1 Background to the research**

In 2014 West Africa saw the largest EVD outbreak ever recorded with over 28,000 confirmed cases and almost 11,300 lives lost in the three most affected countries; Guinea, Liberia and Sierra Leone (WHO, 2016a). The morbidity and mortality impact of the 2014 EVD outbreak is far larger than all previous Ebola outbreaks combined (WHO and Team, 2014). In addition to the human loss, the outbreak had significant social and economic impact on the region. A World Bank study (Thomas et al., 2015) estimated that the Ebola-attributable gross domestic product (GDP) loss for the three countries in 2015 was approximately US\$2.2 billion. The individual country estimates for losses were reported at US\$240 million for Liberia, \$535 million for Guinea and \$1.4 billion for Sierra Leone (Thomas et al., 2015). The extractive industry plays a major role in the West African countries and the mineral sector is one of the major sources of tax revenues for governments in the region (World Bank, 2014). Extractive<sup>1</sup> projects are also at high risk of exposure to pathogens such as the Ebola virus, as their activities are frequently associated with increased contact between wildlife, humans and domestic animals - a major risk factor for the emergence of infectious diseases (Bausch and Schwarz, 2014). According to reports mining companies in the region have been considerably affected by the outbreak, particularly in Liberia, where firms like China Union, Ltd and Aureus Mining Inc. have either shutdown operations or have been hit with short and medium term stoppages in their operations, affecting long-term investment decisions (Thomas et al., 2015).

The unprecedented scale of the epidemic also triggered responses from the private sector, including extractive companies, to protect their employees, operations and business interests against these threats (Llamas et al., 2015). Many companies were compelled to act out of a sense of corporate social responsibility and participated in the Ebola response. Responses of mining firms to the outbreak are likely to be influenced by its perceived cost to them. Information on the economic costs of the outbreak on a business firm are not readily available, and businesses may use data on societal costs inappropriately (Farnham, 1994). Estimating economic impacts of a complex

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<sup>1</sup> Extractive industry is defined here as the operations that involve extraction of metals, minerals and aggregates from the earth, and the processing of extracted raw materials. Throughout the thesis the terms mining and extractive are used interchangeably.

phenomenon like natural disasters and epidemics is methodologically difficult and requires a careful assessment (Guha-sapir et al., 2011).

This study applies a retrospective firm-level single case study design to understand the impacts of the 2014 EVD outbreak on a mining firm and seeks to employ a systems approach to documenting the impacts. This study will explore the application of systems thinking, which uses qualitative methods like interviews and focus group discussions on helping contextualize the quantitative data taken from the finance department of the firm as an approach to understanding the hazard impacts for large firms in the private sector. Understanding the nature of hazard impacts across social, economic and built components of systems and the relationships between them and an organization embedded in that system is one of the motivations for using the systems approach. A systems approach can study resilience holistically, as more than just a sum of its parts. This is contrary to the current methodological practice in the sciences of dividing problems or systems into ever smaller parts and to study them individually for simple linear cause and effect relationships (Sterman, 2000, Sterman, 2006).

## **1.2 Justification of the research**

Several estimates of economic consequences of the 2014 EVD outbreak have projected a slowdown of macroeconomic growth as well as the decline in important sectors of the concerned economies (World Bank, 2014). While macroeconomic and sector-level estimates are important, it is also vital to estimate the economic impact of the EVD outbreak on large extractive firms at the firm level. This can be done by exploring the mechanisms of how an outbreak affects the operational business environment of mining firms in detail thus helping increase our understanding of their ability to continue business activities, i.e. be a resilient enterprise, even in the face of threats like emerging infectious diseases (EIDs). The extractive sector is an important industry to consider the larger economic impacts of the EVD outbreak as it contributes to a significant proportion of GDP in the affected countries in the 2014 Outbreak. Additionally, how they respond to the outbreak will be directly influenced by the perceived cost of the event to them, both in regarding the direct costs and indirect costs as well as the costs of the preventative measures that are adopted and the perceived effectiveness of those measures to them.

The Global Assessment Report of 2013 (UNISDR, 2013) shows that previous assessments of the economic impact of disasters in the decade of 2000-2013 had grossly underestimated the costs by



approximately 50 percent. These losses were in large part attributable to damages incurred by the private sector from direct and indirect impacts. The size of these impacts through damages to infrastructure, supply chain disruptions and loss in business continuity make a strong case for the need for the private sector to consider investment in risk management and mitigation strategies. These investments will in the long run be a benefit to both their business and the communities that they are a part of (UNISDR, 2013). Firms need to evaluate the relative costs and benefits of alternative mitigation and preparedness strategies to choose the one that is most efficient and cost-effective. Inaccurate or low reporting of costs, due to lack of reporting systems or other methodological issues, may lead to incorrect assessments of the economic consequences. This can result in an impact on the decision-making process of taking or not taking certain preventive actions, hence leading business firms to underestimate the true impact of a hazard or disruption (Ingirige et al., 2015) like the EVD outbreak to their business. There is a gap in the literature that looks at impacts of epidemics at the firm level. This study seeks to address that gap by focusing on one particular firm during the 2014 EVD outbreak and trying to understand in detail the chronology of the impacts as they occurred. This is documented largely through the eyes of the employees working during the epidemic as well as through the gathering of information and data on the types of the preventative measures undertaken during the period and their costs.

### **1.3 Research problem**

The large size and scope of the extractive sector in the Ebola-affected countries warrants a more detailed analysis of the impact and costs of the EVD outbreak incurred by the extractive firms that are traditionally not measured in the macroeconomic or sector level analyses. The impact and costs of the EVD outbreak estimated at the firm level could help in developing and designing interventions that may limit significant health (morbidity and mortality) and economic impacts of the EVD outbreak to extractive firms and the communities in which they operate.

In this context, the study aims to explore how the 2014 EVD outbreak has affected the operations of ArcelorMittal Liberia (AML); a major mining company operating in Liberia. The study aims to assess how the outbreak has affected the company's operation, and its preventive response to protect employees, contractors and maintain business continuity. By understanding the exact nature of the preventive measures and how costs have been realized for ArcelorMittal at the operational level, the study could provide insights into the different channels of impact of the outbreak that could affect a mining operation. The study will explore if AML could be classified as a Resilient Enterprise in the

face of this particular disaster by assessing its disruption profile through the experiences of employees at different levels of management and operations.

**Aim: To investigate the impact of a disruption from a natural disaster on the operations of a firm by using systems analysis methods and to determine if the firm was a Resilient Enterprise or not**

In this regard the specific objectives are:

- 1) **To identify the common attributes of a Resilient Enterprise and recognize if those attributes were present or not in the case study firm**
- 2) **To document the chronology of events and preventative measures/actions taken by the firm during the disruption event**
- 3) **To estimate the cost of preventative measures taken by the firm during the disruption event**
- 4) **To develop and validate a conceptual model with stakeholders that can be used to assess how various preventative measures (and attributes) could be used to enhance resilience**

## **1.4 Research methodology**

The research methodology section comprises of two sections that discuss; a) the underlying paradigm related to the chosen research design and strategy and b) the research process as indicated throughout the different stages of the applications of the research design during the study.

The discussion in the section first looks at the methodological paradigm chosen for the research starting with the complexity paradigm and then going to the data collection and analysis process. According to the complexity paradigm, and keeping in mind the research questions, the researcher had adopted systems analysis as the approach to the case study. Additionally, the single holistic case study is used in the research as it illustrates the key nature of the case under consideration as a resilient enterprise during a natural disaster event.

Within the case study, in-depth interviews (IDIs), focus group discussions (FGDs) and group model building sessions (GMBs) are used as the main data collection technique. The collected data was analyzed using a combination of code based content analysis and casual loop diagrams drawn from both the individual interviews and the focus group discussions. Two group model-building sessions were conducted to form the basis of a conceptual resilience model. Finally, this conceptual system dynamics model of organizational resilience was shared with senior management in a final validation workshop to visualize how they understood resilience.

## **1.5 Contribution to knowledge**

The study seeks to address a gap in disaster impact literature, particularly the impacts of epidemics, which focuses on the experience of the single firm, as a case study of a resilient enterprise. As mentioned above, a number of macro-level studies previously have been published, but very few case studies are focusing on the impacts of a single firm have been considered by researchers. To fully capture and understand the impacts of complex phenomena like natural disasters – a more detailed micro-level approach is needed where individual firm-level impacts are recorded. This can help in developing a more detailed understanding of the economic and social cost of disasters on firms and can be used to understand the decision-making process in these firms better.

Additionally, a large number of resilience frameworks have been published, some them focusing on organizations but fewer studies have been published looking to validate those frameworks. This study seeks to validate an existing framework from the literature on the characteristics of a resilient enterprise by searching for the presence or absence of those characteristics within the case study. It is thought by using a holistic systems approach to understanding disaster impacts would further highlight the importance of using such methods towards the better understanding of the complex phenomenon.

The findings of the research identified the presence of systems for early detection, redundancy in human resource use and to some extent supply chains, flexibility in management and a corporate culture that took new emerging threats to its operations seriously. This resulted in the firm taking well thought out preventative measures that contributed to its resilience and resulted in continued operations.

## **1.6 Synopsis of the thesis:**

This section discusses the structure of the dissertation with a brief summary of each chapter as indicated in the list of chapters as follows.

### **1.6.1 Chapter 1 – Introduction**

Chapter 1 sets the scene for the dissertation by introducing the research, the background and provides the justification for the study. This chapter also discusses the research problem followed by a brief discussion on the research methodology as well as providing a brief account of the expected contributions to knowledge.

### **1.6.2 Chapter 2 –Theoretical Background and Literature Review**

Chapter 2 covers the theoretical background and the literature review of the research particularly covering the literature on systems approaches to disaster management and the literature on resilience.

### **1.6.3 Chapter 3 – Methods and Methodology**

Chapter 3 discusses the research design and the steps of the research process. Within this chapter, a discussion on the complexity paradigm behind the use of systems analysis is discussed and why the systems approach is best suited for the research is explored.

### **1.6.4 Chapter 4 – Results and Analysis**

Chapter 4 will discuss the results of the study.

### **1.6.5 Chapter 5 – Discussion and Conclusions**

Chapter 5 will discuss the main findings and limitations of the study. It will also conclude with a discussion on recommendations as well as future work.

## **1.7 Summary**

The chapter introduces the research and provides the background, justification of the research, the research problem, the research methodology and contribution to knowledge followed by a brief summary of the whole dissertation. The next chapter covers the literature review.

## **CHAPTER 2      Theoretical Background and Literature Review**

This chapter looks at some of the theoretical background to the study by looking at the evolution of disaster perspectives or paradigms and their effect on disaster research in general and the emergence of complexity as the new disaster paradigm. The chapter also provides a theoretical for the complexity paradigm and the systems approach (which is covered in more detail in Chapter 3) and what that entails for disaster research into impacts as well as looking at organizational resilience and the attributes of a resilient enterprise. The chapter also looks into the specific nature of epidemics as disasters and their potential impacts at the firm level.

### **2.1 Understanding Disaster Impacts**

The study of hazards and how disasters have impacted human society over the ages has undergone an evolutionary process, one that has affected how researchers define and conceptualize natural hazard events and disasters. The following section first looks at those changing perspectives on disaster impacts and how these different “paradigms” affect the nature of investigation and approach to understanding disaster impacts and how this has broadly evolved over the history of human settlement till today.

#### **2.1 .1 Paradigms in Disaster Research**

The understanding of disasters and disaster impacts has broadly gone through several perspective changes or paradigm shifts that can be broadly highlighted throughout the history of disaster research (Smith, 2015). These paradigms determine the perspective from which scholars and researchers understand and interpret the impacts of disasters across human society, as well as how society can protect itself from these hazards. Hence, they are directly related to how societies have tried to tackle and address issues considering disaster risk reduction and their management. These can be broadly categorized as follows in Table 2.1 below: 1) the Engineering Paradigm, 2) the Behavioural Paradigm, 3) the Developmental Paradigm and, recently, 4) the Complexity Paradigm (Montz and Tobin, 2011, Coppola, 2015, Smith, 2015).

Period	Paradigm Name	Main Issues	Main Response
Pre-1950	Engineering	What are the physical causes for the magnitude and frequency of natural hazards at certain sites and how can protection be provided against them?	Scientific weather forecasting and large structures designed and built to defend against natural hazards, especially those of hydro - meteorological origin
1950-70	Behavioural	Why do natural hazards create deaths and economic damage in the Developed Countries and how can changes in human behavior minimize risk?	Improved short-term warning and better long-term land planning so that humans can adapt and avoid sites prone to natural disasters
1970-90	Development	Why do people in the Less Developed Countries (LDCs) suffer so severely in natural disasters and what are the historical and current socio-economic causes of this situation?	Greater awareness of human vulnerability to disaster and an understanding of how low economic development and dependency contribute to disaster
1990-	Complexity	How can disaster impacts be reduced in a sustainable way in the future, especially for the poorest people in an unequal and rapidly changing world?	Emphasis on the complicated interactions between natural and human systems, leading to improvement in the long-term management of hazards according to local needs

**Table 1. The changing disaster paradigms (Smith, 2015)**

Several scholars like Wisner et al. (2004) and Smith (2015) have indicated that for a large majority of human existence natural hazards were attributed as largely external, inevitable events based on the belief that catastrophic disasters were a result of “Acts of God.” Disasters were considered as a form of divine punishment for the populace. In many societies, this resulted in a fatalistic approach to understanding disaster impacts where the general populace had an attitude of acceptance. Often large-scale catastrophes would be assigned to the will of the divine and to act against this will was considered futile (Wisner et al., 2004). Unfortunately, this attitude can still be seen in many societies today (Schipper, 2010).

According to Covello and Mumpower (1985), as civilizations developed and populations increased rudimentary planning was undertaken by rulers and governing bodies to protect themselves against some of these events leading to the earliest recorded instances of disaster planning in Mesopotamia and Egypt for earthquakes and famine (Covello and Mumpower, 1985). Even later, as construction and building techniques improved, these civilizations began building large-scale public

infrastructures. Public works, like dams and flood defenses on rivers (first used almost 5,000 years ago) and adaptation in building techniques of structures for earthquakes (first used almost 2,000 years ago). These mitigation and adaptation measures were undertaken with the intention to limit the damaging impacts of natural disasters indicating the beginning of a very broadly defined perspective called the engineering paradigm (Smith, 2015).

According to Wisner et al. (2004), despite the continued importance of divine punishment in explaining disaster events for the general public, the engineering paradigm grew to become the predominant perspective used throughout most of human history even up to now in the modern times (the 1950s). This approach primarily looked at “hardening” of built structures or the building of large-scale public works like flood defenses and civil defense actions like mass evacuations during emergencies (Perry, 2007). As scientific knowledge accumulated and technology developed new tools were made available. For example, tools to understand better weather leading to advances that improved metrological analysis and forecasting of storms. The availability of these tools further improved the ability of societies to protect themselves reinforcing the need for science-based government agencies to provide essential services for the populace (Smith, 2015). The engineering paradigm is still a very important part of disaster sciences and continues to provide the basis of most preparedness and emergency response strategies which are essential components of any disaster risk reduction and management initiative (Wisner et al., 2004, Smith, 2015).

Although the engineering paradigm prevailed for a long time, there were some limitations that were first pointed out by social scientists in the twentieth century (Wisner et al., 2004). This paradigm was first heavily criticized by geographers like Gilbert White (1945) in his seminal paper on “Human adjustments to Flood” and then later by sociologists like Kates (1971) and Burton et al. (1978) who advocated for a different approach based on the new behavioral paradigm. This perspective arose from the view that there was a limited understanding of disaster planners and researchers on the link between natural hazards and the people those hazards affected both directly and indirectly (Wisner et al., 2004). Gilbert White and his followers began to pose the question about the difference between natural hazards on their own and disasters as social phenomenon emphasizing that human actions and behavior are primarily responsible for hazards becoming disasters (Smith, 2015). They advocated that instead of trying to regulate and control nature through more and more expensive engineering works – people should adapt their choices and behavior rather than physically competing with nature (White et al., 1975). The application of the behavioral paradigm led to a more blended approach where both engineering approaches, such as stronger building regulations and early warning systems, were combined with behavioral approaches like insurance and land planning

to limit hazard impacts (Burton et al., 1978). This combination of approaches was a more effective approach to understanding both the impacts of disasters and the ways that those impacts could be limited across the population, at least this was the view in the industrialized and developed world where it was mostly applied.

In stark contrast to this there was little progress in reducing disaster impacts in the least developed countries where most the world population lived and in the 1970s a new radical approach called the developmental paradigm was theorized to explain the experience of these underdeveloped countries (Wisner et al., 2004, Perry, 2007). The developmental paradigm arose from the work of social scientists that argued that catastrophic disasters continue to occur in these regions primarily due to the marginalization of disadvantaged people as an outcome of the global economic structure (Perry, 2007). This paradigm advocates that economic dependency increases the frequency and impact of natural hazards in the developing countries context and that poverty increases the magnitude of those impacts. Accordingly, under this paradigm the concept of vulnerability, where poverty plays a key role, became a central factor in determining the impact of disasters (Wisner et al., 2004). Contrary to the behavioral paradigm, it argued that there were long-term root causes of disasters (not just from the hazard) and that there were limits to the actions individuals could take that were forced by powerful actors with financial and political interests (Smith, 2015). This paradigm was, perhaps, best embodied in the writings of Wisner et al. (2004) where they argued that "...disasters are the outcome of a direct clash between the socio-economic processes that create human vulnerability and the natural processes that create geophysical hazards (Wisner et al., 2004).

This paradigm helped draw attention to the crucial role that poverty plays in disasters due to the link between poverty and greater vulnerability of populations indicating that geophysical processes are not the only contributors to disaster impact (Wisner et al., 2004). The emphasis in poverty highlighted the importance of understanding the underlying socio-economic conditions of the population under consideration and indicated a need to conduct vulnerability analysis along with geophysical analysis for understanding disaster impacts (Perry, 2007). Disaster research experts and scholars like Perry (2007) and Smith (2015) indicated that in the late twentieth century both the behavioral paradigm and developmental paradigm were being used by differing groups to provide a framework for understanding and addressing disaster risk and impacts. They both argued that those scientists with physical science backgrounds continue to use the hazard-specific behavioral paradigm for their analysis. Meanwhile, sociologists and anthropologists used the development paradigm to



look at an all hazard, disaster based view that looked at failings within the political and social systems as key components to understanding disaster impact (Perry, 2007, Smith, 2015).

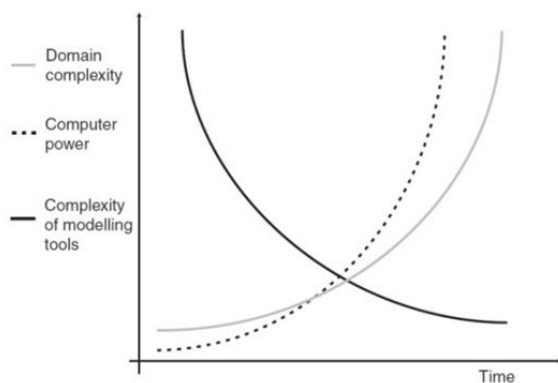
While both paradigms contributed to the development of tools and methods that greatly increased the overall understanding of disasters and their impacts, several scholars such as Dyness (2004) and McEntire (2004), drew attention to the potential weaknesses in both paradigms when applied singularly. McEntire (2004) argued for the use of a more holistic integrated approach that viewed disasters as the result of complicated interactions between many systems – physical, socio-economic, technological and organizational (McEntire, 2004).

Criticisms as those cited above and an accumulation of experience where governments and people still underestimated or misunderstood disaster impacts led to disaster management researchers and practitioners to adopt a more interdisciplinary approach to understanding disaster impacts. This combination of the natural and social science approaches in a more holistic framework resulted in the current paradigm used for understanding disasters and their impacts called the Complexity paradigm (Simonovic, 2011, Smith, 2015). This paradigm uses a “system of systems” approach that shifted the emphasis away from preparedness and response to incorporate mitigation and long-term recovery with issues such as vulnerability and resilience (Simonovic, 2011). The new Complexity based approach emphasized the importance of sustainability as a key factor in developing disaster strategies (Mileti and Myers, 1997, Smith, 2015).

Complexity Science approaches to disasters propose that these impacts are best understood by looking at how components of a system interact with each other rather than the studying components just by themselves – this is even more important when looking at complex situations such as disasters (Smith, 2006). Understanding these interactions as system states can lead to valuable insights into “emergent behavior” – a state of the system that develops spontaneously without any planning indicating that the system might exhibit signs of regulation or self-organization (Johnson, 2009). This approach can be used to classify disruptions not as chaotic events but rather as shifts in the interactions within a system so that the system starts to operate differently either temporarily or even permanently depending on the extent of the impact (Ramalingam et al., 2008, Simonovic, 2011). Complexity Science can bridge the gap between the previously mentioned disaster paradigms by highlighting the impacts of a disaster as the outcome of interactions within and between the natural, built and human environment systems. This approach also looks at the importance of sustainability to the understanding of vulnerability and resilience, concepts that are covered in more detail in subsequent sections (Smith, 2015).

### 2.1.2 Complexity Paradigm and Disaster Management

Simonovic (2011) has indicated that the complexity paradigm is going to be most influential in the formation of research methods and tools for the future in Disaster management - as shown in Figure 1 below. He attributes three components to this change in perspectives that explain why this paradigm is playing such a crucial role in the development of tools and methods that are more suited to the analysis of the dynamics surrounding disaster resilience before and during hazard shocks. Tools and methods such as Social Network Analysis (SNA), Systems Thinking & System Dynamics (ST & SD), Discrete Event Simulation (DES) and Agent Based Modelling (ABM) (Simonovic, 2011).



**Figure 1. The Complexity Paradigm. Source: Simonovic (2011)**

The first component of the complexity paradigm is that disasters are increasingly becoming more and more complex which Simonovic (2011) calls Domain Complexity. The other two components of the complexity paradigm are related to the technical advances made over the last half-century both in the processing power of personal computers and in the ability of scientists to use that computing power to develop methods and tools. These changes have reduced the difficulty in using methods developed relatively recently such as SNA and ABM, hence making these tools more accessible to more researchers. The spread of these tools has resulted in their application to complex phenomena like epidemics, stock markets, traffic congestion and variability in weather patterns due to climate change (Johnson, 2009, Ramalingam, 2013).

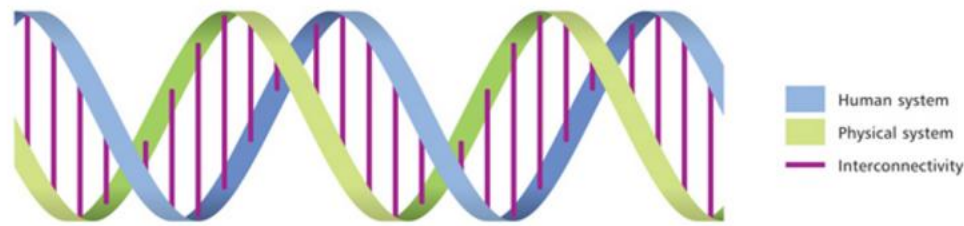
The phenomenon of climate change impacts and extreme weather events perhaps best illustrates the tension between those that adhere to a linear cause and effect understanding of the world and those that utilize a complexity perspective (Johnson, 2009). Harrison and Sundstrom (2007) indicate that much of the skepticism that exists on climate change is the result of how people think about cause and effect relationships. The limitations of reductionist science approaches where cause and

effects are presented through linear relationships and controls can be theoretically applied cannot cope with the complexity of the huge numbers of variables, the large number of interactions and feedbacks involved. The way researchers think about complex phenomenon determines the solutions they advocate and if their mental models are incorrect about how they generate evidence then how confident can they be about the validity of the policy based on that evidence. Therefore, climate change is a complex phenomenon that is contributing to an increase in both complexity and uncertainty in disaster management. Hence researchers need to develop and use tools more suitable to understanding complexity for instance social network analysis, agent-based modeling, discrete event simulation, or as used in this research, systems analysis (SA) (Simonovic, 2011, Ramalingam, 2013).

It is pertinent to note that unlike paradigms in other fields, like economics or psychology, new hazard disaster paradigms do not mean a total rejection of previous approaches but rather an evolution of the approach. In this case, the paradigm shifts are more related to the shift in emphasis or focus of analysis and how that affects how researchers interpret hazards as disasters and their impacts (Perry, 2007). Another point worth repeating is that the complexity paradigm emphasizes the interdisciplinary nature of disaster research by encouraging natural and social scientists to work together to understand the interconnections between social and physical systems and the impacts on them both (Simonovic, 2011). Finally, the paradigm also encourages investigators to look at disaster impacts as a chain of events that affect resilience and intervening in or breaking this chain of events could either reduce or even prevent impacts from the hazard – effectively stopping it from becoming disasters and catastrophes (Smith, 2015).

### **2.1.3 Complexity and Disaster Causation**

To better illustrate how complexity science interprets disasters and their impacts, Petley (2009) has developed a DNA model of complexity in disaster causation. In this model, Petley (2009) has explained how the physical systems and social systems can be depicted as two strands while the interactions between them represent the numerous interconnections between them which he calls the Coupled Human-Environment System (CHES) – as shown in Figure 2 below.



**Figure 2. DNA strand model of complexity and disaster causation (Petley, 2009)**

For example, the other paradigms mentioned previously focused on one strand or the other, but the complexity paradigm gives both strands an equal importance and stresses the interconnections between them. He has stated that during disasters the impacts are a result of the pattern of interconnections between the physical and social strands (Petley, 2009). For example, during complex disasters such as an epidemic, interactions can take place in the affected population (inside the social system), within the disease outbreak (complexity of the virus itself), and between the organizations embedded in the population (within the complexity of the coupled physical and social systems). The complexity of epidemics will be touched on in a later section below.

Accordingly, impacts could vary because the interactions between individuals, private sector firms, emergency agencies and government organizations are socially complex and can have different outcomes due to the level of communications or interconnections between them (Comfort, 1999). Pelling (2003) notes that those communities with higher levels of social interaction or cohesion often have more effective disaster response and that technology can play a major role in developing these interactions (Pelling, 2003). Private sector firms can play a vital role in risk communication and developing social cohesion before, during and after a disaster event to help limit disaster impacts (MARSH, 2007). Communication plays an important role in forming the linkages between the different nodes of the system and it is vital that communications remain functional during a disaster for effective coordination and response (Simonovic, 2012).

## **2.2 Resilience Theory in Disaster Management**

Resilience as a concept has received considerable attention both in academic literature and practitioner circles and has generated considerable debate on its definition, applicability, and use (Manyena, 2009). It was first described in the literature as the capacity to absorb, adapt and then recover in the biological sciences about the stability and adaptation of organism populations to change within ecosystems (Holling, 1973). Since then the concept of resilience has emerged from the

discourse on sustainability science and vulnerability that took place during the 1970s-90s when disaster researchers were considering the shift from behavioral and developmental paradigms to the more holistic complexity paradigm (Smith, 2015). Resilience became an important aspect of community-based disaster risk reduction where it was linked to the capacity of a community to overcome its vulnerabilities to hazards. International agreements, such as the Hyogo Framework for Action 2005-2015, required that communities work towards building their capacities to respond to and recover from hazard events hence improving their overall resilience (Manyena, 2006, Manyena, 2009, IFRCRCS, 2011).

Arguably the most used definition in the context of strategic objectives such as those of the Hyogo Protocols and community resilience in general is the United Nations International Strategy for Disaster Reduction definition (UN/ISDR, 2009). UN/ISDR has defined resilience as: "...the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions." (UN/ISDR, 2009). The elements contained in this and other definitions from the literature are covered in more detail below in the next section.

Despite widespread use of the term resilience, there has been some criticism leveled at its use in the literature. For example, some critics of the term indicate that it is a derogatory "colonial" term implying the difference between haves and have-nots regarding the availability of material resources only. Proponents of this debate argue that it only serves to highlight the resilience differences between the developed and developing world as a case for western style modernization of "primitive" non-resilient societies (Hornborg, 2009) while others have argued that its meaning is vague and can cause more misunderstandings (MacKinnin and Derickson, 2013). Manyena (2006) has also noted that there is a linguistic ambiguity attached to the term which hampers its application in the developing world (Manyena, 2006).

Regardless of these criticisms, the term has gained substantial use in sustainable development and aid circles (Resilience Alliance, 2007) resulting in a vast literature of articles detailing methods, frameworks, and models. This literature mostly focuses on qualitative conceptualizations of disaster resilience for individuals, organizations, and communities - though there are notable exceptions to this (Cutter et al., 2010). Despite considerable attention and research over the past decade, there is still a need among researchers to use latest research methods and techniques such as complexity methods. Ramalingam (2013) and Simonovic (2011) both argue for the need to use complexity methods to understand better the dynamic nature of resilience at different levels of society, community, firms and individuals and the interactions and feedback between them for better

evidence-based policy (Simonovic, 2011, Ramalingam, 2013). Complexity methods, such as systems analysis, can help in providing a framework for documenting and analyzing these interactions between components and help disaster researchers better understand the capacity of a community, or an organization within that community, to cope with and recover from impacts of natural disasters.

### **2.2.1 Review of Resilience Narratives and Definitions**

This section looks briefly at some of the narratives and definitions of resilience in the literature, particularly those that are used for organizational resilience and considers some of the elements common to the general resilience definition and how that helps in conceptualizing organizational resilience.

The UN/ISDR definition stated above is fairly recent and has found widespread use among disaster management professionals and aid agencies, yet there is still a wide range of perspectives in the literature leading to a large number of definitions. In an early review of the term resilience in natural hazards, Klein et al. (2003) note that there was little consensus on its exact wording nor its application. Since then the literature has grown considerably across different contexts of the disciplines of the researchers, as well as the scope and scale of the studies. Norris et al. (2008) mention 21 different definitions and again although they note the same lack of consensus in the literature they also note several common perspectives among the definitions. They note that some common elements have begun emerging such as the links between adaptation, bouncing back better, resilience and vulnerability (Gallopín, 2006, Norris et al., 2008).

More recently Bhamra (2015) also conducted an extensive literature review of resilience definitions looking at the perspectives, concepts, and methodologies used in peer-reviewed published work. From this review of over a hundred articles, Bhamra (2015) also noted that despite the variety of disciplines there are some common threads that can be seen to be constant within most perspectives or approaches to the concept of resilience. Accordingly, he specifies that the concept of resilience is linked to the stability of a system, with respect to its purpose, as well as the capacity of a system to return to a pre-disruption state after a hazard event (Bhamra, 2015). While the literature covered in these reviews mostly looks at community level resilience, Bhamra (2015) has noted how several scholars have defined resilience at the organizational level as shown in **Table 2** below.

**Table 2. selected definitions of organizational resilience. Adapted from Bhamra (2015)**

<b>Author</b>	<b>Context</b>	<b>Definition/Characteristics</b>
<b>Horne and Orr (1998)</b>	Organizational	Resilience is the fundamental quality to respond productively to significant change that disrupts the expected pattern of events without introducing an extended period of regressive behavior
<b>Patton et al. (2000)</b>	Disaster Management	Resilience describes an active process of self-righting, learned resourcefulness and growth. The concept relates to the ability to function at a higher level psychologically given an individual's capabilities and previous experience.
<b>Bruneau et al. (2003)</b>	Disaster Management	The ability of social units to mitigate hazards contain the effects of disasters when they occur and carry out recovery activities that minimize social disruption and mitigate the effects of future events.
<b>Hamel and Valikangas (2003)</b>	Organizational	Resilience refers to the capacity to continuous reconstruction.
<b>Dalziell and McManus (2004)</b>	Organizational	Resilience is a function of an organization's situation awareness, identification, and management of Keystone vulnerabilities and adaptive capacity in a complex, dynamic and interconnected environment.
<b>McDonald (2006)</b>	Organizational	Resilience conveys the properties of being able to adapt to the requirements of the environment and being able to manage the environment's variability
<b>Linnenluecke and Griffiths (2010)</b>	Organizational	The capacity to absorb impact and recover.
<b>Braes and Brooks (2011)</b>	Organizational	Resiliency relates to organizational characteristics and resilience refers to a dynamic development process.

Of the selected definitions above, the definition put forward by Dalziell and McManus (2004) has been one of the more comprehensive ones as it contains most of the elements that need to be explored to understand and assess an organization's ability to cope with disruption events. This definition seems to resonate closely with the attributes of a resilient enterprise as detailed by Sheffi and Rice Jr. (2005) which is covered in slightly more detail below.

Additionally, Srivastav and Simonovic (2014) review a number of definitions across these multiple perspectives and note that they contain the eight key elements. These are 1) the ability to recover quickly, 2) buoyancy, 3) the property of assuming back its original shape, 4) elasticity, 5) ability to withstand stresses, 6) capacity for collective action in response to an event, 7) the capacity to absorb shocks, and 8) the capacity to adapt existing resources and skills to new situations and operating conditions (Srivastav and Simonovic, 2014).

Finally, in another example of a review of resilience definitions, Smith (2015) identifies three basic strands the definitions of resilience in the literature. These are 1) the amount of stress that a system can absorb in a sustainable fashion, 2) the potential for self-organization and recovery within the

system and 3) the ability to use local experience and skills to adapt and improve in the future (Smith, 2015).

Bhamra (2015) and (Smith, 2015) both have indicated that resilience and its definitions have naturally been influenced by factors such as disciplinary perspectives as is expected but also by the overall shift in disaster paradigms. These paradigms have contributed to the narratives of disasters and disaster impacts that have emerged over the years in the literature (Bhamra, 2015, Smith, 2015).

Raco and Street (2012) also indicate that these varying perspectives have created selective narratives around the concept of resilience – each based on the context and disciplinary background of the researcher or research group. For example, the “ecological” perspective was represented in the writings of (Adger, 2000, Folke et al., 2002) and the “engineering” perspective in the writings of (Bruneau et al., 2003, Bruneau and Reinhorn, 2007). Both perspectives have contributed to the development of resilience as a concept, and subsequent researchers have benefited from the works of these pioneering academics (Peck and Simonovic, 2013).

It is interesting to note that building on Holling’s (1973) original work, Gallopin (2006) has emphasized stability as a key feature of community/organizational resilience (Gallopin, 2006). He writes that stability is a function of vulnerability and a system’s capacity to respond, or in other words, its adaptive capacity thus enabling us to conceptualize resilience as a subset of these two features. More recently, Simonovic (2016) has warned that disaster managers and professionals that focus solely on vulnerability analysis may lead organizations to focus only on risk management and not adaptive capacity hence underestimating the value of resilience research (Simonovic, 2016). The distinction between vulnerability, resilience and adaptive capacity is further covered below in another section.

Although there is considerable literature on the links between vulnerability and resilience (Dalziell and McManus, 2004, Adger, 2006, Gallopin, 2006), Bhamra (Bhamra, 2015) has noted that there is a distinct lack of empirical case studies in the field. He points out that there is a gap in the literature to support the evidence base for a conceptual link between them, especially at the organizational level.

In addition to these narrative perspectives, Shaw and Maythorne (2013) have identified, what in their view are the two main contrasting narratives in the resilience literature based on the “recovery” discourse and the other on the “transformation” discourse. Recovery discourse focuses on the resistance to events and a subsequent return to pre-event operations as soon as possible,



and this has been the focus of much literature on disaster management especially true of research designs focussing on the phases of response and recovery (Nigg et al., 2006, Phillips, 2014).

The transformation discourse, on the other hand, explicitly recognizes that the impact of a disruption event may be larger than the current capacity of a system and hence the impact is not absorbed and requires the system to adapt in response to the event (Shaw and Theobald, 2011). This narrative borrows elements from the ecological narrative to suggest a “living” and learning system (Bhamra, 2015).

Finally, another perspective that has pushed resilience research toward a specific narrative is the security perspective of public response agencies and their concern for building preparedness into communities in response to terrorist events or disruptions (Coaffee, 2013). This narrative seeks to build resilience as a long term goal for communities and enhances the system’s capacity to respond to disruptions indicating a pro-active approach rather than a reactive approach to disaster management (Bhamra, 2015). By pro-actively seeking to improve system resilience, this perspective places the responsibility of adaptation and response on the impacted systems or communities. This highlights the importance of research on preventative measures and the allocation of scarce resources for mitigation and preparedness (MacKinnin and Derickson, 2013). This narrative also fits with the direction of the GAR (2013) and its emphasis on the private sector adopting a more pro-active role in disaster risk reduction through mitigation and preparedness (UNISDR, 2013).

This distinction between proactive and reactive approaches is particularly true of the preventative measures taken by private sector firms with regards to pandemic preparation and response (Llamas et al., 2015). International health response agencies, for example as the WHO and USAID, have been trying to make the investment case for long-term investments into local health systems rather than the quick and short term (often more expensive) reactive responses that typically take place in response to an outbreak (MARSH, 2007).

Additionally, concerning notable research into organizational resilience, the research stream developed at the Multidisciplinary Centre for Earthquake Engineering Research (MCEER), based at the University of Buffalo in the US, shows great potential for application in this field. MCEER has used the framework to assess the impact of seismic and hydrological events on organizational entities such as hospitals, power plants, and other key infrastructures and has an all-hazard approach (Bruneau and Reinhorn, 2007, Vugrin et al., 2011).

This approach is suitable for adaptation to the organizational level. Accordingly, as an extension to this research stream, Simonovic (2016) has derived the following definition of organizational resilience having five components as follows:

- 1) the minimization of losses, damages and business disruption;
- 2) maximization of the ability and capacity to adjust when there are shocks to systems (finding adaptation strategy);
- 3) returning systems to a functioning state as quickly as possible;
- 4) recognition that resilient systems are changing in time and space; and
- 5) acknowledgment that the post-shock system performance levels may not be the same as pre-shock levels (Simonovic, 2016).

After considering these elements, he proposes the following definition of organizational resilience; “...the ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a system disruption in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its system performance or its essential basic structures and functions (Simonovic, 2016).”

From the different definitions and reviews discussed briefly above it can be seen that there is a considerable focus in the literature on theoretical frameworks and conceptualizations and very little empirical work that apply or test these frameworks in the organizational context (Srivastav and Simonovic, 2014). Bhamra (2015) has concluded that there is a need within the literature to apply methods such as case studies or survey methodologies to validate these frameworks and definitions to form a wider base in the literature on organizational resilience.

### **2.2.2 The Systems Approach to Organizations**

The systems approach, which will be covered in more detail in the next chapter, is used in many disciplines especially in ecology, physics, business management, urban planning and sociology (Senge, 1994, Sterman, 2000, Meadows, 2008, Gharajedaghi, 2012). The field is currently finding value in other fields as well such as public policy, health and now disaster management (McManus, 2008, Simonovic, 2011, Ramalingam, 2013). The systems approach to understanding resilience at the organizational level has been adopted by several scholars over the last decade (Dalziell and McManus, 2004, Starr et al., 2004, McManus, 2008, Srivastav and Simonovic, 2014). According to

McManus (2008) the systems approach to organizational resilience was first highlighted in the seminal work of Jeff Horne (1997) in his article "A New Direction: The Coming Age of Organisational Resilience." and was further elaborated upon in a follow-up publication "Assessing behaviors that create resilient organizations." (Horne and Orr, 1998) which formed the basis of some of the research on attributes of resilient organizations and enterprises published later (McManus, 2008).

As mentioned in more detail in the next chapter on Methods, systems thinking uses a holistic point of view where the relationships between elements in a system are more important than the elements themselves. Johnson (2009) describes that as the number of elements in the system rises and the resulting behavior of the system becomes non-linear, then the system becomes complex, or in other words, there is an increase in the domain complexity (Johnson, 2009, Simonovic, 2011).

The systems approach requires researchers to carefully list the elements in the organizational system, first those elements that are external and then those elements within the firm, to understand how behavior might be influenced (McManus, 2008, Gharajedaghi, 2012, Srivastav and Simonovic, 2014). This approach is consistent with the complexity paradigm detailed above and requires researchers to explore both the external environment (i.e. suppliers, competitors, markets) and the internal environment (i.e. organizational processes, supportive technologies and employee relationships) (Gharajedaghi, 2012). This is especially true when looking at disruptions in the organizational system and the vulnerability of the system to disruptions and shocks.

McManus (2008) discusses how disruptions could be studied in organizational systems through an understanding of disruption types and the vulnerability of the organization to those disruptions and uses a classification initially proposed by Charles Perrow (1984) for technological systems (McManus, 2008). Perrow (1984) has defined two interrelated terms for technical systems in organizations, that can also help disaster researchers understand disruptions and vulnerability, by looking at 1) the Interactive complexity in the systems and 2) the loose or tight coupling of systems (McManus, 2008).

Interactive complexity refers to the unknown sequence of events that occur in interconnected systems that cannot be observed directly and hence are not planned for by the organization. This could be due to the problem or disruption arising in other systems and that the processes within the organization were not able to detect the problem and act in time (McManus, 2008).

Loose and tight coupling denotes the extent to which the parts, or elements, of the system, are close to one another. In a tightly coupled system, the components of the system or organization are very closely linked to each other, and a change in one part of the system quickly has an impact on

another part. On the other hand, loosely coupled systems are linked but the performance of one element in the system is not too dependent on the other. Meaning that the system has the capacity to absorb disruptions and still function overall (McManus, 2008).

Perrow's approach (1984) allows researchers to understand disruptions as "system failures" that can be unpredictable and potentially cascading in nature. McManus (2008) indicates that these terminologies can help researchers to understand critical failures or system disruptions by assessing their key vulnerabilities across both internal and external environments. This is especially true for business enterprises that can usually be classified as tightly coupled and with high interactive complexity (Dalziell and McManus, 2004, McManus, 2008).

There are several examples in the literature of such disruptions occurring in business enterprises such as the 1984 Bhopal chemical plant disaster in India (Shrivastava, 1992) , the Exxon Valdez oil spill in 1989 (Grabowski and Roberts, 1996), Toyota suppliers after Great East Japan Earthquake (Sheffi, 2015a), and others. For researchers to assess how these disruptions affect the organization at the enterprise level, they need a framework to conceptualize vulnerabilities and disruptions, and the next sections will look at how some scholars in the literature have done this conceptualization.

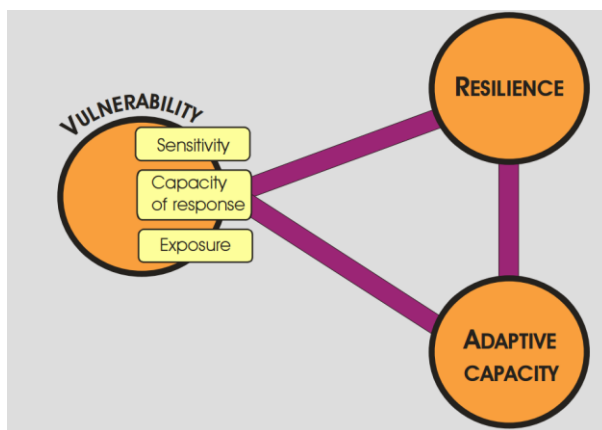
### **2.2.3 Conceptualizing Vulnerability at the Enterprise level**

As mentioned in the discussion above on the narratives and elements of resilience definitions in the literature - two elements that require greater understanding while conceptualizing the resilient enterprise are vulnerability and the system's capacity to respond, i.e. adaptive capacity. This section takes a closer look at these two concepts at the organizational level while also describing how these concepts will be used in this research.

Over the last few decades, disaster research has been emphasizing the need to look at the vulnerability of social systems and their capacity to bounce back and recover after a hazard. Vulnerability is a broad concept but can be linked to the susceptibility of a system to harm (Adger 2006). UN/ISDR (2009) have defined vulnerability as: "...the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effect of a hazard." Dalziel and McManus (2004) have described vulnerability as inherently complex and subject to a range of effects that are dynamically linked to the capacity of response of the system as well as its ability to withstand exposure (Dalziell and McManus, 2004, Gallopin, 2006). This understanding includes both

the sensitivity and the exposure of the system to the hazard or disruption and forms the basis of conceptualizing the interconnections between these complex concepts.

Gallopín (2006) has described these linkages between vulnerability, adaptive capacity and resilience in detail helping researchers conceptualize how they are related to each other as a part of a system. He has described vulnerability to have three components; sensitivity, the capacity of response and exposure – as shown below in **Figure 3**. Furthermore, Gallopín has conceptually linked resilience and adaptive capacity as subsets of the capacity of response within the overarching concept of vulnerability, hence describing how this determines the dynamic (over time) role resilience plays in vulnerability.



**Figure 3. Resilience as a function of Vulnerability and Adaptive Capacity (Gallopín, 2006).**

In this model, vulnerability is described as a capacity to maintain the structure of a system, i.e. in organizational terms, this relates to the function and purpose of that system. Regarding this research, the function or purpose of a system is described as the system performance. Additionally, resilience is shown as the capacity to recover or bounce back from a disruption while Adaptive capacity is the ability to evolve and to cope with the changing environment and the ability to expand the range of response or mitigation options (Gallopín, 2006). In this research, these options are identified as preventative measures that the system can use over time. Preventative measures enhance the adaptive capacity of an enterprise and hence contribute to greater overall resilience (MacKinnin and Derickson, 2013).

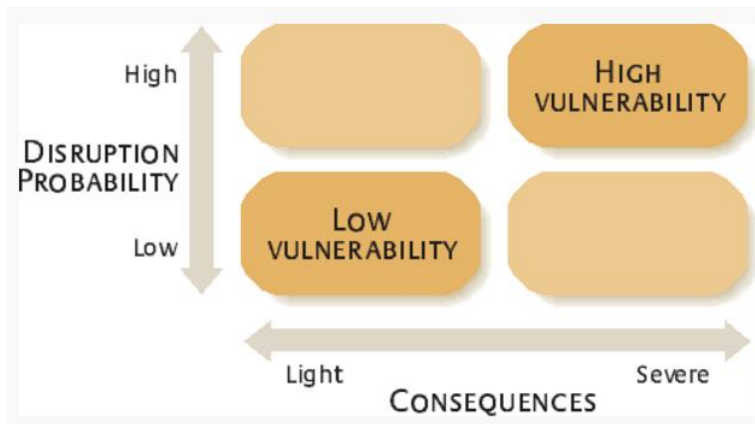
Accordingly, the adaptive capacity of a system also includes the learning aspect of system behavior or activities that occur before, during or after a disruption event. Folke et al. (2002) have linked this

learning behavior to the ability of an organization to deal with unforeseen circumstances – effectively an organization’s ability to deal with the unknown (Folke et al., 2002). This indicates that organizations that are resilient will not be passive in relation to the external environment and will pro-actively develop and apply knowledge about the challenges they face in the social, economic and ecological environments (Folke et al., 2002, Bhamra, 2015).

This understanding of adaptive capacity links resilience of the enterprise with its general competitiveness and long-term sustainability as well. As mentioned previously, Gallopin (2006) has shown several influences on this view of vulnerability and resilience from both the ecological and the sustainability perspectives (Gallopin, 2006).

The other two sub-components of vulnerability, exposure, and sensitivity, also require further description as they are crucial to understanding the different threats facing an organization as well as the consequences of those anticipated threats. Sheffi and Rice Jr. (2005) have specified that understanding system vulnerability involve two processes - finding out what the level of exposure is and how sensitive the system is to that exposure. Sheffi (Sheffi, 2007) goes on to state that these concepts can be explored by answering the following three questions: 1) What can go wrong? 2) What is the likelihood of that event happening? and, 3) What are the consequences of that happening? (Sheffi, 2007).

Based on extensive research into resilient organizations (Sheffi and Rice Jr., 2005, Sheffi, 2007) that look in detail at the questions raised above, Sheffi (2007) has developed a very useful and versatile tool called the Organizational Vulnerability map. This vulnerability map allows stakeholders to qualitatively visualize the key vulnerabilities facing a firm and rank them according to the likelihood of occurrence or the disruption probability (exposure) and the consequences of the impact (sensitivity) – as shown below in **Figure 4**. Each firm can form a vulnerability map corresponding to its own perception of threats and impacts forming a qualitative assessment of disruptions that might impact the firm and can be used to prioritize planning and allocate scarce resources (Sheffi, 2007).



**Figure 4. The vulnerability map (source: Sheffi, 2015b)**

These maps need to be frequently updated as new threats emerge and old ones become redundant as the likelihood of these threats would change according to the firm’s actions such as preventative measures before a disruption (Sheffi and Rice Jr., 2005). These preventative measures that may or may not be taken can lead to changes in either the likelihood or the impact of a disruption changing and this can be directly lead to an increase in the resilience of the firm (Sheffi, 2007). For instance, human resources policy might affect the number of people being exposed (at the workplace) to a virus, and this may result in increased resilience to worker infection during a flu epidemic.

Using tools such as the vulnerability map, a firm can identify many disruption events and classify them according to the likelihood vs. impact criteria. For instance, High Impact, High Probability (HIHP) events are events that are usually handled by the risk management department where it is their job to plan for and mitigate against events that may frequently cause disruptions in a firm’s operations (Sheffi, 2015b). On the other hand, High Impact, Low Probability (HILP) events can be of great concern to firms as justifying large investments on preventative measures might not be easy to do when the threat is unlikely to materialize in the short term (Sheffi, 2015b, Fiksel, 2016). Some of these events may not even be on the firm’s risk horizon and may be called “Black Swan” events where both firms and governments are not prepared because they had failed to consider for this type of disruption and these can have devastating consequences (Fiksel, 2016). An example of these can be the September 11 attacks in 2001 (9/11), the SARS outbreak in 2003 and the Ebola outbreak in 2014.

## **2.2.4 Attributes of the Resilient Enterprise**

To recap, the previous sections have looked at various definitions of resilience, looked at the components of these resilience definitions and commented on the narratives of resilience that influence researcher perspectives. This section brings together the previous discussion by identifying attributes of a resilient enterprise from the literature identified in the above sections and synthesizes them into a framework for analysis for this study.

With the different elements or components described above, it is important to realize the context in which resilience is conceptualized. In the case of this research, it is specifically to explore and understand what attributes of a resilient enterprise were present in the case study or not. These attributes are key to highlighting the existence of best practices that exist within successful enterprises. Research into these success case studies can show what it takes to be demonstrably resilient in the face of disruptions and help other enterprises to use these frameworks for understanding their resilience.

Thus, resilience may be used to understand and measure the ability of a system, or an element within that system, to restore function but perhaps more importantly for private sector firms looking to invest in preventative measures - resilience may be used to conceptualize various adaptation measures. Any tool that can help in the ranking of these measures based on the cost and the perceived benefits would be useful for decision makers within these organizations.

Consequently, many organizations use scenario planning to model the changes arising from the consequences of high impact risks such as loss of critical infrastructure, terrorism, and epidemics as well as civil and worker unrest (Dauelsberg and Outkin, 2005). Dauelsberg and Outkin (2005) have shown that simulation models like system dynamics models can deliver insights into the direct effects of these types of disruptions as well as their ancillary or cascading effects. These models can also show impacts on other parts of the systems such as supply chains which may lead to public panic and hoarding behavior or adverse reactions from governments (Dauelsberg and Outkin, 2005). Both these external factors – the behavior of the public and the government - can severely impact a firm and its business continuity after a disruption (Funk et al., 2010, World Bank, 2014).

In many High Impact, Low Probability (HILP) case events, the disruption can cause confusion and panic leading to governments to take drastic steps often with little information and making the problems even worse (Funk et al., 2010). As mentioned earlier, after the attack on 9/11 the US government ordered a border closure, by all counts an extreme measure, which led to the large-



scale disruption of supply chains across the country (Andel, 2002). This impacted a large number of firms that were nowhere near the impact site of the actual attack leading to a considerable loss for companies like Ford who did not have manufacturing plants in the affected zone but were heavily dependent on cross-border supply chains from Mexico and Canada (Fiksel, 2016).

Similarly, in 2001 during the foot and mouth disease outbreak, the UK government decided to slaughter 6.5 million cows, pigs, and sheep but also took the drastic step to enforce a tourist ban into the countryside. This tourist ban led to a far larger economic impact than the destruction of the livestock causing long term damage to many local authorities dependent on tourist trade (Alister et al., 2004). Therefore, firms must consider the consequences of possible government actions as part of their analysis when considering disruption scenarios.

Although HILP events are extremely rare, specifically for small firms, for multinational firms like GM, BP and Pepsi Co. – the risks of something happening across their whole supply chain and operations network is significantly higher as they are present in many locations across the world (Sheffi, 2015b). Hence the probability of a major disruption occurring somewhere in a multinational's vast network sometime during an annual period is considerably higher - perhaps making the case that large firms should invest in their resilience if they wish to be competitive in the long run (Sheffi, 2015b, Fiksel, 2016).

Several researchers and scholars on organizational resilience have highlighted a few of the crucial attributes of resilient enterprises. These attributes have been validated to exist in many case studies of resilient enterprises conducted by these researchers leading them to consider these as essential attributes of successful organizations that were resilient to disruptions. McManus (2008) has defined the attributes of resilient organizations as consisting of the following functions; 1) an organization's situational awareness, 2) identification and management of keystone vulnerabilities and 3) adaptive capacity in a complex, dynamic and interconnected environment. She has constructed an index of indicators that explore each of these three attributes listed above in detail. Similarly, Fiksel (2016) has also indicated key attributes of resilient enterprises and has identified the following: 1) diversity; the presence of multiple forms and behaviors, 2) efficiency: the performance with modest resource consumption, 3) adaptability: flexibility to change to new pressures and 4) cohesion: the existence of unifying relationships and linkages between system variables and elements.

After careful consideration of the various attributes and their approaches, this research will use the criteria defined by Sheffi (2015a) as it has been used extensively in the literature and has been validated across multiple case studies (Sheffi and Rice Jr., 2005, Sheffi, 2007, Sheffi, 2015b).

Additionally, these attributes are relatively easy to explain to stakeholders, especially important when using stakeholders inputs as in the group model building done in this study - discussed in detail in Chapter 3 (Sheffi, 2015a). These criteria highlight several features of a Resilient Enterprise that can explain good practice and have proven useful in other case studies where they have been identified as; 1) they have early detection capacity; 2) they have built in redundancy; 3) they have built in flexibility; and 4) they have the right corporate culture (Sheffi, 2015a).

### ***Early Detection***

Early detection is a key component of the Resilient Enterprise, as it must realize as soon as possible the potential for a disruption before it occurs and not when it is too late. This proactive approach means that not only does the firm receive early warning signs but that it can also process, understand and act on those warning signs (Dalziell and McManus, 2004, McManus, 2008). A tragic example of not responding to a disruption after receiving many days of notice could be the response to Hurricane Katrina in 2005. In this case, the evacuation of the city was announced too late, the State called for federal resources too late, and the Federal Emergency Management Administration responded with too little resources after underestimating the impact (Sheffi, 2015b). Another example where early detection plays a major role in response is during pandemics and epidemics. International health organizations like the Centre for Disease Control (CDC) in the US, and the World Health Organization (WHO) internationally, spend a lot of resources on early detection of infectious diseases that can be transmitted to humans (Bloom et al., 2005, MARSH, 2007). In this case, the best defense against such an outbreak is early detection and quarantine until vaccination or antiviral treatments can be developed or delivered (MARSH, 2007).

Firms must have the capacity to understand what disruptions might be developing based on early warning signs which mean they must monitor all sources that may inform them of such signs (McManus, 2008). Improving this key capacity may mean hiring other organizations that specialize in early warning detection such as risk management firms or developing their capacity to monitor and assess the risk of disruptions potentially occurring both externally and internally (MARSH, 2007, Llamas et al., 2015).

### ***Redundancy***

A firm may improve its resiliency by developing redundancies throughout its operations – especially its supply chains. These measures also clash with the current cost-saving paradigm utilized in firms called “Lean” optimization where efficient supply chains cut costs significantly indicating that some Lean techniques might lead to loss of resilience. Redundancy might also apply to human resources where local employees might be replaced or supplemented with an additional workforce from other locations (Sheffi and Rice Jr., 2005, Sheffi, 2015a).

### ***Flexibility***

Flexibility is a management term used to denote the ability of a firm to change or adapt quickly to dynamic conditions with a minimum of time and cost. It is usually a management paradigm adopted at the strategic level and could represent several processes depending on the context of the industry and sector (Dalziell and McManus, 2004, Sheffi and Rice Jr., 2005). It is often linked to the concept of interchangeability where the firm develops the ability to interchange components within its supply networks and production systems quickly (Sheffi, 2007, Fiksel, 2016).

### ***Corporate Culture***

Corporate culture may be one of the hardest features to define, but at the same time, it is one of the most important as the right corporate culture can mean that the impacts of a disruption are minimized and that when opportunities arise from such crisis that is leveraged for long-term advantages (McManus, 2008). According to Sheffi and Rice Jr. (2005), the following number of key features of a corporate culture that are common between resilient organizations; i.e. continuous communication, distributed power, passion for work and conditioning of disruptions (Sheffi and Rice Jr., 2005).

One of the most important features of a resilient enterprise during a crisis or disruption is continuous communication between all levels of employees (McManus, 2008). Resilient enterprises spend a lot of time and effort on effective communication by keeping all managers informed of strategic goals often informing line employees across multiple levels of goals at the operational and tactical levels to facilitate sharing of corporate vision (Fiksel, 2016). During the crisis, communication is equally important at the external levels as it is internally especially when working with external partners such as contractors, partners, and other associated service providers.

The other key feature is a distributed power structure where resilient enterprises empower lower levels to act immediately in response to disruptions and not wait for the usual approval processes. The delegation of decision making to lower levels who are closer to the ground and who more often have greater experience and knowledge of local conditions can help limit the time taken in responding to disruptions (McManus, 2008, Sheffi, 2015a).

Passion for work is also necessary among employees of a resilient enterprise especially in difficult conditions like epidemics or other natural disasters where the first instinct might be to panic and abandon responsibilities (Sheffi and Rice Jr., 2005). If employees feel their presence contributes to the overall resilience of their communities, they would be more likely to maintain functional operations of the firm and contribute to the response or recovery effort (Sheffi and Rice Jr., 2005). Finally, constant practice and drills for small disruptions can condition firms and keep preparedness

at high levels for larger scale HILP disruptions. The ability to be flexible and adjust to small scale disruptions through regular training exercises allows teams to develop the capacity to respond to large-scale disruptions that may occur in future (McManus, 2008, Sheffi, 2015b).

This study will use the attributes identified above as the key attributes of a resilient enterprise to be explored in our case study. This study will use qualitative interviews, focus group discussions and group model building sessions to understand how employees of the case study firm felt about how the firm acted during the disruption period and how the presence or absence of these attributes contributed to the resilience of the firm.

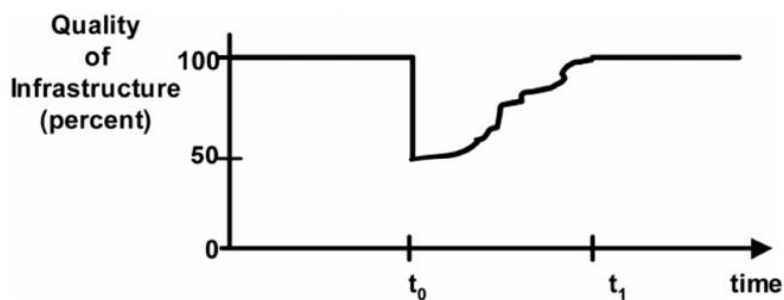
### **2.2.5 Conceptualizing Disruption at the Enterprise level**

From the many definitions considered in the above section, this research will use the definition considered by Simonovic (2016) in one of his latest publications and will try to validate this definition in the study. Simonovic (2016) has proposed the following definition of organizational resilience; "...the ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a system disruption in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its essential system performance and function (Simonovic, 2016)."

Many of the definitions of organizational resilience, like the one above, mention system performance as a key indicator of disaster impact - especially the ability to bounce back and return to a prior system performance as a key concept in understanding resilience. As part of the MCEER approach discussed previously, Bruneau et al. (2003) first proposed a system performance measure for conceptualizing and measuring disaster impact for physical infrastructure in earthquake prone areas. Subsequently, Sheffi and Rice Jr. (2005) used this conceptualization to develop a qualitative disruption profile which could be used to look at impacts at the enterprise level. Peck and Simonovic (2013) later integrated this approach into a quantitative system dynamics approach to disaster resilience of urban systems that could be scaled up to the city level or scaled down to an individual asset level if required. This section looks at how disruptions can be conceptualized as system performance and how this can help researchers to understand impacts as well the effect of preventative measures on system performance.

Bruneau et al. (2003) at the Multidisciplinary Centre for Earthquake Engineering Research (MCEER), University of Buffalo, developed a conceptual framework for seismic resilience measures of communities that can be potentially adapted for use at the organizational level. The conceptual

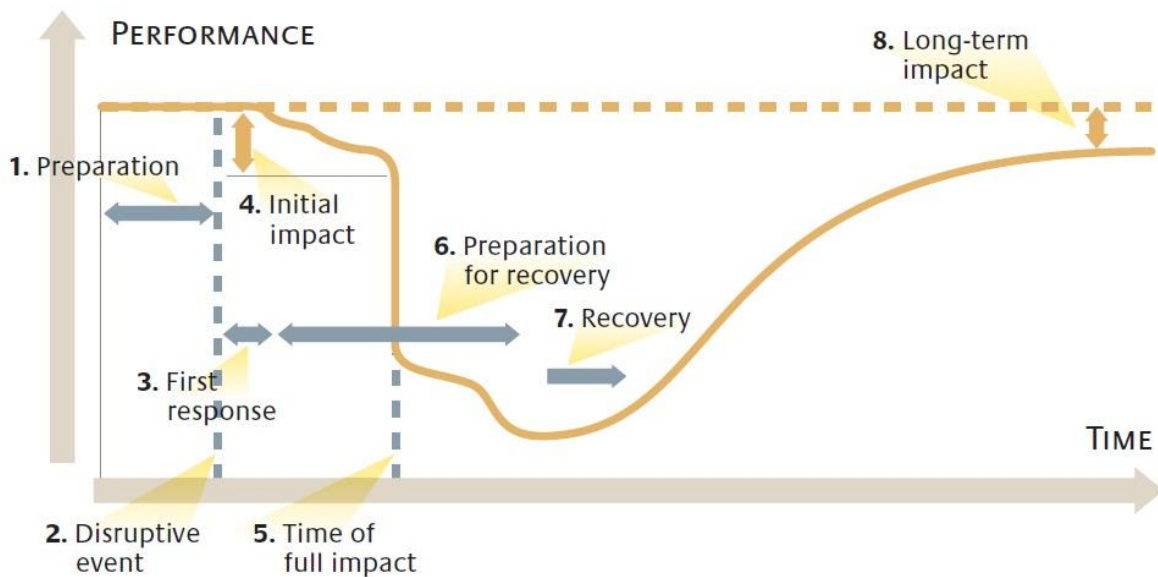
framework also called the R4 framework, defined the impact on system performance as a function of a resilience triangle in a graph as shown in **Figure 5** below. This resilience triangle could be used to represent the loss occurring from a disruption or disaster event regarding service delivery or system performance. System performance can range from 0% to 100%, where 100% means no impact on service and 0% means no service available. The R4 framework sought to further define the resilience of an asset as a function of four R's: 1) resourcefulness, 2) rapidity, 3) redundancy and 4) robustness (Bruneau et al., 2003, Bruneau and Reinhorn, 2007). These components of resilience will be further defined below when discussing the modeling of resilience in Chapter 4.



**Figure 5. Conceptual resilience triangle proposed by Bruneau et al (2003).**

An important starting point for understanding any disruption to a firm's operations, whether from natural or man-made hazards, is to develop a disruption profile (Sheffi and Rice Jr., 2005). Sheffi and Rice Jr. (2005) have developed a qualitative representation of the disruption profile to understand the different stages of a disruption on an organization. Any significant disruption event will have a typical profile (Figure 6) regarding the impact on a firm's performance, which can be linked to performance measures for instance production, distribution, and sales or any other such performance metric(s) that the organization may identify as relevant for continued operations. The more resilient a firm, the smaller the resilience triangle or disruption profile, indicating a quicker return to pre-shock level performance. The area under the curve could be used to represent the loss to a firm regarding lost system performance due to a shock.

**Figure 6. Profile of a shock to the performance of a firm. Source: Sheffi and Rice Jr. (2005)**



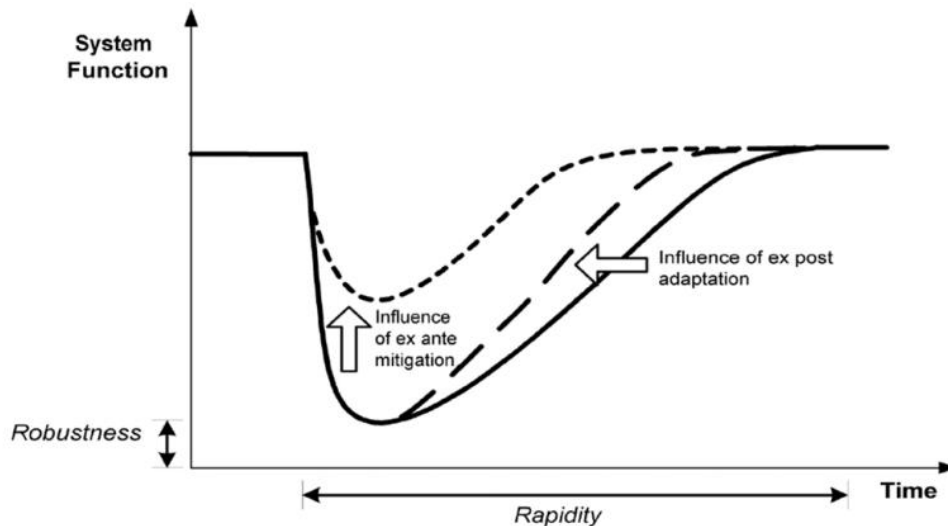
Sheffi and Rice Jr. (2005) has described eight distinct phases; 1) preparation, 2) the disruptive event, 3) the first response, 4) the initial impact, 5) the full impact, 6) the preparation for recovery, 7) the recovery and, finally, 8) the long-term impact. The different phases of the profile can help unpack the impact of the disruption and allow researchers to look at the impact more closely while keeping an overall system level view of the organization as well.

Developing organizational resilience to relatively rare events, such as emerging infectious diseases (EIDs) like the Ebola Viral Disease (EVD), may seem costly and unnecessary considering the low probability of such disruptions locally. Even though these risks are assessed at the country level for large multinational corporations, this risk may be more significant as they have a larger global presence sometimes operating across borders in the same region (Fiksel, 2015). Many firms in the extractive industry are multinationals and typically have a global reach with operations spread across multiple continents. Since the activities of extractive firms necessarily lead to changes to the natural environment, such rare events may be more likely for them in the future due to climate change and other factors, than for other smaller organizations dealing with conventional risks from different disruptions to business continuity.

The disruption profile provides researchers with a useful framework for understanding how a disruption can potentially affect the system performance of a system of an organization or enterprise as in our case study. This conceptualization can help in understanding the chronology of events as well as the timing of response and mitigation measure or preventative measures that may be considered. This study will try to understand the impact of the EVD outbreak on an extractive firm by documenting which systems were impacted and how. The research aims to provide an estimate of the actual cost of the preventive measures that the firm adopted during the outbreak while also identifying the channels of impact. This information could then be used to develop a framework for understanding the operational resilience of mining firms to shocks like EIDs and form the basis of linking business continuity, investment and corporate responsibility and sustainability to community resilience over the long run.

#### **2.2.6 Modelling Resilience**

As mentioned previously, Bhamra (2015) notes that despite increasing awareness of organizational resilience and its critical elements there has been a lack of studies that extend beyond qualitative definitions (Bhamra, 2015). Those studies that do propose a quantitative framework for organizational resilience have not been validated through rigorous case studies research. For quantitative measurement of resilience, the work of Bruneau et al. (2003) was further expanded upon by Srivastav and Simonovic (2014) where the resilience triangle was modeled in terms of a system dynamics model. The model developed by Srivastav and Simonovic (2014) forms the basis for developing the conceptual model used in this study. Conceptualizing disruption at the enterprise level as the impact on system performance allows researchers to use this as a framework for understanding impacts on a firm as well as providing a reliable and valid basis for understanding how preventative measures can potentially impact system performance and hence overall resilience of the enterprise.



**Figure 7. Impact of preventative measures on system performance (source: Peck and Simonovic, 2013)**

Srivastav and Simonovic (2014) Have indicated how preventative measures can be interpreted within this framework shown above in **Figure 7**. Conceptually it can be seen that any such measure would reduce either the impact of the disruption or affect the duration or both. In other words, either the sensitivity or the exposure of the system to the disruption. This results in either a smaller impact on the system performance or faster recovery. As indicated previously, this corresponds to how Simonovic (2016) defines resilience of a system and can also be derived from the breakdown of the elements of resilience in his definition. A more detailed explanation of the model will be covered in Chapter 4 Results as the study uses group model building sessions to develop the conceptual model with direct stakeholder involvement.<sup>7</sup>

### **2.3 Nature of Epidemics as Disasters**

Experts estimate that infectious diseases may be responsible for more than a quarter of all premature deaths occurring annually in the world, this figure rises to two-thirds when considering the mortality of children under five years old (Dry and Leach, 2010). Accordingly, epidemics are one of the most common and widespread natural disasters occurring across the world particularly in lower income countries (Thomas et al., 2015). In disaster literature, epidemics can be classified as biophysical hazards which can be sensitive to climate conditions both in the short and long terms but occur due to several factors not limited to just climate. Bio-physical hazards could include hazards that are slow moving and creeping, or they may result in rapid onset disasters more commonly like other natural disasters (Smith, 2015).



Other examples of biophysical hazards are wildfires, locust infestations or crop/livestock diseases that can have a significant impact on people and their livelihoods. Due to the nature of epidemics and their impacts on social-economic and built environments, it can be classified as a complex disaster where impacts are hard to assess (Price-Smith and Price-Smith, 2009). Studies looking at regional and national level impacts are common in the literature (Thomas, 2015) but firm-level impact studies are rare (Westwood et al., 2015). This gap is surprising as a number of publications in the past decade have highlighted the important role of the private sector in disaster risk reduction especially by organizations such as the UN, World Bank and the World Health Organization (WHO) (MARSH, 2007, Bingu and Dilanthi, 2012, UNISDR, 2013, Llamas et al., 2015).

The WHO is the primary world body charged with monitoring and response at the international level and maintains a constant surveillance for international transmissions of dangerous infectious diseases. The World Health Organization (WHO) defines epidemics as: "...the occurrence of a number of cases of a disease, known or suspected to be infectious or parasitic origin, that is unusually large or unexpected for the given place and time. An epidemic often evolves rapidly so that a quick response is required (Smith, 2015)."

A number of recent events such as the SARS, H1N1 (Swine flu) and HPA1 (Bird flu) epidemics have led to large human and economic losses (Price-Smith and Price-Smith, 2009). Despite the large losses, these previous epidemics were tragically surpassed (in regards to human loss), by the almost 14,000 dead in the 2014 Ebola Viral Disease (EVD) outbreak in West Africa (WHO, 2016). Although EVD was responsible for a large number of deaths in a relatively short time other diseases such as HIV or Malaria, that are transmitted more slowly or manifest themselves over a longer period, also have a large impact both in term of loss of life and economic value (Smith, 2015). These emerging infectious diseases (EIDs) are differentiated by epidemiologists based on how they are transmitted, and this largely affects what type of preventative or mitigation measures can be taken.

There are three primary modes of transmission of these communicable or infectious diseases as follows. They could be 1) a vector-borne transmission where the transmission of bacterial, viral or parasitic infections to humans of pathogens is through insects, rodents or other vector organisms, i.e. Malaria, Dengue fever, Yellow fever. The transmission method could be 2) an enteric (intestine) transmission where the transmission of pathogens to humans is through ingestion or consumption, i.e. Hepatitis, diarrhoeal diseases. Lastly, they could be 3) person to person transmission where the transmission of bacterial, viral or parasitic infections to humans is through interactions with other humans, i.e. Tuberculosis, measles, influenza, Ebola (Smith, 2015).

This research plans to look at the impacts arising from the Ebola outbreak in 2014 which was transmitted person to person through touch and close contact. These types of infections have a stigma of fear associated with them where all human contact could potentially be dangerous during an epidemic, and human psychology often plays a large role in how infections are handled specially in low-resource settings as in low-income countries (Price-Smith and Price-Smith, 2009).

Studies have shown that epidemics, similar to the impacts of other natural disasters, have a disproportionate distribution across lower income countries (LICs). It is estimated that almost sixty percent of mortality due to communicable diseases is among the twenty percent of the poorest in the world while only seven percent of the deaths are in the richest twenty percent (IFRCRCS, 2011). This mortality inequality is expected to remain as only five percent of the global medical research spending is used to address the problems faced by these LICs (Smith, 2015). Research in global trends has also indicated that there a number of complex factors that are contributing the frequency and magnitude of epidemics worldwide (Price-Smith and Price-Smith, 2009, Bausch and Schwarz, 2014).

Bausch and Schwarz (2014) indicate that these factors can be aggregated into three broad categories explained below as changing environmental, socio-economic and biological factors. They argue that shifting environmental factors where human exposure to vectors is potentially increased due to encroachment on habitats of infected hosts may be responsible for greater frequency and impact of epidemics. This change can be attributed to processes such as increased urbanization, economic development and extensive exploitation of natural resources which may also contribute to global issues such as deforestation and climate change (Dry and Leach, 2010, Bausch and Schwarz, 2014).

Another factor contributing to the increase in frequency and magnitude of epidemics is the changing socio-economic factors that result in changing of human behavior over time, e.g., Changing sexual behavior over time and rates of HIV infections. Other factors, for example increased international travel and cross-border trade are also some factors that are considered in this category (Bausch and Schwarz, 2014, Westwood E, 2015).

Finally, the third category of complex factors is the change over time in biological profiles of the pathogens themselves resulting from a genetic mixture or natural evolutionary process as well as overuse of antibiotics on both human and livestock populations (Bausch and Schwarz, 2014).

Before concluding this section on the nature of epidemics as disasters, a brief note is required on epidemiology as a science and how it is used to understand the impact of epidemics. Epidemiology is defined as “the quantitative study of the distribution and determinants of health-related events in

human populations (Bonita, 2006).” All international and national organizations concerned with epidemics and infectious disease have epidemiologists working with them to understand the statistical trends of morbidity (diseases incidence) and mortality (death) across populations (Smith, 2015). Examples of such organizations are the WHO, the Centre for Disease Control (CDC) in the US and Public Health England (PHE) in the UK. Although the CDC and PHE are responsible for national health issues, they keep a close eye on events internationally as the world is now ever more connected (Bonita, 2006, Smith, 2015).

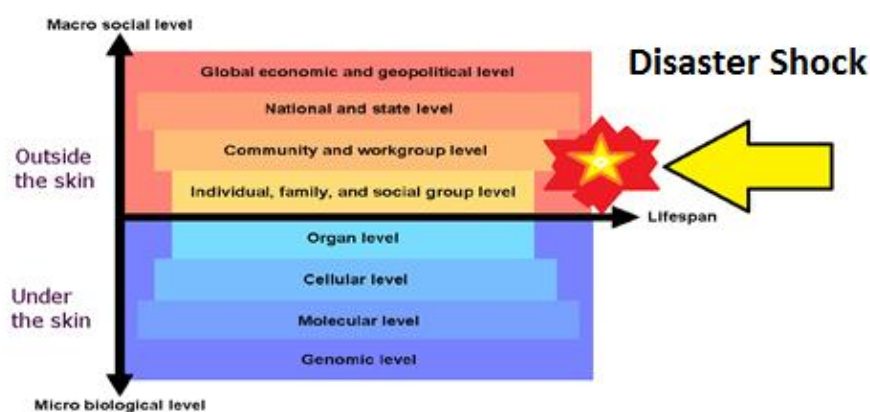
The primary role of these organizations is to reduce the occurrence of diseases and epidemics by conducting surveillance for flare ups of old diseases and as well as the occurrence of new ones in populations across the world (Bonita, 2006). They also monitor post-disaster conditions by conducting an impact analysis of natural and manmade disasters - considering the risk of disease and epidemics in the populace afterward. Another key function is that they evaluate how local health systems are responding and dealing with diseases and outbreaks to either provide aid if required or to improve planning for future potential flare-ups (Smith, 2006). These organizations also play a key role in understanding the health impacts of not only disasters like epidemics but also other natural and manmade disasters. This includes disasters like floods, droughts, famine, civil conflict and other instances where populations may be affected and may require mass movement, displacement or sheltering in interim refugee camps (Price-Smith and Price-Smith, 2009, Smith, 2015).

Accordingly, these organizations provide research into preventative measures and provide an evidence base for the benefits of health planning and contribute to the improvement of health policy not only in their countries but also in low-income countries (Price-Smith and Price-Smith, 2009). While the WHO’s mandate requires it to respond internationally, both the CDC and PHE also do so, to help local health authorities in affected countries to provide effective response especially when they are unable to do so on their own (Clift, 2013). Other organizations like the United Nations and its affiliates, United States Aid (USAID) from the US and the Department for International Development (DFID) in the UK also have long-standing programs to improve health outcomes in countries where they are working (Coppola, 2015, Smith, 2015).

These organizations produce a considerable amount of research output regarding peer-reviewed journal articles, good practice guides, policy recommendation documents, response manuals and guidelines which focus on health response at the national and local levels (Clift, 2013). There is a debate in the field of epidemiology on where the emphasis on greater expenditure and research should lie. This debate highlights either a greater allocation of funds to finding cures or towards preventative medicine where the emphasis is on prevention and expenditure on health

systems. This debate is also known as the investment between vertical or horizontal health systems with pros and cons of each being researched in the literature (Balabanova et al., 2011).

Health specialists like Urban et al. (2011) also recognize the complexity of resilience issues as particularly complex phenomena. The complexity is based on the interactions and trajectories across different levels across the social, economic and built environments as well as both “...outside and under the skin” (Urban et al., 2011) shown in Figure 8 below. Complexity science and its tools are well suited to describe and understand those processes. Understanding and addressing disaster resilience issues from a complexity perspective requires an emphasis on the processes involved in the dynamic relationships between the individual, the ecosystem, the social and the built environments. Current research methods focused on linear methods that focus on individual parts, or “reductionist” methodologies may be less suited to do this in a holistic and inclusive manner and hence present very real measurement and methodological challenges for researchers (Urban et al., 2011).



**Figure 8. Complexity of Resilience issues and the uncertainty present in disaster settings (adapted from Urban et al., 2011).**

Understanding disaster resilience at the firm level is inherently complex because they result from a complex interaction between different layers of systems involving individuals and organizations with potentially different cultures, history, and traditions to affect behavior (Tremblay and Richard, 2014). This can be especially true when a disaster shock is unfolding in tightly coupled systems as these effects are further complicated by greater interdependence and fast changing environmental issues. These problems are not necessarily just in an ecological sense, but changes in the social and built environments can also rapidly escalate through cascading effects leading to devastating consequences necessarily requiring methods and tools that can help understand the complexity involved (Pescaroli and Alexander, 2015).

### **2.3.1 Overview of the origin and spread of EVD outbreak 2014**

The 2014 EVD outbreak reportedly started in the Guinean border district of Guéckédou during December 2013 (Bausch and Schwarz, 2014) and then spread to Liberia and Sierra Leone (WHO and Team, 2014). The first manifestation of the trans-border spread was the confirmation of cases in Liberia on March 31, 2014 (Johnson, 2014). The Ebola virus quickly spread to Sierra Leone (May 26) and subsequently to Nigeria (July 25), Senegal (August 29), and Mali (October 23) (Westwood et al., 2015). Cases were also reported in Spain, Italy, the United States and the United Kingdom. However, the international transmission was linked to health workers, with mainly isolated cases (CDC, 2015). This is the first EVD outbreak to reach epidemic proportions, previous outbreaks were localised and were brought under control within a few weeks.

The EVD outbreak of 2014 was spreading quickly, and it appeared to be uncontrollable at times (WHO, 2015). On August 8, 2014, the World Health Organization (WHO) declared the outbreak to be a 'public health emergency of international concern' (PHEIC)(WHO, 2014a). In September 2014 WHO stated that the EVD outbreak ravaging parts of West Africa is the most severe acute public health emergency seen in modern times and the Director General of WHO called the outbreak 'the largest, most complex and most severe we have ever seen' (WHO, 2014b). In September 2014 the UN Security Council passed a resolution declaring Ebola a threat to peace and security and for the first time in the history of the organisation dedicating a UN Mission specifically for a medical emergency – UN Mission for Emergency Ebola Response (UNMEER) (UNMEER, 2016). State of emergency was declared, and curfews were enforced within the affected countries to halt the spread of the Ebola virus (Mark, 2014). Governments enforced the closure of schools, markets, workplaces, and imposed restrictions on movement to control the transmission of the virus. As the outbreak continued, countries also imposed border closures and banned flights to and from the affected countries (SOS, 2015).

The Ebola outbreak in West Africa was unprecedented leading to a public health emergency of new proportions and scale. Almost two years after the first confirmed case of Ebola was recorded in 2014, 11,315 people are reported to have died from the disease (BBC, 2016). Despite the considerable scale of this human tragedy, the initial forecasts in September 2014 were much higher, with 1.4 million cases predicted in a worst case scenario by January 2015 if the disease kept spreading without measures to stop it (CDC, 2014). Ultimately, the total number of reported cases is approximately 28,637, according to figures published by the World Health Organisation in January 2016. The World Health Organisation also reported an average Ebola case fatality rate of around 50%. As of January 3, 2016 (WHO, 2016a), Sierra Leone experienced the largest number of cases (14,122), followed by Liberia (10,675) and Guinea (3,804). Liberia reported the largest number of deaths (4,809), followed by Sierra Leone (3,955) and Guinea (2,536). The outbreak has finally been halted, though it has been a very slow process to stop the transmissions. Guinea was declared Ebola-free by WHO on December 2015, and Sierra Leone has been largely free of the disease since November 2015 (News, 2015)., Both countries have since reported several further cases with Sierra Leone reporting two cases in January 2016 and Guinea reporting two in March 2016 (CIDRAP, 2016). Liberia was the first of the three countries to be declared Ebola-free on May 2015, but the virus was reintroduced twice since then, with the latest flare-up in April 2016 (WHO, 2016b, WHO, 2016c). The transmission of Ebola has now been effectively contained in the region, but it may flare up again in the future. The virus can persist in some individuals who have recovered from the disease and there can be reintroduced into the population. While this is a rare event, it has been recorded about half a dozen times already (WHO, 2016b).

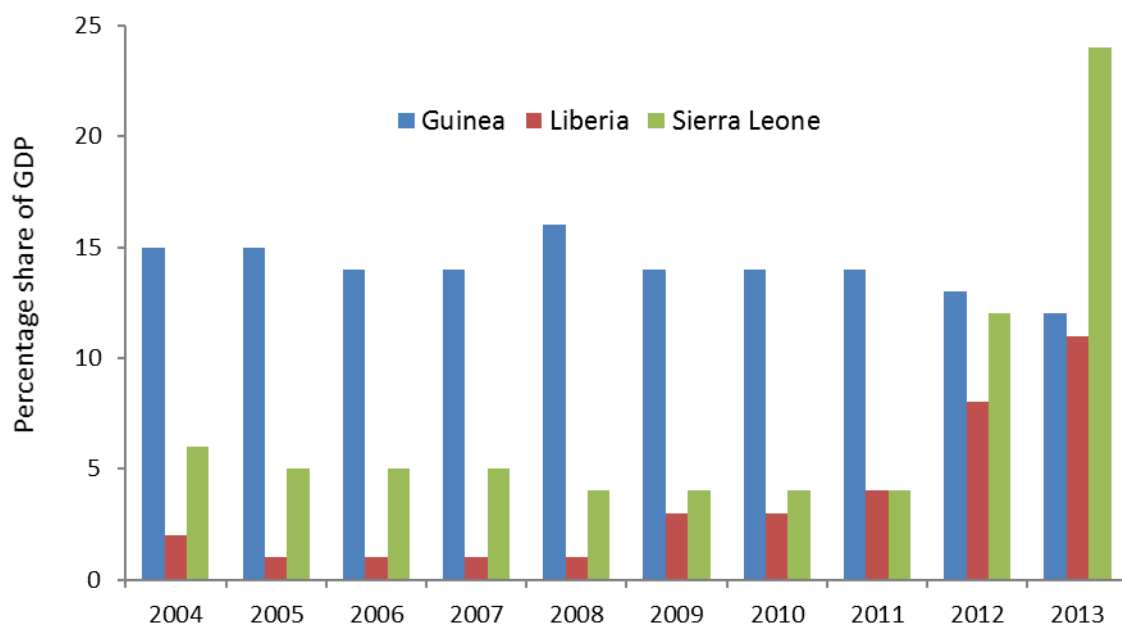
### **2.3.2 Overview of extractive industry in West Africa**

Liberia, Sierra Leone and Guinea are heavily dependent on the mining sector. These countries are rich in many mineral deposits including alumina, bauxite, cement, diamond, gold, mineral sands, and iron ore. The Iron ore industry, in particular, has played a key role in the economic growth of Liberia and Sierra Leone contributing heavily to their economies over the last few years since they started exporting iron ore. Guinea has great prospects for

iron ore development with projects including those in Simandou and Nimba. The huge iron ore deposit at Simandou is set to become one of the largest iron ore mines and infrastructure project of its kind. For Liberia, the export of iron ore means a resumption of ore exports since 1990 when the Liberian-Swedish-American Mining Company (LAMCO) operated mines in the country. LAMCO stopped production and ceased operating in the country during the 14-year Liberian civil war ((SDI), 2011). The other contributors to the extractive industry in Liberia are cement production, rough diamonds and small amounts of gold but iron ore production is the single largest contributor (Survey, 2015). Guinea is also richly endowed with metals such as iron ore and bauxite and has one of the largest integrated iron ore mines in Africa (Survey, 2015). Mining plays a key role in Sierra Leone's industry with its share of 85% of the industry in the country. Mining in Sierra Leone is dominated by the iron ore sector (Thomas et al., 2015). There are other less significant operations in rutile, ilmenite, bauxite, and diamonds. Large deposits of iron ore discovered in many parts of the country have placed Sierra Leone as having the largest deposits of iron ore in Africa (Ministry of Mines & Minerals, 2016). A significant percentage of global iron ore production was generated from these countries in the last decade.

**Figure 9** below shows the share of mineral sector to GDP for the three EVD affected West-African countries. Mineral sector's share of GDP for Guinea fluctuated between 14 & 15 percent from 2004 to 2013. In Liberia, before 1990, the share of mineral sector to GDP was as high as 25 percent, mostly driven by diamond and iron ore production (Survey, 2015). Between 2004 and 2007 the share of mineral sector to GDP was low and began to increase in 2007 as the embargo on diamond exports was lifted. The mineral sector contribution to GDP was about 8 to 12 percent during 2012 and 2013. In Sierra Leone, the contribution of the mineral sector was relatively low before 2011 and began to increase steadily from 2012. In 2012 and 2013 the share of mineral sector to GDP has increased to about 12 and 23 percent respectively

**Figure 9. Mineral sector share of GDP**



Source: Central Bank of Liberia (2015), Guinea Institut National de la Statistique (2014), and International Monetary Fund (2014), US Geological Survey (2015)

The outbreak of EVD has caused major economic concerns for international mining firms looking to invest in local economies. Ebola is having a significant impact on investment in the mining sector, which provides employment opportunities to thousands of people directly (and impacting millions of people indirectly) in the region and contributed to the fast growth of these countries in the post-civil war era. The emergence of the EVD crisis was accompanied by changes in market conditions including a decrease in the global price of iron ore. Iron ore prices plummeted to 5-year lows in September 2014 with analysts expecting prices to continue into decline with no recovery in sight (Survey, 2015). This has posed an even bigger challenge to mining operations in the region, fighting Ebola in the short run and to continue mining operations in the medium and long term given unfavourable commodity prices. Most of the mining companies operating in the EVD outbreak affected countries reported that mining had been resilient to the outbreak and



production continued mostly uninterrupted in 2014 except for the case of Sierra Leone where both iron ore mines were placed on a care and maintain status during the EVD outbreak in 2014. The economic impact of the EVD crisis came into sharp focus on 10<sup>th</sup> October 2014 when London Mining, Sierra Leone's second largest iron ore producer, suspended its operation and shut down (Institute of Development Studies, 2015). Those mines have still not restarted production due to the continued low prices in the international markets.

In Liberia, ArcelorMittal Liberia, the largest mining company in the country, has delayed its planned investment to expand its production capacity from 5.2 million tonnes of iron ore to 15 million tonnes. China Union, the other iron ore mining firm is operating in Liberia, shut down its operations in August 2014 (Institute of Development Studies, 2015). The mining sector is expected to contract by 1.3 percent in 2014 in Liberia compared with an initial projection for growth above 4 percent (World Bank, 2014). Ebola is also having a considerable impact on the informal mining sector in the three countries. Informal mining generates disposable income for thousands of families in an employment-constrained economy (Institute of Development Studies, 2015).

### **2.3.3 Epidemics as disruptions**

The extractive industry, through its operations, necessarily brings about changes in the social and natural environments such as advancing into new uninhabited areas where operations like exploration, extraction/mining activities and developing transportation networks in these remote areas lead to increasing contact with wildlife. This places a significant burden on local ecosystems, and as local economic systems emerge to support increasing worker populations, opportunities increase for infections like EVD to breach the species barriers between animals and humans (Bausch and Schwarz, 2014). Outbreaks can potentially lead to suspensions or shutdowns in extractive projects causing significant disruptions to business continuity that can adversely impact the profitability and in some cases, the survivability of firms in the industry (Survey, 2015). The industry, therefore, may have an interest in developing a better understanding of how disruptions can impact their

activities at the firm level. It is important for decision makers to have accurate cost estimates to factor in any cost-benefit analysis for building operational resilience (Ingirige et al., 2015) by adopting prevention strategies and considering to invest in local health systems to strengthen their response capacities (Llamas et al., 2015).

Disruptions to extractive industry operations can have significant ramifications beyond the short run considerations of temporary shutdowns. The medium to long-term implications of the outbreak can heavily impact the investment available for firms and go beyond just the direct impacts associated with economic loss to the single firm. These operations can be disrupted in multiple and unexpected ways. Some disruptions like accidents, industrial action and civil unrest are relatively well-understood risks that could result in stoppages in operations and are part of standard risk management practices that can be overcome with well-established processes. Other events classified as a low probability but high consequence events are harder to anticipate and plan for as these disruptions are of a far different nature from past experiences and standard risk management practices may be unable to cope with these challenges. These are the type of disruptions that need to be studied in greater detail to develop resilience building within organisations (Sheffi, 2015b).

## **2.4 Research in context**

The large size and scope of the extractive sector in the Ebola-affected countries warrant a more detailed analysis of the impact and costs of the EVD outbreak incurred by the extractive firms that are traditionally not measured in the macroeconomic or sector level analyses. The impact and costs of the EVD outbreak estimated at the firm level could help in developing and designing interventions that may limit significant health (morbidity and mortality) and economic impacts of the EVD outbreak to extractive firms and the communities in which they operate.

In this context, the study aims to explore how the 2014 EVD outbreak has affected the operations of ArcelorMittal Liberia (AML); a major mining company operating in Liberia. The study aims to assess how the outbreak has affected the company's operation, and its preventive response to protect employees, contractors and maintain business continuity. By understanding the exact nature of the preventive measures and how costs have been realised for ArcelorMittal at the operational level, the study could provide insights into the different channels of impact of the outbreak that could affect a

mining operation. The study will explore if AML could be classified as a Resilient Enterprise in the face of this particular disaster by assessing its disruption profile through the experiences of employees at different levels of management and operations.

**Aim: To investigate the impact of a disruption from a natural disaster on the operations of a firm by using systems analysis methods and to determine if the firm was a Resilient Enterprise or not**

In this regard the specific objectives are:

- 1) To identify the common attributes of a Resilient Enterprise and recognize if those attributes were present or not in the case study firm**
- 2) To document the chronology of events and preventative measures/actions taken by the firm during the disruption event**
- 3) To estimate the cost of preventative measures taken by the firm during the disruption event**
- 4) To develop and validate a conceptual model with stakeholders that can be used to assess how various preventative measures (and attributes) could be used to enhance resilience**

Accordingly, the research question is:

What attributes and preventative measures are necessary for building a resilient enterprise?

Answering this research question will achieve the objectives stated above leading to a solution to the research problem. By successfully addressing the research problem and context, the research study will be able to achieve its stated aim.

## **2.5 Summary**

In this chapter, the importance of research paradigms in understanding disasters was highlighted followed by the emergence of the complexity paradigm as a key development in disaster research. Subsequently, the literature on organizational resilience was reviewed, key definitions and components of resilience were discussed as well as determining the key attributes of the resilient enterprise. The discussion on resilience ended with the discussion on conceptualizing disruptions on system performance and using that for modelling organisational resilience.

In the final section, the chapter looked at the nature of epidemics in general and the 2015 EVD outbreak in West Africa specifically. The chapter concluded with a restating of the aim and objectives with the research question. The next chapter looks at the way forward to answering this

question by covering in detail the complexity paradigm, systems analysis and its application in research.

## **CHAPTER 3            Methods and Methodology**

The previous chapter introduced the complexity paradigm, its relationship with disaster management and the way researchers look at understanding disaster impact as well as some of the literature on the resilient enterprise. Building on that discussion, this chapter argues for a holistic systems approach to the research problem of understanding the impact of a disruption on the operations of a firm and by using system analysis methods to determine if the firm was a resilient enterprise or not.

The current chapter covers the methodology used in the research study to address the aims and objectives as stated previously in Chapter 1. This chapter will first cover a short discussion on the methodological perspective and place the study within the complexity science paradigm. This discussion is followed by the selection of case studies as the approach and link between systems thinking and the holistic approach as advocated by complexity science approach. Finally, we conclude with the research setting and data collection process.

### **3.1 Complexity Science as a research paradigm**

Complexity as a concept first appeared in an article published in 1948 in Scientific American written by Warren Weaver, in which he examined how science approached different kinds of problems. Crucially Weaver criticized the deterministic approach and the increasingly reductionist methods employed by scientists to understand the increasingly complex phenomenon and which was leading researchers to miss or ignore larger patterns or connections between those diverse events or phenomenon (Ramalingam et al., 2008). Along with this criticism, Weaver prophetically indicated that there was little that can be done about it until two developments take place in the future. First, he indicated that computational ability of “...electronic computing devices” should increase and, second, “...a mixed team approach to operations analysis” should become common place (Ramalingam, 2013).

Since then, with increasing computational power and advances in statistical theory, researchers have begun to analyze the increasingly complex phenomenon. Phenomena like instability in financial markets, low-intensity conflicts and climate change that require a multidisciplinary approach leading to an increasing interest in non-linear methods using a new set of concepts and ideas which became increasingly referred to as complexity science (Johnson, 2009). Hawe et al. (2004) define complexity as: “a scientific theory which asserts that some systems display behavioral phenomena that are

completely inexplicable by any conventional analysis of the systems' constituent parts" (Hawe et al., 2004). Other scholars indicate that a definition of complexity is not possible without understanding its properties which can better indicate its nature (Keshavarz et al., 2010).

Johnson (2009) recognizes this difficulty and describes seven key components of complexity, shown in **Table 3** below that can help us understand what complexity scientists mean when they talk about complex systems. He also prefers a simpler definition as "...the study of the phenomena which emerge from a collection of interacting objects" – with emphasis being, particularly for human systems, on the emergent phenomenon arising from the interaction of people and other systems (Johnson, 2009).

**Table 3. Features of Complexity (Source: Adapted from Johnson 2009)**

No.	Key Components that are present in most if not all examples of Complex Systems
1.	The system contains a collection of many interacting objects or "agents."
2.	These objects' behavior is affected by memory or "feedback."
3.	The objects can adapt their strategies according to their history
4.	The system is typically "open."
5.	The system appears to be "alive."
6.	The system exhibits emergent phenomena which are surprising and may be extreme
7.	The emergent phenomena typically arise in the absence of any "invisible" hand or central controller
8.	The system shows a complicated mix of ordered and disordered behavior

To study complex systems effectively, scientists have to study both agents and networks together otherwise, they will miss key feedback pathways that form systems or relationships between agents and among networks. It is also important to understand that these systems are open in that they cannot be isolated from one another and are at times both interdependent and interconnected in usually more than one way. Complex systems are also "alive" in that they evolve by themselves without any active coordination "driven by an ecology of agents who interact and adapt under the influence of feedback" (Johnson, 2009).

This interaction between these components results in the emergent phenomenon. Traditional methods are not designed to analyze social phenomenon holistically (like the role of the built environment in the social and economic systems). These reductionist methods rather emphasize looking at individual smaller parts of the phenomenon under consideration. This approach might mislead investigators into being unaware of the emergent phenomenon that may arise and may even lead to either a misdiagnosis or a failure to analyze (Ramalingam et al., 2008, Johnson, 2009).

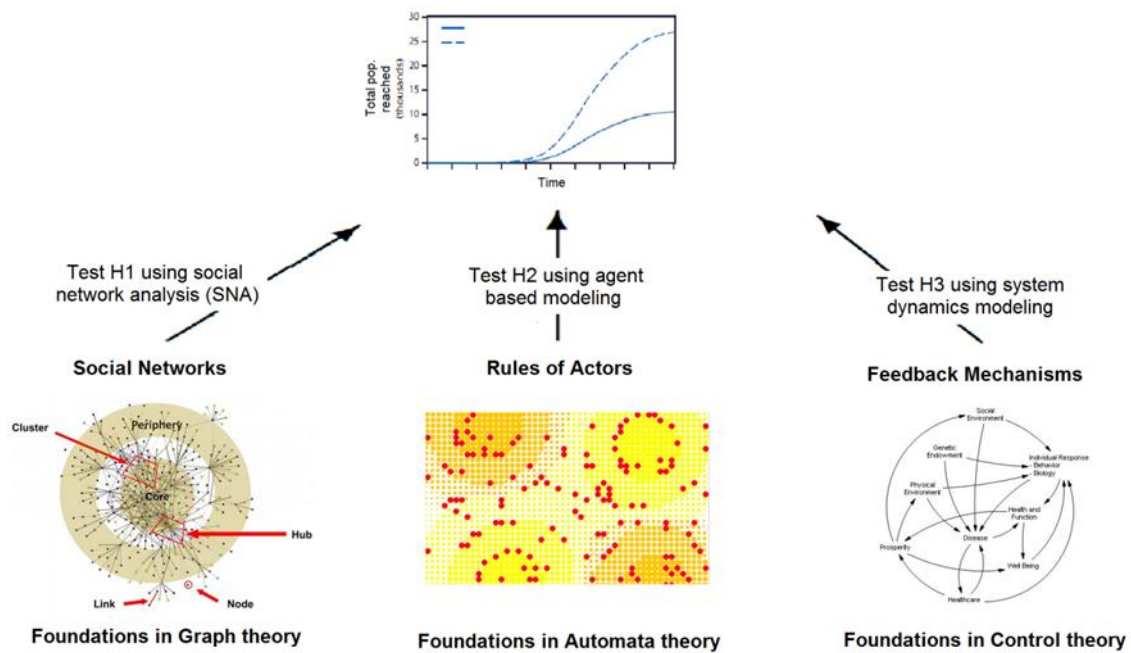
Sterman (2006) points out that to generate reliable evidence scientific methods require the ability to conduct controlled experiments, discriminate among rival hypothesis and replicate results but this process is considerably difficult the more complex the phenomena under study is. According to him complexity challenges researchers in three inter-linked ways: i) complexity hinders the generation of evidence, ii) complexity hinders learning from evidence and iii) complexity hinders the implementation of evidence-based policies (Sterman, 2006). Challenges like these would be very familiar to those working in disaster settings and resilience building, particularly when issues of vulnerability and exposure to the hazard are concerned (Ramalingam et al., 2008, Ramalingam, 2013).

### **3.2 Methods of Complexity Science**

Complexity science is considered as a family of methodologies that enable the study of complex phenomena. These methods allow researchers to represent the complexities of the problem in a tractable form by simplifying it while retaining the salient characteristics. Hence, these methods attempt to address both a holistic approach that looks at the “big” picture as well as the components that make up the system (Mabry et al., 2010). It is important to note that these methods complement traditional linear, reductionist methods. They do not seek to replace these methods and are not necessarily separate or completely distinct from them. Rather Sterman (2006) points out that the main difference between traditional and complexity methods is the way the researcher approaches the research question (Sterman, 2006). If following a traditional approach, a researcher will use a reductionist point of view that is the basis of the current scientific research method used in the natural and physical sciences. This approach breaks a phenomenon into smaller and smaller parts to understand causality among variables often ignoring the role of emergent phenomenon. The reductionist approach can result in mistakes in attributing cause from the complex set of interactions between variables to simple relationships by avoiding to understand causality in a holistic system (Johnson, 2009).

Complexity science methods are designed to capture the dynamic behavior of a system as it changes over time and are particularly helpful in understanding phenomenon where a bidirectional relationship exists between components of a system or even across systems. These relationships are known as feedback mechanisms and can be shown diagrammatically in causal loop diagrams (Sterman, 2000). These methods are also designed to understand non-linear relationships where disproportionate responses or feedback may exist in a system, for example where threshold limits or tipping points exist before large changes within a system. Another aspect of social phenomenon that these methods can help in understanding are time-delayed effects in the feedback process where

delays in the response may cause significantly different effects than expected if the feedback was simultaneous (Mabry et al., 2008, Mabry et al., 2010).



**Figure 10 . Methods of Complexity**

Three of the most popular complexity tools used in disaster management research that may prove useful for our research context are social network analysis (SNA), agent-based modeling (ABM) and systems analysis (SA) (Simonovic, 2011). Even though there may be some overlaps between these three methods, they employ three very different approaches to understanding complex phenomena as can be seen in **Figure 10** above. For example, if the study was looking at individual actors and their behaviors in a system then either SNA and ABM would be better suited to understand and analyze this particular phenomenon. For SNA, this is due to the focus on the social networks in which those actors are embedded. On the other hand, if the researchers are interested in what impact individual rules actors follow in the system then ABM would perhaps be the preferred tool (Lich et al., 2013). Alternatively, if feedback mechanisms between the components of the system are to be the focus of the research question, then SD would be better suited (Sterman, 2000). **Table 4** below presents the aspects of complex phenomena that each method is particularly suited to address (Luke and Stamatakis, 2012).



**Table 4. Primary Strengths of selected Complexity Methods (Luke and Stamatakis 2012)**

<b>Systems Property</b>	<b>SA</b>	<b>SNA</b>	<b>ABM</b>
<b>Model breadth</b>	X		
<b>Feedback loops</b>	X		X
<b>Dynamic systems in real time</b>	X		X
<b>Interactions of individual actors</b>		X	X
<b>Interactions between multiple levels</b>	X		X
<b>Complex relational structures</b>		X	
<b>Heterogeneous actors</b>	X	X	X

In the context of our case study, the research question is looking at the attributes of the resilient enterprise, specifically to disruptions such as an epidemic in our case study. With this in mind, and considering the time and resource restrictions, SA is determined to be the most appropriate method for this study. SA, which consists of ST and SD, will inform the research study of the feedback mechanisms that could help understand and evaluate how different preventative measures and resilience components of the firm can help in making it more resilient to disruptions.

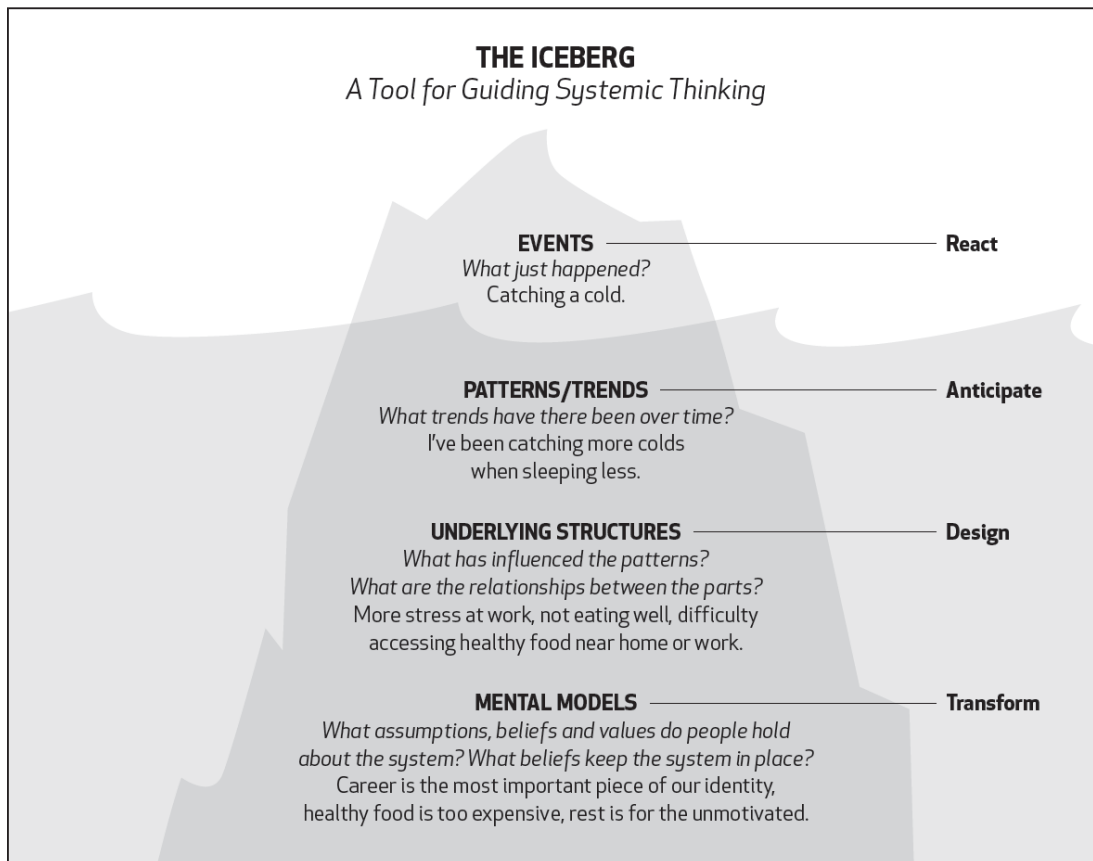
### **3.3 A Systems Approach**

As mentioned earlier, the response of systems to real world phenomenon is often complex, especially when considering public policy matters related to disaster impacts and when considering preventative measures for mitigation and preparedness (Ramalingam et al., 2008). Systems analysis provides researchers with an integrated approach to developing mitigation and prevention strategies. This holistic approach highlights interconnections between elements, drawing attention to root causes and providing insights into new opportunities for “bouncing back” better (Simonovic, 2011).

**Systems analysis** is a problem-solving technique that decomposes a system into its component pieces for the purpose of studying how well those parts work and interact to accomplish their purpose (Johnson, 2009). Several methods qualify for use as systems analysis – two that are utilized in this study are systems thinking (ST) and system dynamics (SD).

Social scientists need to understand the characteristics of systems because human capacity is limited in its ability to directly understand cause and effect relationships in complex situations like disasters (Sterman, 2000, Simonovic, 2011). Systems scholars like Maani and Cavana (2007) have developed an iceberg model of four levels of thinking to illustrate why complex situations may be

misunderstood using traditional methods. These four levels consist of events, behavior patterns, system structures and mental models or worldview/paradigms as shown in Figure 11 below.



**Figure 11. Ice berg model of systemic thinking (Maani and Cavana, 2007)**

Events are explained as surface level occurrences, and research has shown that most individuals are satisfied with explanations provided by very simple direct causal links without requiring additional information or data. Most social phenomenon is interpreted and accepted by lay persons at this level (Sterman, 2000). Understanding behavior patterns and trends need a more detailed and nuanced look at a phenomenon that might provide some insights previously not considered as an explanation resulting in a slightly more comprehensive analysis. Most statistical based research looks at these first two levels of understanding complexity and rarely delves into system structures, which provide a richer, deeper approach to deriving insights into complex social phenomena. At the level of system structures, different elements interact to feedback and deliver outcomes that could not be observed otherwise if the investigation is restricted to the first two levels of understanding (Sterman, 2006). Methods like systems thinking and system dynamics go to the deepest level of consideration looking at the mental models behind actors in the system whether at the individual level or the organizational level. These mental models, in turn, are based on the worldview, or paradigm of the individual(s) or organization(s) under study and these determine why certain

policies might work or might not work (Sterman, 2000, Maani and Cavana, 2007, Sterman, 2006). The iceberg model helps us understand why there is a need to use systems methods for investigating certain complex phenomena. System analysis uses a holistic approach that helps develop insights into unintended consequences and has proven useful in research when considering phenomenon as a whole especially in case study research (Thomas, 2015a).

**Systems thinking** is the process of understanding how individual elements that may be regarded as systems together influence one another within a larger system forming a complete entity. Systems thinking is primarily used to explore the elements, components, and boundaries of a system while also using the language of systems analysis to depict cause and effect relationships between those elements visually. This study will use SSIs, FGDs and other methods to make Causal Loop Diagrams that will help develop a better understanding of relationships on the underlying issues of disaster resilience and their components. The qualitative diagrams thus developed will be used by the researcher as the first step towards developing a system dynamics model.

**System dynamics** is a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems — literally any dynamic system characterized by interdependence, mutual interaction, information feedback, and circular causality. In this study, a preliminary SD model will be used to develop insights into the feedback relationships between the resilience elements in the organizational system on the disruption profile due to disasters. A complete system dynamics simulation model could be used for scenario modeling where perhaps different levels of hazards can be simulated, or the impacts of different mitigation strategies on the impacts of hazard could be simulated.

The systems analysis process in the literature consists of four major stages which can be broken down into subtasks depending on the preference of the authors. As summarized by Luna-Reyes et al. (2012), typically these stages are classified as 1) conceptualization (problem definition and system conceptualization), 2) model formulation, 3) testing (model behavior and model evaluation) and 4) model validation (policy analysis and use). The different stages of Systems Analysis and the data collection methods that can be used at each stage are shown in **Table 5** below

**Table 5. Stages of Systems Analysis with methods that can be used at each stage. Adapted from Luna-Reyes et al. (2012).**

Stages in the Modelling Process		Methods used
Problem Identification and Conceptualization	Problem Definition	<ul style="list-style-type: none"> <li>• In-Depth Interviews (IDIs)</li> <li>• Focus Groups Discussions (FDGs)</li> </ul>
	----- System	

	Conceptualization	
Model Development/ Formulation	Model Formulation	<ul style="list-style-type: none"> <li>• In-Depth Interviews (IDIs)</li> <li>• Focus Groups Discussions (FDGs)</li> <li>• Causal Loop Diagrams (CLDs)</li> <li>• System Dynamics Model (SD)</li> </ul>
Model Refinement	Analysis of Model Behaviour ----- Model Evaluation	<ul style="list-style-type: none"> <li>• Causal Loop Diagrams (CLDs)</li> <li>• System Dynamics Model (SD)</li> <li>• Group Model Building (GMB)</li> <li>• Sensitivity Analysis (SA)</li> </ul>
Model Validation and Use	Policy Analysis ----- Model Use	<ul style="list-style-type: none"> <li>• Causal Loop Diagrams (CLDs)</li> <li>• System Dynamics Model (SD)</li> <li>• Group Model Building (GMB)</li> <li>• Scenario Modelling (SM)</li> </ul>

This study will seek to apply these four stages to understand and develop a more detailed understanding of the resilience of an organizational system and in the process of doing so will also develop the platform for a system dynamics model that could be used as a simulation learning tool for policy makers and decision makers in the future. The formulation of these models will help decision makers within the firm to plan for disaster resilience and to better understand their environment regarding the impacts of complex events like epidemics. These models may even be used to test the cost effectiveness of different mitigation measures before adopting them and will contribute to the overall disaster resilience of the organizational system.

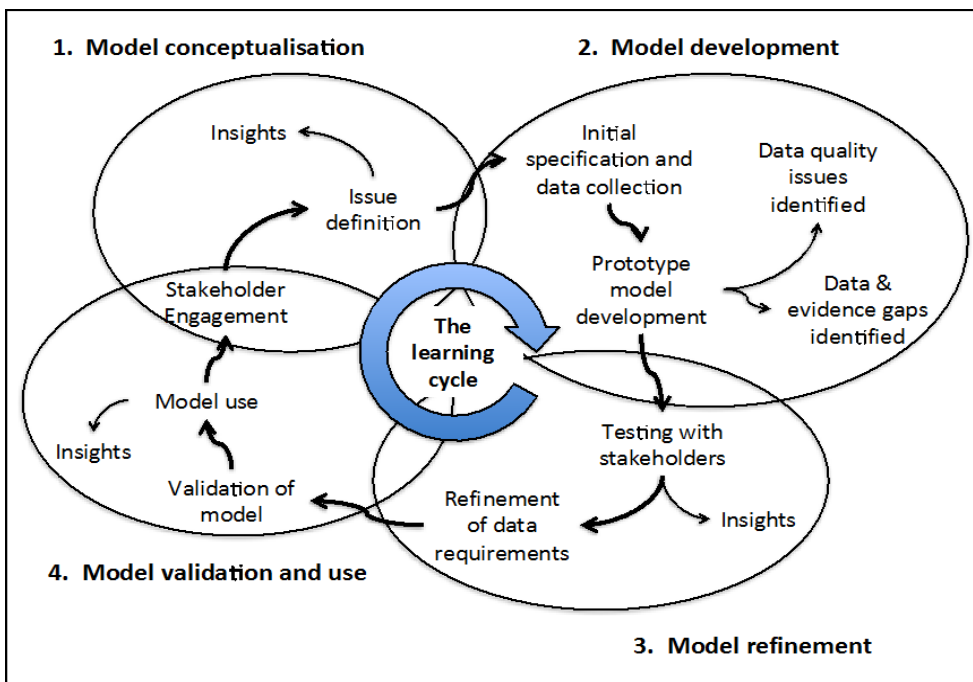


Figure 12. Stages in Systems Analysis Modelling (Source: Lacey (2014))

### 3.4 Systems thinking and case study research

As mentioned in the previous section, Complexity science seeks to address the problem of using tools based on the reductionist approach to the scientific method of analysis that is the preferred approach in physical and natural sciences (Johnson, 2009). This approach tries to break things down into smaller components and seeks to statistically manipulate variables by trying to discover cause and effect relationships between individual variables. Complexity science, in contrast, looks for a more holistic approach where the whole is more than a sum of its parts. Similarly, case study research design also naturally tends to use the holistic approach of investigating and addressing issues of social inquiry. Peter Checkland (1981) and Gary Thomas (Thomas, 2015a) have both indicated that systems thinking is a good tool for case study research because of the emphasis on investigating holistically and looking at the wider phenomenon around the case itself.

**Table 6. Procedure for Case Study approach justification. Adapted from (Thomas, 2015a).**

Subject	Purpose	Approach	Process	
Outlier	Intrinsic	Testing a theory	Single	Retrospective
	Instrumental	Building a theory		Snapshot
Key	Evaluative	Drawing a picture		Diachronic
Local	Explanatory	Experimental	Multiple	Nested
	Exploratory	Interpretive		Parallel
				Sequential

Thomas (Thomas, 2015a) has indicated that to conduct a systems analysis of a case study; the researcher must be able to justify the use of the case study approach by following a procedure outlined above in *Table 6* above. The procedure provides a step-by-step guide to the researcher to clarify how, why and what choices to make among the possible choices shown above.

Regarding the selection of the subject of the research, it must be determined why a case study method is appropriate for its inclusion in the study. In this case study, we have chosen to investigate AML as case study firm for reasons that can be justified as an Outlier case. Outliers are those cases that are unique and deserve attention on their own for being an exception to the case. Key case studies, on the other hand, look at the case study as a key example of a type previously defined. The local nature of a case study is due to special access afforded to a researcher because of a connection or familiarity that is not possible for other researchers to have. This research study can be classified as a key example of a resilient enterprise that has been selected for clearer and more in-depth understanding. Although the case study tries to compare AML to the theory of resilient enterprises

built over time in other case studies – there is also an element of the outlier and local access involved in its selection. For example, at the time of the outbreak AML was the only major mining company that did not stop its operations and continues as planned showing a commitment to working in Liberia not shown by others – this itself is a reason to explore AML and how it survived the EVD outbreak without shutting down. Additionally, there is also an element of local access involved as the researcher worked during the Ebola outbreak in Liberia and formed a working relationship with the members of the EPSMG where he interacted with executives from across private sector organizations. The researcher thus had personal knowledge and contacts within the extractive sector in Liberia before the beginning of the research study and could secure access to a firm like AML, and its employees, relatively easily as compared to an outsider. Regarding purpose, the research study seeks to be exploratory and tries to investigate the impact of the disruption on AML as well as provide insight into the decision-making process taking place during the time of the outbreak in 2014-15. This exploratory nature of the study is apparent in the way a conceptual model of organizational resilience is developed and validated with senior management within the organization.

Regarding the approach adopted, it is to partially test the theory of resilient enterprise as indicated in the literature as well as to be interpretive in how the firm thinks about the reasons why it was resilient and how actions taken, like preventative measures, might have contributed to that resilience. The process chosen was the single case method using retrospective analysis as the firm had just gone through the outbreak and the event was relatively fresh in the minds of the employees in terms of organizational memory. Retrospective case studies are common in disaster research as they deal with effects and impacts of events (Phillips, 2014a). Hence, the case study approach has been chosen as the most suitable method to be used in this research.

### **3.6 Systems dynamics and Participatory Modelling**

As mentioned previously, system dynamics is a research method that has both qualitative and quantitative components that it combines into an approach that can be used to understand the dynamic behavior of systems, especially complex social systems (Sterman, 2000, Luna-Reyes et al., 2012). In SD, the behavior of a system is a function of its structure hence if an intervention wishes to change behavior in a system it should examine carefully and understand the structure of the system (Sterman, 2006).

SD was developed at MIT by Jay Forrester in the late 1950s to combine his experience and background in science and engineering to the problems faced in managing large corporations (Meadows, 2008). Over the years it has been used in various contexts ranging from modeling the US counterinsurgency operations in Afghanistan and Iraq to developing community resilience in city neighborhoods in the US and Canada (Johnson, 2009, Peck and Simonovic, 2013, Hovmand, 2014). It can also be described as an evolving method that has taken advantage of advances in both computing power and statistical methods to help researchers use interdisciplinary approaches to understanding complex problems (Lich et al., 2013).

It is essentially a method that adopts a feedback perspective on complex behaviors within a system that results from the interplay of feedback loops, stocks and flows, and delays between elements of a system (Sterman, 2000). Model building and simulation methods play an important role in SD both for conceptualizing a problem or issue as well as using the simulation method for social learning (Lich et al., 2013, Hovmand, 2014).

Forrester, the founder of SD, defined SD as a theory of the structure and behavior of complex systems and defines four hierarchical levels in the application of the method (Vennix, 1996, Richardson, 2011):

- 1) the closed boundary
- 2) the feedback loop as the basic system component
- 3) stocks and flows
- 4) goals, observed conditions, the discrepancy between goals and observed conditions and desired action

These four components form the basis of an SD study and will be detailed in the application of the method in the case study later in the results section in Chapter 4. Richardson (2011) also emphasizes that feedback loops and mechanisms are crucial to the understanding of systems behavior because they are a direct consequence of the endogenous point of view within the system and are based on the mental models and worldviews of those participating in the model construction (Maani and Cavana, 2007).

The method has proven especially useful in generating insights about non-linear processes that can be seen in complex phenomena like policy resistance, unintended consequences and counter-intuitive behavior of social systems (Sterman, 2006). These are valid problems of interest to government ministries, local authorities, and humanitarian response agencies, especially when

designing interventions for resilience building in disaster scenarios like in our case study context (Johnson, 2009, Ramalingam, 2013).

Although most applications of SD are based on interactions with different stakeholders and hence are participatory in some ways there is a particular branch of SD applications called participatory modeling (PM), also known as group model building (GMB), that takes this involvement to a higher level (Vennix, 1996, Andersen et al., 2007). GMB uses the principles and techniques developed for participatory modeling and have been successfully used in many public policy applications most recently in public health (Hovmand, 2014). Participatory modeling is the process of incorporating stakeholders; including public and private sector decision makers into the modeling process and are particularly useful in soliciting information from stakeholders and integrating scientific knowledge with local knowledge (Sterman, 2006, Luna-Reyes et al., 2012). GMB can be particularly relevant for understanding community or organizational resilience and can be potentially useful in mitigation and recovery planning as well, and this research will investigate its application in disaster management in a case study.

Participatory modeling has evolved in SD through several roots from the theory of collaborative learning in the 1960s to the “Sunshine laws” in the US during 1970s that required federal and state governments to have meetings with different stakeholders in public services for decision making in the 1970s (Voinov and Bousquet, 2010). The US Army Corps of Engineers (ACE) also used the method for stakeholder participation in environmental decision-making and assessment during floods and emergency response – later these experiences helped form the foundations for the Shared Vision Planning approach. The 1990s saw a particular rise in the use participatory modeling methods with the development of Companion Modelling at CIRAD in France, Shared Vision Planning used by the ACE in the US and Group Model Building by Jac Vennix in the Netherlands (Vennix, 1996, Voinov and Bousquet, 2010).

In the last decade, the method has been used extensively in public policy research. In the public policy literature, it is known by various names such as Mediated Modelling, Companion Modelling, HubNet (where applications are available for free for open source use), and particularly as Group Model Building (Voinov and Bousquet, 2010). It is important to note also that these techniques were developed and applied for not only research into system dynamics models but also for research on agent based models and social network analysis.

The GMB process has been described by Vennix (1996) as “... a process in which team members exchange their perceptions of a problem and explore such questions as what exactly is the problem



we face? How did the problematic situation originate? What might be its underlying causes? How can the problem be tackled?” It has been used successfully in the past to bring about consensus on complex issues and problems between decision makers at different levels in both the corporate and public sectors (Vennix, 1996, Rouwette et al., 2000, Andersen et al., 2007). One of the key objectives of GMB is to involve a relatively large client or stakeholders group in the process of model formulation and not just conceptualization (Andersen et al., 2007). This leads to the question why would researchers want to involve a large number of people in the modeling process and what are the benefits of using a GMB approach.

The GMB process benefits from the ability of SD methods to reveal insights into the feedback mechanisms that may exist in a system. This process, if done properly, is complemented in a group environment wherein a relatively little time a large amount of information can be processed that a skilled modeler can immediately turn into informal causal maps to be verified and approved by the group (Sterman, 2006, Luna-Reyes et al., 2012). This process then becomes the source of information for the structure, the dynamics, the non-linear relationships, the parameters and the boundaries of the model. The process grounds the study in the mental models of those participating – both from the researcher’s perspective and the community or organization perspective. In our case study, this would be the perspective of senior management of the firm and forms the basis of our understanding and evaluation of organizational resilience.

Also, a model developed through this process has a higher chance of acceptance amongst the stakeholders because in effect they have developed the model – this ownership effect can potentially facilitate implementation of any intervention developed with the participants after the process (Sterman, 2000). Stakeholder acceptance is crucial in the development of disaster risk management and reduction strategies. These tools could be then used for evaluating resilience in multiple scenarios across different situations in the case study applying the developed SD model and methods (Sterman, 2006).

Proponents of the process also point out a key advantage of the approach, participation as a form of intervention. This means that participating in a GMB exercise can potentially be an intervention in itself because it may lead to changed mental models or lead to the social construction of new realities. Although the outcome of the process is the model as an artifact, the main benefit may be the significant behavior change in the participants (Hovmand, 2014).

This benefit could be linked to the “Dignity of Risk” narrative in the development and humanitarian sectors of participation and involvement of primary stakeholders and promotes the concept that

people should have an opportunity to be involved in designing the systems that are intended to benefit them (Burns-Lynch et al., 2011). In this case study, GMB will be used to understand the mental models of decision makers within a firm and also their understanding of organizational resilience with respect to disruptions.

## **3.7 Research Process**

### **3.7.1 Study setting**

This research case study was based on ArcelorMittal (AM), one of the world's largest steel companies, and its subsidiary ArcelorMittal Liberia (AML), the leading iron ore producer in Liberia. ArcelorMittal Liberia is one of 13 iron ore mines around the world owned and operated by ArcelorMittal contributing a significant percentage of its total iron ore production. ArcelorMittal Liberia is one of the largest contributors to the GDP of Liberia and has plans for a large-scale expansion which has been temporarily suspended most likely due to the unfavorable price of the iron ore in the international market.

Adopting the perspective of ArcelorMittal Liberia, the study investigated the disruption impact on the firm and calculated the costs of preventative measures adopted by the firm during the EVD outbreak. The study aims to gain insights on how the EVD outbreak impacted the mining firm by measuring the economic costs of various preventive activities. The study takes into account the views of the key staff of ArcelorMittal (both in London and the Liberia offices) across various departments including production, finance, corporate responsibility, supply chain, communications, transport, human resources, and medical staff at the health facilities. Views and feedback from International SOS staff, the medical service providers, stationed in both Liberia and London were also taken into consideration as they were directly involved with ArcelorMittal in their effort to place preventive measures to fight against Ebola.

### **3.7.2 Design**

The study applied systems analysis to understand the impact of the EVD outbreak in ArcelorMittal Liberia with particular emphasis on assessing the total costs of the preventative measures taken by the firm in the EVD outbreak period from March 2014 until December 2015. The study used the systems thinking approach to understanding the impact of the EVD outbreak on the operational activities of ArcelorMittal Liberia from the perspective of the employees, and some selected contractors, while also trying to understand the response of the firm to the EVD outbreak and then estimate the cost of those responses. The research has captured this by combining insights from the qualitative component with the quantitative financial data collected from relevant departments.

The qualitative component also helped the team to develop a conceptual model for understanding the operational resilience for extractive firms. The model can help decision makers in mining firms to better understand how disruptions like EIDs (e.g. EVD) impact critical company functions. The model can be used to gain insights into their organization's ability to plan for future impacts of disruptions and to bounce back quicker from those disruptions. A preliminary system dynamics simulation model is developed to show how different preventative measures can contribute to overall operational resilience. The study used methods commonly utilized in the systems thinking approach including in-depth interviews (IDIs), focus group discussions (FGDs), several group model building sessions (GMBs) and, a final validation workshop. The validation workshop was held towards the end of the study to confirm certain assumptions about the data generated from both the qualitative interviews and the quantitative data collected through documents from the finance department (Luna-Reyes et al., 2012).

### **3.7.3 Data collection**

The study used IDIs and FGDs to collect data and explore the main focus of the research. The study also used group model building sessions and a validation workshop to share results (including the conceptual resilience model) with key stakeholders of ArcelorMittal in London. To facilitate and guide interviews and FGDs, guidance notes were prepared in

advance, which are enclosed in the appendix (see Appendix A & Appendix B). The interviews were conducted in English and took about 45-60 minutes each. The FGDs were conducted in English and lasted almost an hour, consisting of 5 to 7 participants. The group model building sessions also consisted of 5 to 7 participants but lasted up to 2 hours. These sessions were expected to generate additional insights into the structure and function of the system. The data and insights gathered during this process provided the foundation for estimating the cost of preventive measures used by the firm during the outbreak period and developing the conceptual resilience model shared in the validation workshop. The final validation workshop consisted of 7 participants from senior management in London and took almost 3 hours.

Participants in the interviews and FGDs were asked for permission before digitally recording their responses. There were some participants that agreed to an interview or focus group but felt uncomfortable recording their information and refused permission to audio record. All paper and soft copies of field notes, audio files, contact summary form, enrollment forms, consent forms and any other notes are kept securely under lock and key. The digital formats of the interviews/FGDs are password protected and saved in a secured location. The data collected were anonymised with the researcher developing a numbering code corresponding to the participant's interview. An agreement was signed between the researcher and ArcelorMittal on the confidentiality of the data and the discussions that have been shared with the researcher. AM have allowed the use of the data for academic use but require advance information and approval from the AM focal person if submitted for publication or conference participation.

After the first set of interviews in London, the researcher reviewed the interview schedule, which required some small changes. It was decided that there should be an emphasis on asking the respondents to list the critical components of the firm that were, in their opinion, impacted the most (those that were most vulnerable) as well as adding some occupational specific questions regarding their work and how that was specifically affected. It was decided that where more quantitative information was required, like from respondents in finance or logistics, additional spreadsheets would be developed to be either self-administered or filled with the respondent after the end of an interview to get a better

sense of the actual costs associated with the impact. It is important to note that quantitative data received in this way was to be validated with several members of that department in FGDs at various time points during the study period. The study faced specific challenges with regards to obtaining and validating data within the timeframe of the study especially due to changing size and scope of the study (see limitations in the discussion section).

The interview guide (see Appendix A & B) was used to ask respondents about their current occupational role, background, and extent of experience in the company and industry. Additionally, questions on the impact of EIDs on their work (in the past) and the impact of the recent EVD outbreak on ArcelorMittal operations, specifically their work and the departments they belonged too in general. They were asked to list what they believed were the most critical systems impacted within ArcelorMittal Liberia by the EVD outbreak and, if relevant/applicable to them; they were asked to provide information on how the cost structure within the firm may have been affected accordingly. Questions were asked about the preventive measures taken by the company, their knowledge and opinion about the implementation of those measures and their understanding of how it may or may not have affected their work and, if known to them, the costs of those measures.

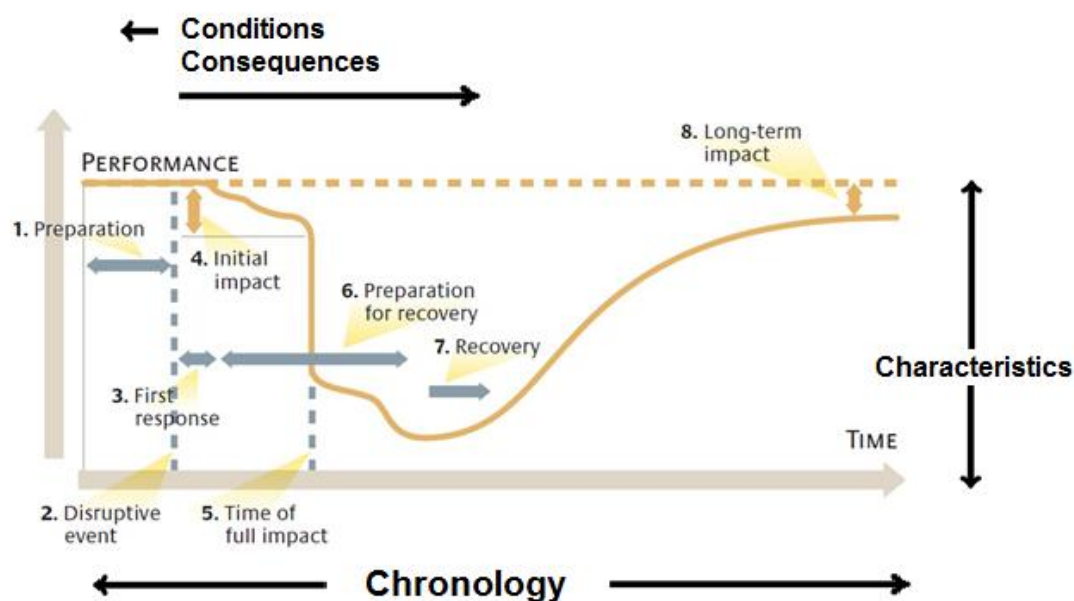
After realizing the practical challenges in receiving, confirming and validating financial data from the study setting within the tight timeframe, the researcher assessed that the qualitative information received could be used to understand the thinking behind preventative measures and that a framework could be developed based on the interviews. The published literature also provided some templates to understand the operational resilience of the firm better. The resultant conceptual model was validated with the senior management through the final workshop.

#### **3.7.4 Analysis of data**

The researcher used the initial interview data from London to develop a system map to understand the boundaries of the system. The researcher also used those interviews to develop an initial set of themes for coding/identifying key resilience attributes from the literature, as well as components of the system within AM's response to the Ebola outbreak and trying to establish the chronology and

initial conditions present at the time of the EVD outbreak. Additional aspects and dimensions were also identified according to themes emerging from the interviews based on the “C4” method used by researchers to study disruptions like natural and man-made disasters: Chronology, Characteristics, Conditions and Consequences (Quarantelli, 1997). The C4 method has been used extensively in retrospective case studies of disaster events and was used in this study as it is a generally accepted valid method of documenting the impact of a disaster event (Phillips, 2014b).

Each of these themes helped unpack how the outbreak affected the different aspects of AM Liberia as an organization from the perspective of their employees. **Figure 13** shows how each of the phases of the disruption profile is covered by the four main themes drawn from the interviews in the study – conditions, characteristics, consequences and the chronology (C4). The disruption profile helps us understand how the system performance of AML was impacted across the different phases, which were then used to develop a conceptual system dynamics model of resilience.



**Figure 13. The 4Cs and the disruption profile. Adapted from Sheffi and Rice Jr. (2005) and Phillips (2014b).**

Statements from interviews were arranged in order of which primary theme they addressed and were then used to develop an understanding of different aspects of the epidemic. For example, statements related to the state of conditions that existed before the outbreak would be used to understand preparedness in the first phase of the disruption profile. Similarly collecting themes under consequences allows us to focus on the impacts. The statements were classified and

rearranged according to emerging sub-themes and these could then form a part of more than one theme or sub-theme as some statements naturally overlap when considering the C4 dimensions. Special notice was made of statements that referred to the presence or absence of the attributes of the resilient enterprise identified in Chapter 2. The approach allowed the study team to visualize the system as perceived by the participants and enabled the research team to understand how the outbreak may have affected the critical functions of AM.

As indicated, the study used the initial interviews to develop an initial set of themes for identifying key aspects of ArcelorMittal Liberia's response to the Ebola outbreak. This was also used to establish the chronology and initial conditions present at the time of the EVD outbreak. Additional aspects and dimensions were also identified according to themes emerging from the second set of interviews conducted in Liberia.

The study used the interviews to identify the main themes and developed CLDs to identify additional themes regarding the vulnerability of critical functions of the firm to the EVD outbreak. After the initial round of IDIs had been completed, a set of CLDs emerged from the process identifying the main feedback loops operating in the system during the outbreak that may have had an impact on the decision making within AM.

### **3.7.5 Systems thinking**

The data emerging from the IDIs and the CLDs were used to identify the impacts of the outbreak on the different components of ArcelorMittal Liberia. Once these had been outlined, the team then defined the relationships between the elements contributing to the development of a conceptual model for understanding the impacts of EIDs on an organization as well as the preventive measures they employed during the period.

#### ***Causal Loop Diagrams***

CLDs are qualitative models widely used in decision support that can help to visually convey relationships between issues including the cyclical loops of causality that often exist (Senge, 1994). Variables in CLDs are joined by arrows showing the causal links between them. Diagrams are developed by gathering information about a problem, identifying the key

variables, mapping the causal links between them and identifying reinforcing and balancing loops – this was done through the in-depth interviews as well as content analysis of documents and literature relevant to the period and event.

CLDs can be used to illustrate possible outcomes of decisions in a relatively simple way. The diagrams have the advantages of being easy to create and to understand, and can help to predict and represent cumulative and indirect impacts. They are particularly powerful tools in decision-making under uncertainty when they are developed through dialogue processes (Hovmand, 2014).

The lack of availability of participants for focus group discussions and the failure to share additional financial data at the early stages hampered the ability of the researcher to develop a more detailed model of organizational resilience. CLDs based on indications from quantitative data could not be developed effectively and hence could not be validated as frequently as desired due to certain challenges faced by the research team (see limitations in the discussion section).

### ***Quantitative costing method***

For analysis of the quantitative data provided by AM a retrospective cost analysis was performed. Detailed data on the costs components identified in the systems thinking approach were sought from concerned departments of ArcelorMittal Liberia. The researcher requested data regarding the preventative measures and other costs incurred that affected system performance. For most of the identified cost items regarding preventative measures data was available with detailed information on resource use and unit costs while the researcher was unsuccessful in receiving other financial data related to system performance such as logistic and supply side information (see limitations section in chapter 5).

As an additional outcome of the GMBs, interest was generated in a micro-costing exercise to calculate additional relational costs of the outbreak. This was performed by calculating the time costs of staff dealing with outbreak rather than their normal duties. It was assumed



that there were opportunity costs of staff time devoted to deal with the outbreak. The impact of the EVD outbreak on relational costs was investigated using qualitative interviews as a part of the system thinking approach. The opportunity costs of the relational items were quantified using wage data of ArcelorMittal Liberia staff obtained from both qualitative interviews and quantitative data.

### ***Group Model Building: Conceptual Model of Resilience***

The study used the information from the qualitative and the quantitative components to develop a conceptual model for understanding the impact of outbreaks on the organizational resilience of a firm in the extractive industry. The model is based on the premise that system performance, defined as any relevant performance metric chosen by stakeholders, can be used as a proxy for understanding the changing level of resilience of a firm during a disruption or shock event. The model was adapted from an initial framework developed at the Multidisciplinary Centre for Earthquake Engineering Research (MCEER), based at the University of Buffalo in the US. MCEER has used the framework to assess the impact of seismic and hydrological events on organizational entities like hospitals, power plants, and other key infrastructures and has an all-hazard approach (Bruneau and Reinhorn, 2007, Vugrin et al., 2011). The approach has been used in the literature to look at the impacts of floods and outbreaks on cities and their key infrastructures and was considered amenable to be adapted to this study (Lannigan et al., 2014, Srivastav and Simonovic, 2014b). The conceptual model was particularly suitable for the study because it gives a better understanding of what drives the decision making of a firm during the period and can be used to understand the impact on the firm of a disruption like EVD in 2014 particularly for the preventative measures that were taken and their consequences within the firm. The conceptual model may also be extended to understand how these measures may have significant impacts on other sectors of the economy. The conceptual model is outlined in more detail in the results section.

### **3.8 Summary**

This chapter looked at the complexity paradigm and its use as a research approach, and using systems methods for looking at disasters and resilience. It also covered the natural link between systems thinking and case study research using participatory modelling. Finally, it covered the research process as used in this study, the design and data collection methods utilized. In the next chapter, the discussion will be directed towards the details of the case study, such as sample of participants, results of the data collection and the outcome of the research process explained in this chapter.

## **CHAPTER 4        Results and Analysis**

### **4.1 Introduction**

Chapter 2 discusses the literature review of the study as well as providing a brief overview of the theoretical background. The chapter also provided the background of the case study selected before concluding with the formulation of the aim and objectives of the study; investigating the impact of a disruption and determining if an enterprise was resilient or not. Subsequently, Chapter 3 discussed the research methodology that was used to address the aim, objectives and research questions of the study. It argued that the research study uses a complexity science approach to understanding disaster impacts; linking it with systems thinking and systems science which is an ideal set of tools for investigating case studies. Furthermore, it indicated that a single holistic case study approach was most suitable for the study context and that the systems approach allowed for the use of semi-structured interviews (SSIs), focus group discussions (FGDs) and group model building sessions (GMBs) for data collection.

This chapter provides the results of the study; the sample size and distribution of participants, the experience level, and other particulars of the case study. Following that, the results of the interviews are discussed identifying the presence of several of the characteristics present in a resilient enterprise over the period of the EVD outbreak. Subsequently, the results from interviews and focus group discussions are covered through causal loop diagramming of key factors during the outbreak. Finally, the outcome of two group model building sessions is discussed which resulted in the development of a conceptual model of the resilient enterprise as perceived by the members of senior management of the firm.

### **4.2 Sample Size and Composition**

The study used a combination of IDIs, FGDs, and a group model building workshop to collect the data on the impact of the EVD outbreak on ArcelorMittal. Table 7 shows the number and composition of the sample of respondents interviewed across different locations and occupational categories within ArcelorMittal. Although a cross section of employees is taken

in the study, more interviews were conducted of those in management and finance than other departments due to their role in decision making in the firm, their knowledge about costing information and their access to financial data. Additionally, for participants in Liberia, interviews were conducted by Skype on a mix of national and expatriate staff to discern if there were any differences in perspective to the impact of the outbreak. A small number of contractors working with the firm were also interviewed for additional perspectives.

The sample size was determined by saturation, both Sterman (Sterman, 2000) and Hovmand (Hovmand, 2014) have indicated that for systems analysis a researcher must conduct interviews till the problem being investigated can be understood and little or no additional information is gleaned from subsequent interviews. Typically for organizations this is around 10-12 interviews but more can be used to explore particular aspects, for example in the case study additional interviews were done for exploring the London-Liberia divide and the expatriate-local difference in decision making (Andersen et al., 2007, Hovmand, 2014) .

**Table 7. IDIs Sample size and composition**

<b>Occupational Category</b>	<b>London</b>	<b>Liberia</b>	<b>Total</b>	<b>Remarks</b>
<b>Senior Management <sup>a</sup></b>	7	7	14	In Liberia (Skype) IDIs with 7 expatriates and 9 locals.
<b>Middle management or Professional, Administrative and Technical Management (PATM) <sup>b</sup></b>	1	5	6	1 FGD with London executives. 1 FGD with expat contractors. 1 FGD with Liberian employees skilled + unskilled. 1 validation workshop in London.2
<b>Labour (Skilled and Unskilled)<sup>c</sup></b>		4	4	Group model building workshop conducted with 6 executives from London.
<b>Total</b>	8	16	24*	

*\*Note only 18 interviews were used in the final analysis (8 from London and 10 from Liberia) due to time limitations (see Chapter 5 section on limitations)*

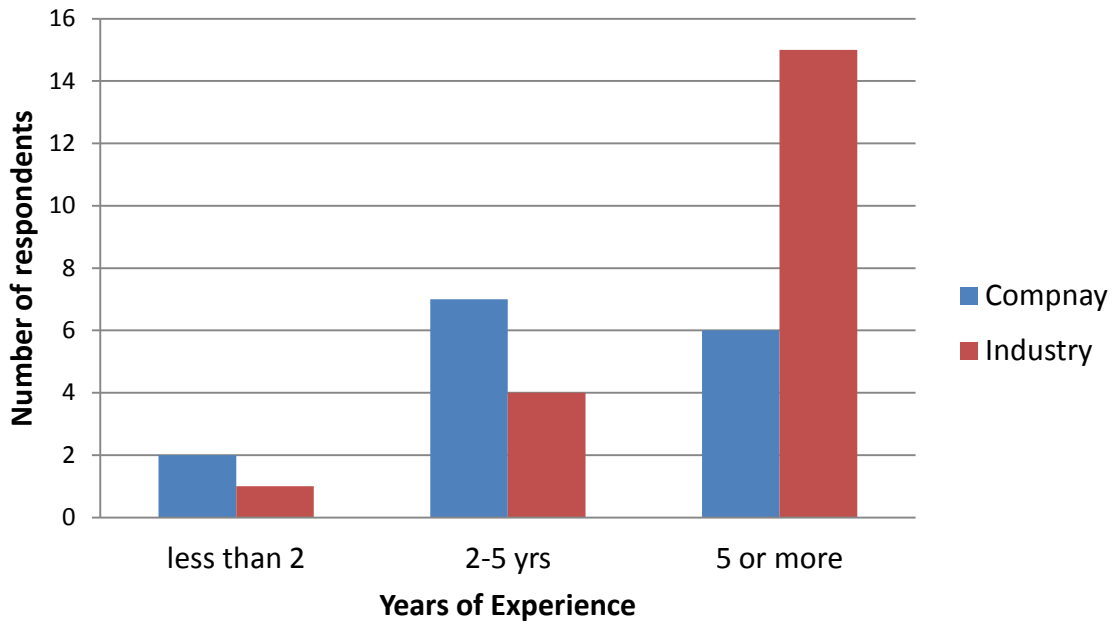
<sup>a</sup>Recruited from the following departments: communications, corporate responsibility, finance, human resources, supply chain/logistics, health & security and government relations.

<sup>b</sup> Recruited from the following departments: administration, risk management, environment, health & safety, supply chain, security, and transport. The term PATM is used by the firm's internal HR system, so it is used here for consistency.

<sup>c</sup> Recruited from the following departments: estate, maintenance, port, mine, rail, security, and transport.

The sampling method was a combination of purposeful and snowballing, as in the first instance the firm was asked to share a chart of its organizational structure showing all major departments both in London and Liberia. After the firm shared this chart, the researcher sat down with the focal person and selected individuals for interviews based on knowledge and experience of the disruption, the department and also their availability. The focal person then initiated contact with those individuals arranging a time for either face-to-face interviews (in London) or through Skype (in Liberia). Although this took considerable time, it was an efficient way to get access to people as the focal person was heavily involved in the Emergency Management Teams during the crisis in London and had first-hand knowledge of the role and involvement of other employees in the crisis. During interviews, respondents also identified personnel that may have additional knowledge or information and these were subsequently added to the list of respondents with the focal person. In most instances, those that were requested were made available for interviews.

Another detail to note is that ArcelorMittal Liberia is divided into two units separated by a 260km long railway line that is operated by the firm itself. These two units are the production facilities at the mine in Tokadeh in Yekepa, Nimba County and the management/port facilities in the port city of Buchanan in Grand Bassa County. There is an additional third unit in Bong County where the railway line passes through as well. The researcher asked the firm to provide access to Yekepa, and they provided access to employees based there. Accordingly, the researcher conducted three interviews with ArcelorMittal staff who worked there – one each from production, health & safety and community services (all were interviewed by Skype remotely). Overall, most respondents were senior management and had considerable industry experience as shown in Figure 14 below. Five respondents had over 20 years of industry experience in mining. Those interviewed had considerable experience working for ArcelorMittal except two respondents who had joined ArcelorMittal recently just before the outbreak period.



**Figure 14. Respondents’ level of experience**

### 4.3 Main themes of qualitative analysis

The main qualitative themes emerging from the interviews are summarized as follows. First, the results covering the conditions before the disruption are covered especially those related to elements of early detection, situational awareness, and flexibility to respond. Second, the characteristics of the disruption, the nature of the epidemic and elements of the culture of the organization is discussed. The discussion is then followed by the consequences or major impacts of the disruption, regarding vulnerability, preventative measures taken and the cost impact of those measures as perceived by respondents and the robustness of the system as well as flexibility in management. Finally, the chronology of events is shown in **Figure 17** based on data from the interviews, documents provided to the researcher and quantitative data shared by the firm. This sequence of events was also verified and validated in the group model building sessions and a validation workshop at the end of the study.

#### 4.3.1 C1 - Conditions before the disruption

This section reports the extent of knowledge of respondents on EVD and the level of preparedness of the organization before the outbreak which indicates the extent of early detection capacity and the subsequent processing of information during this early stage as perceived by the employees.

***Early Detection and Situational Awareness: Ebola a relative unknown***

One of the recurring points made by respondents in interviews was that only a few of them had heard of Ebola before the outbreak with only six knowing what it was and three of those were either medical practitioners or administrators at a medical facility. The relatively low level of awareness was apparent when the word started making its way into senior management meetings in March-April 2014.

*[Name]...at that time he was head of Health and Safety and...he came over and he said that we may have a problem in Liberia...because of Ebola...and I said "Ebola? What is that?"... and that was the first time I had heard about it... but at the time I was not the only one who did not know what it was[IDI 1.401]*

Although there was little awareness about Ebola amongst employees at the initial time, there was an indication in the interviews that some sort of active monitoring of the outbreak was being done. The first reports of disease in Guinea was being noted by members of the risk management team as early as January, indicating that a process for early detection was in place. However, it was when Ebola was placed on the Risk Register on March 22<sup>nd</sup> of 2014 that the need for more information become a priority.

*I was monitoring media reports about Guinea, and they said there was Ebola...I mean I did not know what that was and I had to ask...[IDI 1.202]*

*[March 2014] this is when we have one of our quarterlies, and this was the first time that Ebola was the topic of conversation [at that level]...and because we have quite a lot of risks we are following over time...it takes a lot*

*to be displaced by something new. It is quite a big thing to say that there is something new to consider at one of these meetings [IDI 1.202]*

This perception was also confirmed by other members of senior management who indicated that there was an acute lack of information within the organization about Ebola and that this deficiency made it a priority for the firm to find out more.

*I will not say that I heard about the Guinea infection or any of those, but I clearly knew that there was a corner of Liberia - luckily at that point very far away from Monrovia - that had Ebola and it...I mean like that was obviously now pretty scary though...so as a company our first response was we need more information...so our first point of call was to ask [Outside Organization] if they can help us in this respect. [IDI 1.501]*

It was noted that ArcelorMittal Liberia did not have a management plan for Ebola ready in March 2014. However, management realized that an outbreak in Liberia would have serious consequences for operations in the country and that there was little or no preparedness for such an eventuality. According to a respondent, other organizations in the extractive sector were similarly unprepared.

*It was not like the company, or anybody else had what we would call Ebola Emergency Response Plans...there was nothing to benchmark against...it was completely new to everybody...there were security response plans...emergency evacuation plans [for medical treatment] a lot of those are put in place as standards...but nothing like a response plan [for Ebola] at that time..."[IDI 1.301]*

The initial lack of awareness about Ebola meant that very few decision makers could count on their experience or on established protocols to deal with any potential outbreak of a new or as yet unknown disease. As Ebola was a relative unknown for the industry in the region, this placed special information demands on ArcelorMittal's medical partners, but things came into motion only after EVD was confirmed in Guinea in March 2014.



The evidence in the interviews not only indicates that there was some capacity for early detection, but the firm also had the situational awareness to prioritize the information that was present at the early stages of the outbreak and process that rapidly to their medical partners who had more expertise. The rapidity in processing a potential threat to action is touched upon below in a subsequent section.

#### **4.3.2 C2 - Characteristics of the disruption**

##### ***Nature of the Epidemic: Two outbreaks***

Many respondents commented on the timing of the spread of the outbreak – there were essentially two phases; 1) when the first cases appeared in rural communities near the Guinean border in March 2014 and 2) when cases started appearing in urban areas like Monrovia in June 2014.

*It was March when we heard there was an outbreak in Lofa [Liberian county on Guinean border]...and then between March, April and May it kind of like quieted down...and then in June...it picked up...mainly from Lofa and then we heard that there was a lady who traveled from Lofa to one of the most congested communities in Monrovia..." [IDI 2.402]*

This 'quiet' period may also have played a role in making some people skeptical about Ebola and to be initially complacent about preventive measures especially the citizens of Monrovia and Buchanan (two major cities in Liberia). Some respondents indicated their perception of the risk of Ebola changed after the second phase of the outbreak when the outbreak came geographically closer and wasn't just a rural problem in the border areas.

*The government did not take it seriously...when we first heard about it...it was like a joke...we did not take it seriously until it came down to Monrovia. [IDI 2.902]*

However, these remote rural border locations were where ArcelorMittal Liberia's main production facilities were situated, and the first phase of the outbreak was taken seriously by the firm and the preventative measures recommended by experts were implemented as soon as possible.

*Around summertime, it picked up...with a rise in the number of infections...and it might have looked like we were unprepared but we already had systems in place...and it was an issue that was being dealt with on a day to day basis by health and safety. [IDI 1.202]*

### ***Facing an unknown enemy***

One common analogy that was repeated by Liberian national respondents was that the experience of Ebola was in some ways worse than the civil war because of the unknown nature of where and when the disease will strike.

*It [Ebola] is much worse than before [Civil War]...in the Civil War there were hotspots...where there was firing at least you could tell and avoid it...with a bullet, you know which direction it is coming from...and from who...this thing it could be anyone...your own family even..." [IDI 2.902]*

This view was shared by several respondents, and they reported a level of dread that existed around their normal work routine and their lives.

*"The mood and psyche of the whole place changed...it became...more negative...and there tended to be Ebola talk everywhere and you just could not avoid it, and it put a layer of negativity over everything..." [IDI 2.1902]*

The atmosphere of negativity generally contributed to the feeling of fear and ArcelorMittal Liberia identified this early on and chose to address it. If ArcelorMittal wanted to continue its operations, it had to address its employee's fears. The importance of clear and timely internal communications was apparent.

*The biggest impact [of the Outbreak] was fear, and we spent a lot of time engaging with our employees...the level of fear was something we had to manage effectively to continue working. [IDI 2.1501]*

While this epidemic took place, it is important to realize that these personal level impacts on the employees would have adversely affected the working environment and the culture of the firm. This environment of fear may have impacted the early decision making within AM. The impact of the perception of fear is discussed further in **Figure 25** Section 4.5 below where causal loop diagrams attempt to show how the epidemic was perceived by the employees of AML and what factors contributed to increasing fear in this system. **Figure 26** goes on to discuss the role of communication in AML and how it could act to reduce fear and tension in the system.

### ***Personal level Impacts***

Many of the employees had personal stories to share which gave an added depth to the researcher's understanding of the outbreak on ArcelorMittal Liberia, its workforce and the population in general as well.

*The biggest impact for me was...I have not hugged my kids in a year...now we just do not touch, and they have grown out of it..." [IDI 2.902]*

*This was most stressful time of my life...I did not see my family for long periods at a time because of restrictions [they were in another city]...I hope it never repeats itself...it was dreadful. [IDI 2.402]*

*It was a very scary situation...in the beginning of August and September...a scary situation...I saw for the first time a person in full PPE go and pick someone who died...in front of me on the street... 150 m away [IDI 2.104]*

These quotations are just some of the personal stories that were shared with the researcher and helped in considering some of the conditions that existed at the firm and in the country during the outbreak. Although documenting the fear and horror of an EVD outbreak is beyond the scope of this

study – analysis would be incomplete without understanding some of the personal level impacts of the disaster. This is especially true when these personal experiences can impact the culture and working environment of the employees of the firm

***Ebola here to stay***

Another perception that was commonly reported among respondents was that once Ebola entered a country, it became a permanent risk. The potential for frequent flare-ups of the outbreak had changed the outlook for the country forever in the eyes of some respondents.

*It may have always been here [in animals], but I have no doubt that there will be more outbreaks...once Ebola enters a country it stays...this is an additional risk now [IDI 2.201]*

This perception was confirmed by another respondent who also indicated that Ebola might have an impact on the ability of the firm to attract future investment for the extractive industry in the country.

*There are so many factors where...yes, I think it is huge because it just makes it, so you then move from whether it is political risks or Ebola or other things...it is another factor for a company willing to invest large sums of money in a country...it makes it a lot more difficult...and not mixing that in with current ore prices. [IDI 2.1902]*

The uncertainty that was created impacted not only future investments in mining projects but also had an impact on the supply pool of expatriate workers available to extractive industry firms in the region. The same respondent reported that this has led to some expatriates declining work in countries with Ebola risk – though how prevalent this view is generally amongst expatriates working in the industry could not be confirmed in this study.

*A friend of mine [expatriate] was working in [country], and they [the whole country] only had two cases of Ebola, but three expatriates on site resigned and left because they felt that was not safe...so not only investment but let's face it in West Africa you need to bring in expatriates for certain positions and*

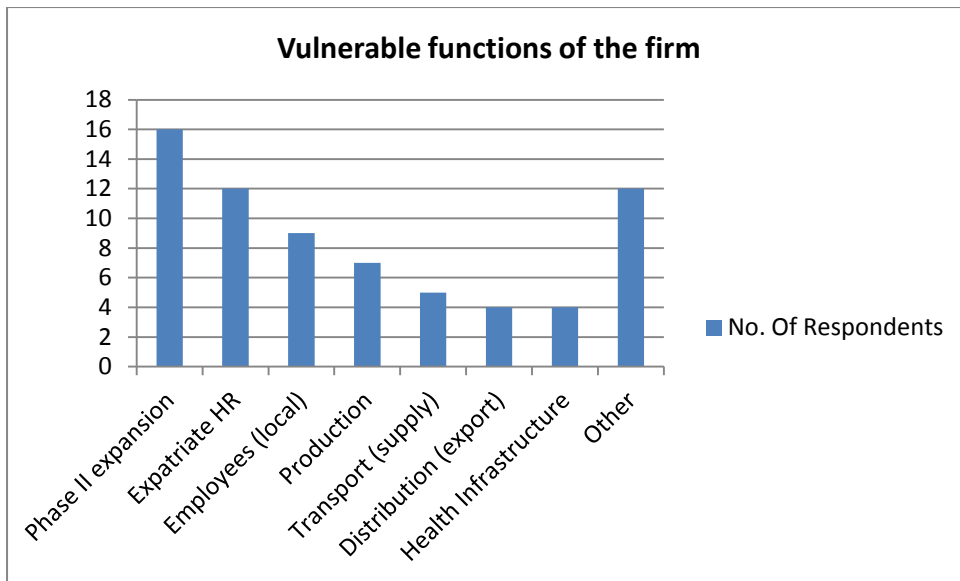
*your pool of resources just shrinks...because people are saying "Oh no...no I am not going to West Africa because there is Ebola" on top of whatever else*  
**[IDI 2.1902]**

The entry of Ebola into West Africa meant that a change needs to take place in the overall risk assessment of working in and investing in countries where Ebola is now a real threat. As indicated above, this will effect to a certain extent the culture of the organization as it faces additional challenges particularly in human resources and extra health & safety regulations.

#### **4.3.3 C3 – Consequences of the disruption**

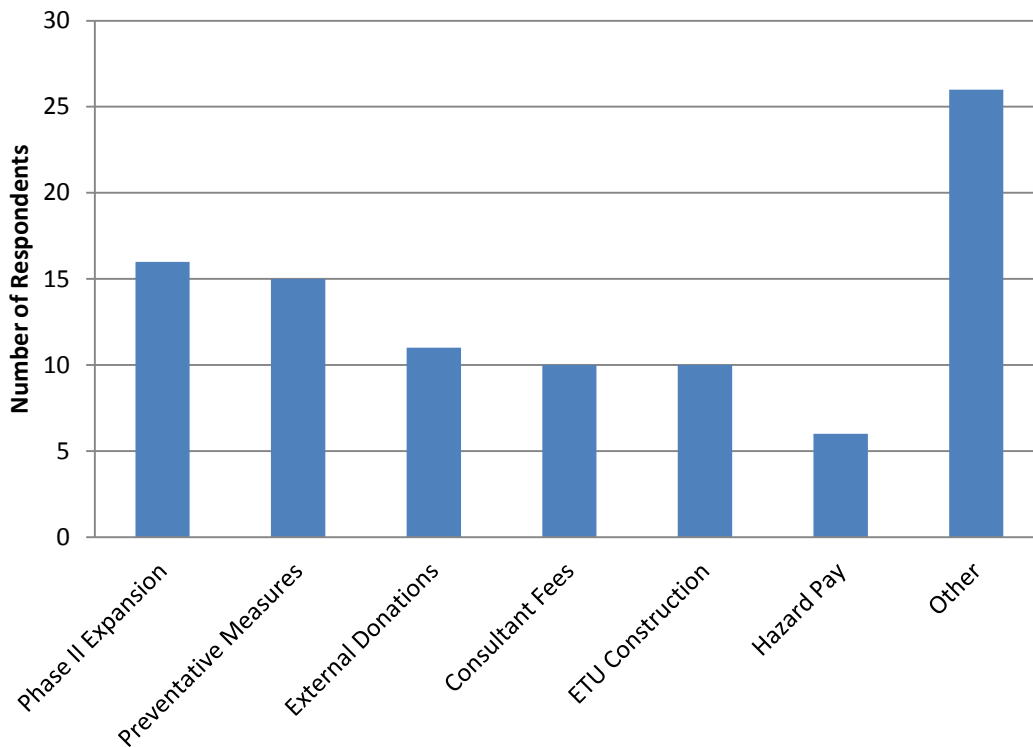
##### ***Vulnerability and major cost impacts***

This section reports the results from the qualitative interviews on the perception of the major vulnerabilities of the firm and the major cost impacts with respect to preventative measures and other steps taken by the firm during the outbreak. First the respondents were asked what the three most vulnerable functions of the firm were. This was framed within the context of the EVD outbreak and is show below in **Figure 15**. The respondents indentified the Phase II expansions project as the most vulnerable function followed by the perceptions that an outbreak will most likely impact the human resources the most – both expatriate and local employees. As a large proportion of those interviewed belonged to senior management (a large number of whom were expatriates), it was expected that this will be indentified but this was reported even by local members of senior management that were interviewed thus identifying this as a key vulnerability for the firm.



**Figure 15. Vulnerable functions of the firm**

Respondents were asked to list and rank what in their opinion were the three major cost impacts of the EVD outbreak on ArcelorMittal Liberia's operations. **Figure 16** below summarizes some of the perceptions of the respondents. Similarly to the response above in key vulnerabilities, the majority indicated that the suspension of Phase II expansion (due to major contractors declaring 'Force Majeure') was the largest cost impact on ArcelorMittal. The next largest cost impact was the preventative measures adopted by the firm to counter the spread of Ebola followed by external donations mentioned as the third largest cost impact. In addition to this a number of other impacts were mentioned like administrative issues, loss of efficiency due to temporary redundancies and hazard pay.



**Figure 16. Major cost impacts as perceived by respondents**

***Phase II expansion***

The Phase II Expansion is a series of projects worth US\$ 1.7 billion that was going to expand iron ore production for ArcelorMittal Liberia from 5.2 million to 15 million tons per annum. Phase II consists of projects for large scale construction of infrastructure in both parts of the mining concession – the expansion of the iron ore mine in Yekepa and a huge iron ore processing and loading plant at the port of Buchanan. This project was expected to last four years over the time period of 2014-2017. The suspension of Phase II expansion was cited the most times by respondents in the interviews and focus groups but the assessment of what was the total cost of this suspension is beyond the scope of the study. Respondents mentioned that one of the reasons for the suspension of Phase II in 2014 may have been due to airlines stopping services to Monrovia.

*The [Phase II] construction was impacted because our contractors had to leave...some of them...because of Ebola fear...they did not leave because of Ebola but because of the restrictions put on travel...and they did not want to be hemmed in. [IDI 2.1801]*

The project is placed on hold till further notice by ArcelorMittal, more due to the international market price of ore than the after effects of the Ebola outbreak and the resultant loss in overall production and revenue has hit both ArcelorMittal and Liberia itself very hard.

*They [contractors] did not just shut down and leave...the Liberians that worked for them had to shut down and go home too...and in our setting one person is responsible for between seven to thirteen persons...so you can imagine the impact on the families in the county. [IDI2.501]*

Despite the advanced stage of the project most of the large contractors could not tolerate the risk of the restricted flight schedules which imposed problems on staff rotations and, in case of emergencies, medical air evacuation protocols for their employees and they had to declare Force Majeure.

*A lot of the contractors left...so essentially we had hundreds [100s] of millions of dollars' worth of equipment lying around ready to go...but we had no contractors to finish it...so essentially we went from going as fast as we could...and then we hit a brick wall. [IDI2.1902]*

Although the EVD outbreak may have been responsible for the series of events that led up to the declaration of Force Majeure with the contractors deciding to pull out of Liberia in August and September of 2014 the situation was different in 2015. ArcelorMittal Liberia decided to delay and eventually to temporarily suspend the expansion which may have been due to the tough international market conditions for iron ore in that year (2015). The suspension has continued till now the time of writing (2017).

*The 2014 dates [of Force Majeure] were more driven by the contractors themselves saying...you know we are pulling out...this [risk] is not acceptable to us - 2015 was more I suppose driven by ArcelorMittal in the sense that we were actually calling the suspension to the project...but one kind of fell after*



*the other...it was a bit of a domino...but certainly you know if Ebola had not come in theory we would have...you know those months we lost we would have had contractors on the ground and they would have been constructing and we would have been further down the road then we are now.*

**[IDID2.1902]**

The impact of contractor behaviour has a crucial role to play particularly with regards to the implementation of Phase II on the system of AML. This is discussed in greater detail below in section 4.5.

***Preventative measures - quick response, consultant costs and training***

A number of the major cost impacts that were pointed out by the respondents were actually part of the package of preventative measures that ArcelorMittal Liberia adopted over the outbreak period. These were recommended by ArcelorMittal's risk management team and medical consultants as mentioned below. The complete list and cost of preventative measures is presented in the next section – costs of preventative measures but here we discuss some costs that were mentioned by respondents.

A number of respondents had the opinion that the one of the factors that separated ArcelorMittal Liberia from other extractive industry members was the proactive nature of the firm in seeking information and getting it out - in the words of one of the respondents "to the shop floor" as soon as possible. The speed at which the decision was taken to seek advice from ArcelorMittal Liberia's health partners and for them to find and put an expert on a plane to Liberia as soon as possible represents perhaps this proactive stance at addressing knowledge gaps as soon as possible.

*The moment they made the decision...we want to maintain our operations...which was a massive decision to make knowing all the unknowns...then they said we need the advice...what we immediately did was to bring to site one of the few people in the world who has responded to a*

*previous Ebola outbreak and this started the process of getting comfortable with this unknown threat [IDI 1.803]*

*We made the request on the 22<sup>nd</sup> [March]...and within a week...on the next Sunday [the Health Expert] was on the ground in Liberia providing advice and awareness...where he spent the good part of April doing meetings, road shows and talks across ArcelorMittal Liberia's concession in Buchanan, Yekepe and even Monrovia. [IDI 1.501]*

The health expert was a world authority on Ebola. The expert spent three crucial weeks of April 2014 in Liberia and advised ArcelorMittal Liberia on preventative measures while collaborating with International SOS in developing their medical response to the outbreak. This intervention was important for ArcelorMittal Liberia both as a tool for the internal communication of risks within the organization and for providing insight into strategies to safeguard their employees, the concession and the communities around it. The effectiveness of this communication was apparent as several of the respondents directly mentioned the health expert by name and indicated that the risk communication activities he was a part of were the initial sources of information they received about EVD from ArcelorMittal Liberia.

In addition to information and awareness the health expert helped deliver practical training to the medical components of ArcelorMittal Liberia hospitals situated in Buchanan and Yekepe. These trainings then were also delivered to public health staff at local health institutions including the first such training delivered to one of the main teaching hospitals in Monrovia well before any other organization - indicating a pro-active approach by at least this member of the private sector to engage with a public sector institution in risk reduction at a very early stage.

The impact of preventative measures on the AML system is discussed in further detail in section 4.5 below.

### ***Social awareness campaigns and programs***

Risk communication materials developed during this initial phase helped ArcelorMittal Liberia to distribute large numbers of printed material across their concessions initially targeting employees, their families and then the wider community at large. As mentioned earlier ArcelorMittal Liberia has a large operational footprint across three counties – Grand Bassa County where the port is located, Nimba county where the mines are located and Bong County which the rail way line connecting the two passes through. Accordingly, ArcelorMittal Liberia has an interest and responsibility to engage with a large number of communities in all three counties and is well placed for delivering social awareness programs.

*We have 52 communities we engage with, 32 in Nimba, 15 in Bong and another 15 in Grand Bassa...and in each we have Community level committees. [IDI 2.402]*

The level and degree of engagement during the outbreak and before is beyond the scope of this study but the interviews with staff members of the concerned department indicated that there were additional roles they had to conduct during the period indicating flexibility in social outreach staff roles as well as the role of others. These roles included conducting a Social Awareness Campaign on Ebola, delivering hand washing buckets and sanitizers and other activities within these communities – particularly those communities inside or in close proximity to the concessions. Staff indicated that additional duties often involved more hours of work than normal and a far greater level of stress was involved.

*We had to put aside our normal work to get involved in awareness and monitoring...we set up monitoring teams within the communities [around the concessions]...we gave them mobile phones to get in touch with us in case they see anything...there were checkpoints [around the concessions] and we had to sometimes physically check and monitor them...there were times I was called out in the middle of the night and I had to go. [IDI 2.402]*

The same teams were also used to develop contact tracing information on all ArcelorMittal Liberia employees – including those living outside of the concessions and in other counties – although this took a long time to develop at the time of the interviews ArcelorMittal Liberia staff indicated that they had residential details and contact information on almost all of their employees located on maps.

This information was used during the outbreak period to monitor suspected employees contacts with relatives that may have died due to the EVD outbreak. When a report was received by contact tracing staff within ArcelorMittal Liberia that a relative of an employee had died due to EVD they were asked by the Medical team to come in for a check-up and were monitored for any signs of temperature or other EVD symptoms.

*Even if your relative died in Monrovia...we call you in...when we hear your relative died even if your story is you did not go you might have gone over night and came back...and I would check by asking you questions...and if I was not satisfied I would put you in 21 days quarantine. [IDI 2.501]*

The 21 day quarantine policy was used in around 20 cases during the outbreak period – where the suspected cases were placed in isolation at ArcelorMittal Liberia’s expense. Most of these cases occurred in Yekepa, Nimba County where the mine was.

There are plans to maintain this contact mapping database and continue using this in the future for monitoring and response. The interviews indicated that a considerable amount of time, and effort was spent on these additional activities in communities within the concessions.

Some of the discussions above highlight the role played by communication, both external and internal, during the crisis. The impact of communication on the system of AML is discussed in more detail in section 4.5 below.

### ***Screening and fencing***

Temperature screening (TS) and access control were some of the first steps recommended by experts and was quickly employed by ArcelorMittal Liberia throughout the concessions. Temperature Screening was made compulsory for everyone entering the concession as well as every structure, building and sub section of the concession and this screening is still part of everyday procedures in all ArcelorMittal Liberia facilities.

### ***Concession safest place***

There were different views on this in the responses with some doubting the apparent effectiveness of security in checking everyone and keeping unknown persons out but a majority of respondents indicated that this combination of TS and fencing made ArcelorMittal Liberia's concessions one of the safest places to be in Liberia during the time of the outbreak.

*During the outbreak the concession [in Buchanan] was the safest place to be in all of Liberia...I brought all my nieces and nephew, all 16 of them, to live with me here during the period...while their parents continued to live outside.*

***[IDI2.902]***

This feeling was also shared amongst the expatriates who remained after the non-essential staff (NES) policy was enacted (see below). Even though they felt safe in the concession pressures from family and friends were always a concern.

*One of the days my son and wife called me...they said leave the place and come...that's it...there is no point to continue in that place [work in Liberia]...today you must travel [back]...I said to them I am in the safest place [in Liberia]...no need to travel [back]. **[IDI 2.104]***

The procedures allowed for the monitoring of all personnel coming in and out of all facilities and areas and may have added positive externalities both in physical terms of higher security and in early detection of other diseases. Respondents indicated the perception that there may have been a reduction in the number of workplace absenteeism due to Malaria.

*For me personally flu became a non-event...and also because of the awareness in the communities...other diseases like Cholera and Malaria...these were reported less. [IDI2.201]*

The effectiveness of the TS and fencing policy also reinforced some of the views presented by some respondents that building a fence with strict security controls around the concession would be sufficient protection to continue operations. According to some of the respondents with experience in providing medical services to the extractive industry, there is a debate within the industry for a security only approach to the outbreak as opposed to combining security and public health approaches with social awareness and external community support programs.

*If you apply measures and put a fence around you – you can operate safely there and that is what [organization] did...and you wait for the whole thing to burn out. [IDI 2.201]*

The Health and Safety culture prevalent in AM, and multinational extractive firms in general who have to follow international standards, may have contributed to the swift implementation of TS and fencing protocols and this, as reported by several respondents, was tested on several occasions when incidents of suspected Ebola persons (later on confirmed as Ebola cases) almost making it into the concessions.

#### ***Proximity of the outbreak – close calls***

A number of respondents commented on the close proximity of the outbreak to the concession particularly near the mining unit in Nimba County on the border with Guinea. Nimba was one of the hardest hit counties in Liberia in terms of number of confirmed EVD cases and deaths.

*We were lucky...the nearest village in Guinea to our concession in Yekepa...just four to five kilometres away – there was a huge outbreak...on a daily basis we heard of people dying of the disease nearby...we made sure we patrolled the border...but again it could have been one slip. [IDI 2.402]*

There were a number of close calls of Ebola suspected persons being turned back at the gates of the concessions and for many of the respondents one case in particular stood out and was repeatedly mentioned. In December 2014 a woman and a sick child crossed the border from Guinea and entered the concession at night but were quickly reported by the community members to ArcelorMittal Liberia and the county authorities. The woman and child were collected by county authorities and quickly placed in isolation where both were confirmed to have EVD.

*A lady came in from [Infected village] with a sick child...she went over night...we did not know anything about it...and she brought the child in during night hours...but for luck and the mechanisms that were in place...in all of the homes our message was when you have a stranger please give a call...so immediately there were people in the area to where she went that gave us a call...that a lady came from Guinea with a sick child and immediately we called a response team...between the time she came and the next morning they were all evacuated to the holding centre in Ganta and they were hospitalized...where unfortunately the child dies and then the lady also dies. [IDI 2.402]*

As soon as the case was reported ArcelorMittal Liberia and community leaders conducted contact tracing and determined who had potentially come in contact with the woman and child. This led to the placement of around 20 community members in 21 day quarantine – at the full expense of ArcelorMittal Liberia to ensure that no community members were infected (fortunately none of them were infected).

### *Ebola treatment unit*

During the outbreak ArcelorMittal Liberia built and maintained Ebola Treatment Units (ETUs) at significant cost as perceived by AM employees. This entailed construction of two new buildings – one at Buchanan and another at Yekepa - specially designed and equipped to handle 3 confirmed Ebola patients each.

*Because we could not evacuate a patient... and because people from non-affected countries were asking...so what is going to happen to me when I get infected?...as there was no place we could send them...because the MSF facilities were overwhelmed. There was just nowhere to go for them. [IDI 1.803]*

The decision to build these units was seen in different ways by the employees of ArcelorMittal Liberia – some of the expatriate employees saw it as a commitment to them until an evacuation could be arranged to their home countries and some national staff who criticised the decision to separate the health facilities. This created some controversy but this was eventually resolved by top management declaring that the units were for all employees and not just expatriates.

*This was the time when it [medical service] were separated...and we were told from the beginning that it would only be for expat staff...but after some of us frowning on that decision...the CEO then in one of our management meetings said...to open the doors to everybody and Liberians can also attend those facilities. [IDI 2.501]*

It was also pointed out in one of the interviews with medical staff that these units should be called “short stay Ebola management units” and not ETUs because the intention was to stabilize and facilitate the evacuation of a case to an expat’s own country and not to manage the whole treatment of the patient but the study uses the shorter term ETU.



### ***Human resource (HR) policies***

A number of HR policies were enacted during the outbreak that had significant cost implications for ArcelorMittal Liberia. Two specific policies were indicated in the interviews – hazard pay policy and the NES policy discussed below in the next section. The hazard pay policy was costly because of the number of employees that qualified for it – in effect all those who were classified as essential would receive it. In addition to this extra cost of production those employees who were sent home were also paid a salary, but at a reduced rate, incurring additional costs for ArcelorMittal Liberia.

*From a financial perspective...danger pay - that cost a lot...a huge impact from the financial side and...also the quarantine procedures when someone was asked to stay at home or in quarantine ArcelorMittal Liberia paid their salaries...and that showed commitment.[IDI 1.803]*

HR policies taken during this time played an important role and had an impact on the system of AML. The impacts of these policies are considered in a bit more detail in section 4.5 below.

### ***Non-essential staff and evacuation flights***

Another significant cost impact were the NES evacuation flights arranged for expatriate and NES which was triggered after most international airlines cancelled their flights to and from Monrovia. This took place after the declaration of a State of Emergency by the Liberian government in early August.

*As airlines stopped flying into Liberia whether for commercial reasons or Ebola...we operated a set of triggers that would escalate [our alert level for evacuation]...and then when one of the [major] international airlines stopped flying into Liberia...we had to go into evacuation of non-essential employees.  
[IDI 1.301]*

This evacuation of NES had its own set of information and data needs which helped in creating a process called the Persons On Board (POB) list. The POB list is where every individual person that is in the country on ArcelorMittal Liberia business – employee,

contractor or visitor – would have details like contact information and location recorded. This list is to be updated regularly to keep track of where everyone is at all times. This tracking information database is still being maintained by ArcelorMittal Liberia and can be used to report exactly how many expatriates are in the country and where at any given moment.

*The persons on board list...we had plans in place...but they were not effective because we did not know how many people were in country at any one time and their locations...and so those plans were only going to be effective as the information we were being provided with and we call that a Person on Board list...for an effective emergency evacuation you need to be able to identify triggers and who is essential and who is non-essential. [IDI 1.301]*

As mentioned above, everyone in Liberia on ArcelorMittal Liberia business was to be evacuated including expat contractors. These contractors needed to be provided with evacuation flights to their home countries. The experience of expat contractors during the evacuation especially those belonging to non-western countries was shared by one of the major contractors in a focus group discussion.

*We sent the first chartered flight [of expatriate contractors] on the 13<sup>th</sup> of August to [Home Country] and when we tried booking the second flight through the Monrovia to Kenya and then to Dubai route as it was for the first flight...they did not give us landing permission...they were scared...then we took ArcelorMittal Liberia into confidence and asked for help...they were lots of problems...we tried the Sri Lankan route...the Kenyan route as well but no one was giving us [transit] landing permission for our flight...this caused a lot of distress for our staff and their families...then on the 26<sup>th</sup> [August] after great efforts from ArcelorMittal we finally got a flight to Johannesburg and then finally back to home from there...but those two weeks were extremely difficult. [FGD 2.105]*

The experience of non-western expatriates in emergency evacuations during this public health emergency of international concern was not similar to western expatriates who were quickly repatriated to their home countries.

### ***Administrative Issues***

Some respondents indicated that there was an administrative productivity loss due to the preoccupation with EVD management and as a direct result of some the measures taken. More than a few mentioned that in their opinions the largest cost impacts on ArcelorMittal operations must have been the NES policy that ArcelorMittal Liberia enacted in August – September 2014 when it was determined that ArcelorMittal Liberia should keep only essential staff on site and either release NES temporarily or have them work from home or other alternative locations. This was mentioned by several respondents in departments across ArcelorMittal Liberia.

*The challenge we had...was when people were removed form site...you then had quite a disjointed workforce...so where you had a 100 people doing 5 jobs now you had 50 people doing 5 jobs [By Jobs he means projects]...I think that was at least from my side as being an Admin...it became convoluted and...people were in different parts of the world and it was harder to actually coordinate. [IDI 2.1902]*

### ***Supply chain***

One of the crucial impacts of any disruption is on the supply chain and the EVD outbreak had its impacts on the supply chain of ArcelorMittal Liberia as well but this could not be documented through quantitative means as desired but some of these difficulties were mentioned by respondents.

*For my department [department]...we have five people working [function] and during Ebola we ended up only to two [due to NES policy] and the time it took to do work...during that time it took us longer...about three times longer to clear things. [IDI 2.1302]*

Not only did it take longer but charges for logistics and air freight also increased due to both supply and demand reasons. As indicated earlier not only were there fewer flights coming in after the airlines decided to stop flights but after the international response started there was considerable demand for logistics coming in to Liberia as well and this had an impact on the logistics cost of firms operating during the outbreak.

*I think in the August to December period [2014] I would say that around 35-40 percent increase in logistic costs...air freight costs probably increased by a 100 percent...as all these large [international] organizations were using air cargo...like the World Bank and all these other foundations...and cargo was coming in at all costs...so you just could not negotiate prices with them. [IDI 2.201]*

Another issue raised by one of the respondents was that sometimes due to pressure from the Emergency Management Team in London items had to be ordered at short notice causing considerable problems for procurement and logistics. There were several examples that illustrate this problem – one was the problems associated with importing alcohol based hand sanitizers, which were a key requirement for disease prevention and were supplied to Liberia in large quantities. Importing them caused considerable logistics issues as they are high in alcohol content and there are stringent air freight rules for transporting such items. They required special packaging and this contributed to its cost of transport – estimated by one of the respondents to be almost three times the normal price of the item.

The outbreak caused considerable issues with logistics and this is confirmed in interviews with members across several departments within the firm. The respondents indicated that some of the extra costs and bottlenecks in operations were a direct result of issues in supply chain and logistics. This is especially true for a firm in the extractive industry working in conditions like Liberia where most supply items, if not all, are brought in from outside of the country.

*“...it was always if we can’t get the people out of here...its logistics...if we can’t get food in...its logistics...if we can’t get this item or medicine in...its logistics...it always came back to logistics...” [IDI 2.201]*

### ***Emergency management teams***

In early 2014 ArcelorMittal Liberia began reviewing and updating emergency management plans in Liberia in case of major security incidents or natural disasters. ArcelorMittal had decided at that stage to develop EMTs in Liberia as part of a crisis management infrastructure within the firm. These teams consisted of senior management and other concerned staff (as dictated by the needs of the crisis) and would be enacted on an emergency by emergency basis. These EMTs played a crucial role in responding to the EVD outbreak as there was a crisis management structure which ArcelorMittal Liberia could build then on and link to a central EMT located in London.

*Even before the outbreak... in Liberia...so for example if we had a major security incident or natural disaster...anything...we could manage it effectively from the company side. So we put in place what was called an Emergency Management Team...due to the geographical spread of the operations in Liberia...we put together...two EMTs one in Buchanan and one in Yekepa...really all they consisted of was a lot of the head of departments from the CEO on to Health & Safety, Security, Communications and Medical. Then in London we did not really have one – so we made one in London [2<sup>nd</sup> August] during the Ebola crisis which became the Global Emergency Management Team based here in London. [IDI 1.301]*

The Global Emergency Management Team linked with the two Liberian EMTs then took the lead role in responding to the crisis. The EMTs connected daily for several hours a day for the duration of the outbreak and played a key role in the decision making process with regards to what preventative measures were to be taken and when. These meetings of senior management and staff for several hours a day for the peak months of the outbreak

had real cost implications as well – this is considered in the next section under relational costs. The use of EMT structure shows that there is flexibility within the firm willing to adapt its structure and way of doing things in response to the environment which is a key attribute of the resilient enterprise.

The preventative measures covered in this section are a good example of the kind of steps considered by a multinational extractive industry firm in case of an epidemic. The contents of this section would be valuable for those looking at what sort of options were considered by the firm during the time and what actions were actually taken in response by the firm. Both are essential pieces of information for decision makers at different levels to consider in case of future events and also as a documented record of what was done. In this case study, the firm itself expressed an interest in the study as a document used to preserve some of the learning experienced during the outbreak as part of their organizational memory.

Additionally, some of the perceptions discussed above also touch on the debate in the literature that organizations should spend more money on local health systems rather than on their own concessions. It has been argued that if their contributions were focused on local health systems from before then such large scale tragedies as the EVD outbreak of 2014 could be avoided in the future or at least detected far earlier in advance (Llamas et al., 2015, Westwood E, 2015). This sort of thinking would definitely play a part in changing the culture of the organization working in those locations and this was apparent to a certain extent in conversations with those employees working in Corporate Responsibility and Community Outreach rather than those working purely in production, supply chain and other functions of the firm. What was not apparent was how long after this would such considerations for greater engagement with local health systems last within those employees as subsequent years of no Ebola cases in the region may once more create a false sense of security. For purposes of clarity, the next section looks at C4 as the chronology of the disruption.

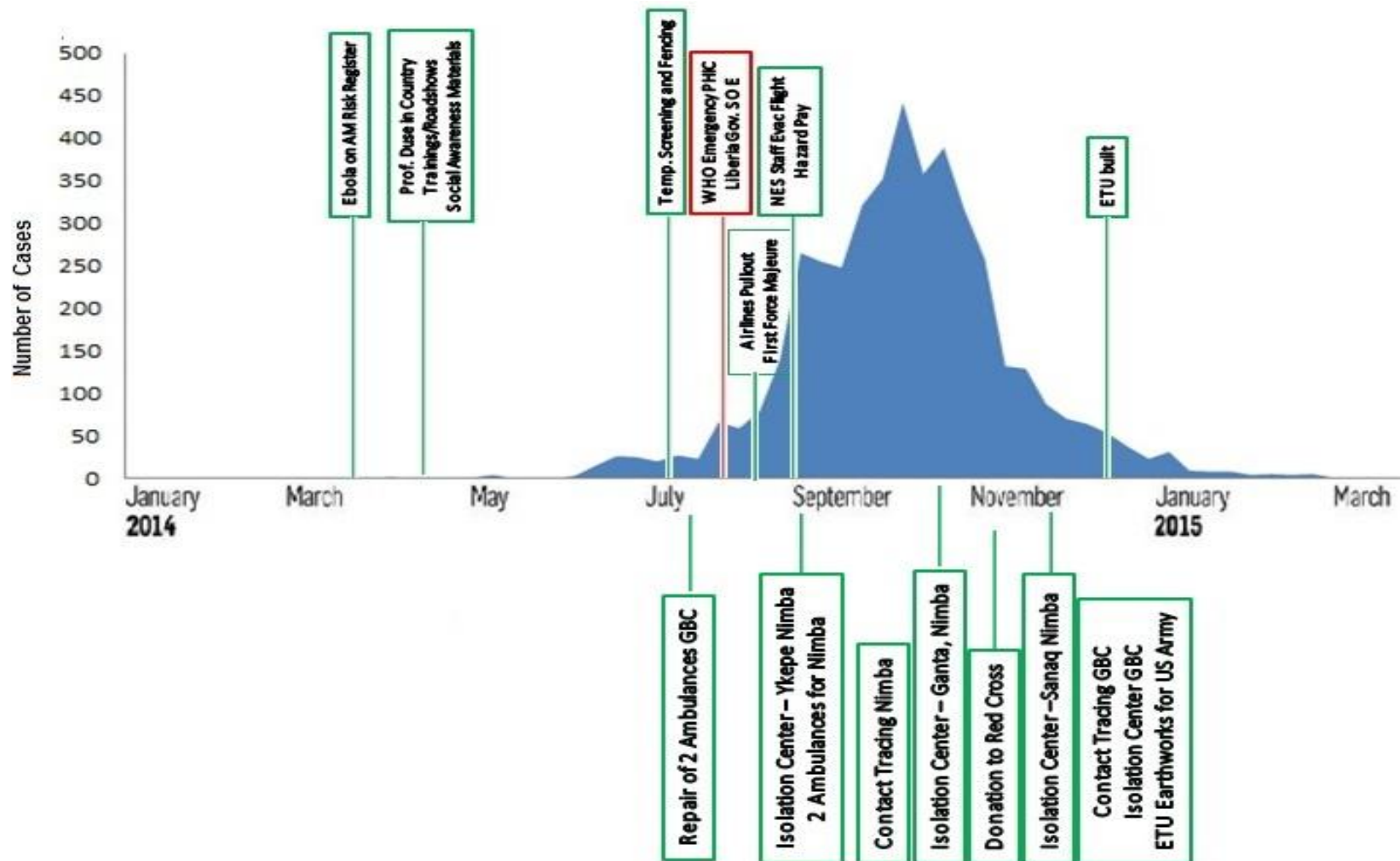
#### **4.3.4 C4 – Chronology of major events during the disruption**

To put these expenditures on preventative measures and external donations in context to the outbreak, **Figure 17** describes the chronology of when (and where) these expenditures were made as indicated in the interviews and quantitative data. The quick response by ArcelorMittal Liberia in bringing in expertise within a week to help increase understanding of the disease is seen here as the first step towards developing and adopting a medical approach to the EVD outbreak. Many respondents of the qualitative study indicated that by early adoption of recommended measures like social awareness campaigns and temperature screening, ArcelorMittal Liberia was reacting proactively regardless of the mortality and morbidity rates prevalent in Liberia at the time. This proactive stance might have been due to the fact that ArcelorMittal Liberia's production was concentrated geographically in those remote areas that were dangerously close to the Guinean border where dozens of cases were already reported.

The timeline of ArcelorMittal Liberia response also shows that when the number of cases per week picked up in June and July 2014 ArcelorMittal Liberia already had systems in place to continue its production. This commitment to be operational allowed it to be in a position to help the communities it was based in to fight back by contributing to the building of critical EVD outbreak control infrastructures when they were needed most at the peak of the outbreak well before the international community's response.

The timeline of response shows that the firm started by adopting timely preventive measures to protect its employees and operations. The success of the firm's response in maintaining the site Ebola free led it to expand its support to humanitarian response in partnership with government and non-governmental organisations. This supports the premise in the literature that a resilient enterprise contributes to a resilient community.

Figure 17. Ebola cases per week and the chronology of preventative measures and external support



Note: GBC stand for Grand Bassau County



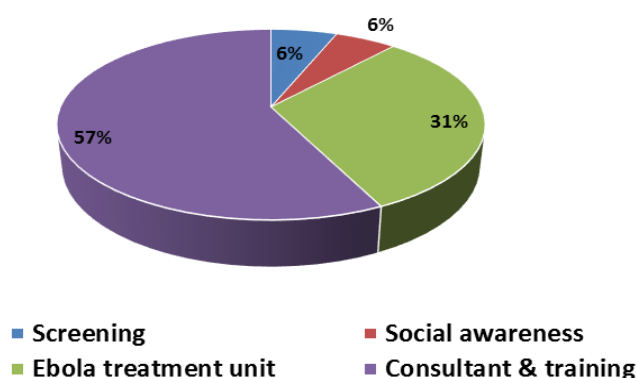
#### 4.4 Estimated costs of the preventative measures

The sources of actual costs incurred by the firm during the EVD outbreak were outlined in conversations with finance staff as well as through documents shared by them. This was also confirmed to an extent by the qualitative study results discussed above. The main sources of costs impact were; (a) preventive measures adopted in ArcelorMittal Liberia concession areas and raising awareness in the adjacent community; (b) in-kind donations of priority materials and direct support to national and international engagement in the health and humanitarian crisis; (c) Ebola-related construction costs; and (d) additional salary paid to workers as hazard pay during the outbreak period, and evacuation of NES. There are other costs as well, such as the lost productivity from workers engagement with health and safety measures during the outbreak period.

##### *Costs related to preventing measures implemented on site and adjacent community*

The calculated costs of preventing the outbreak were USD 3.29 million. The percentage distribution of different preventive costs items is presented in Figure 18. Approximately 60% of preventive costs were incurred from payments to consultants (ex. Consultancy A) and training for laying the security and safety measures in place. Costs of building an Ebola treatment unit for treating suspected/infected case were approximately 30% of the total preventive costs. Costs related to screening of everyone entering the site and building social awareness in the adjacent community was approximately 12% of total preventive costs.

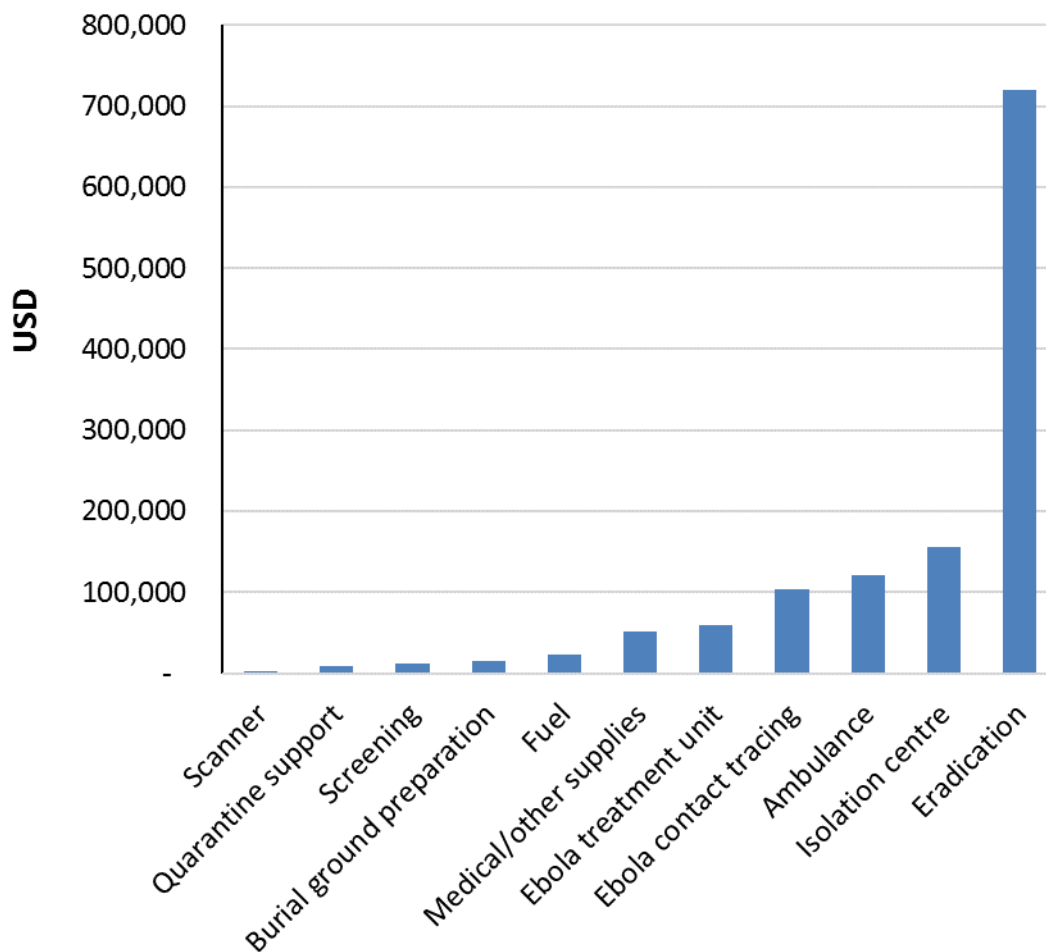
**Figure 18. Percentage distribution of costs related to preventive actions adopted on site and adjacent community**



**Donations and direct support to health and humanitarian crisis**

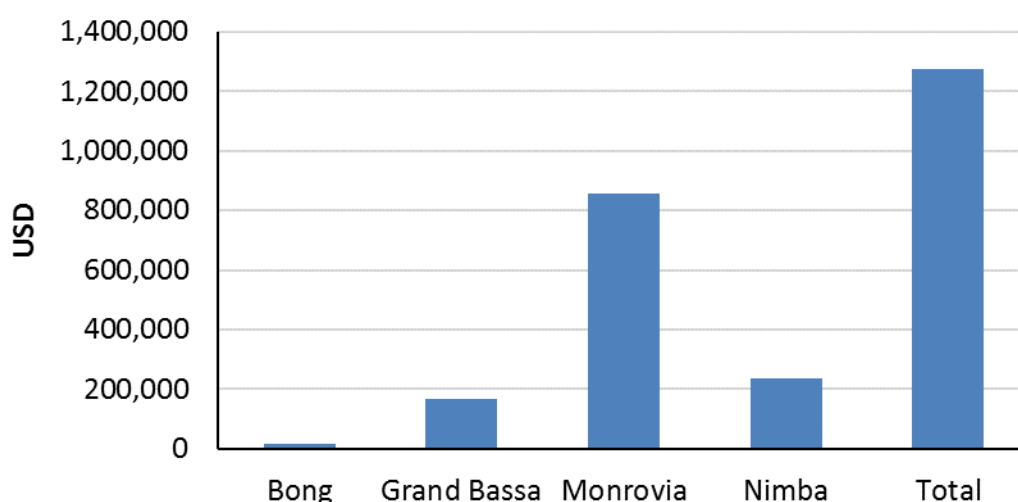
ArcelorMittal made donations to the wider community for supporting prevention and treatment of Ebola. The costs related to donations and support to external Ebola response was approximately USD 1.27 million. The costs of different external support activities are reported in Figure 19. The major share of external support was for supporting response towards eradication of EVD, followed by building an isolation centre, donations towards ambulance services, contract tracing, machinery and capacity to construct external Ebola treatment units, and other essential medical supplies. Donations also included supplying fuel, preparing burial grounds, and other preventive actions (screening, quarantine support and putting in a scanner at the airport).

**Figure 19. Costs of external support by activities**



ArcelorMittal Liberia provided external support to many Ebola initiatives around community. The largest share of external support was provided to support Red Cross activities (56%) shown under eradication in figure 4, followed by providing funds for the regional county task forces formed at the local government level to deal with the epidemic (28%), hospitals (11%), county/township services not covered under the taskforce roles (4%) and other beneficiaries including airport, police and other government departments (1.2%). Geographical distribution of external support is presented in Figure 20. The largest proportion of external support was provided to Monrovia and surrounding county, followed by Nimba, Grand Bassa and Bong County.

**Figure 20. Geographical distribution of external support**



***Ebola related construction costs***

During the EVD outbreak ArcelorMittal also incurred additional construction costs for mining activities while maintaining security and safety of its workforce in light of risks related to Ebola transmission. These costs were incurred from constructing gates, installing washing stations, and building fencing as safety measures adopted to fight Ebola. The additional construction related costs totalled USD 1.56 million. These changes to the built environment had a large impact on how employees considered the concession to be the safest place in all of Liberia – as indicated in the interview section results above.

### ***Additional salary costs***

ArcelorMittal paid hazard/incentive payment to the workforce to help maintain a stable supply of workers during the outbreak period. The costs of additional salary payment during the outbreak totalled USD 2.41 million.

### ***Evacuation of non-essential staff***

The cost of evacuation of expat and NES was USD 1.27 million. These costs were incurred from chartered flights and co-ordinating flights.

### ***Relational costs***

The qualitative interviews and GMBs identified that daily meetings among the senior management were part of the prevention programme that ArcelorMittal adopted. In addition, middle management, skilled and unskilled workers were also spending time during the outbreak period to discuss the company's Ebola action plan and procedures in preparation for preventing Ebola transmission. While spending time on this was considered an essential part of the prevention programme, there is an associated productivity loss. The qualitative interviews and GMBs suggest (Table 8) that on average senior management spent 1.5 hours per day during the peak Ebola period (August to November, 2014), followed by 1 hour daily during the off-peak outbreak period (December 2014 to June 2015) and 0.2 hour daily during the super off-peak outbreak period (July to December 2015). In the base case, only staff time of senior management is costed to value relational costs. The daily hours spent by senior management on Ebola related activities during peak and off-peak period varied between upper (1 hour during peak, 0.5 hour during off peak) and lower limit (2 hours during peak, 1 hour during off peak) as indicated in the qualitative interviews.

The researcher also evaluated time costs of all other employment categories to predict possible relational costs when outbreak affects staff time and productivity across the board.

It was assumed that all other workers spent on average 0.2 hour per day on Ebola related activities over the outbreak period (August 2014 to December 2015).

**Table 8. Duration (in hours) per day spent on Ebola activities during outbreak period**

Employment category	During peak Ebola period	During off-peak Ebola period	During super off-peak Ebola period
Senior management	1.5	1	0.2
Middle Management	0.2	0.2	0.2

It was assumed that the typical ArcelorMittal employee spent 40 hours a week at work.

**Table 9. Distribution of workforce and hourly wage rate**

Employment category	% of total workforce <sup>a</sup>	Hourly wages
Senior management	1.2	150.0 <sup>a</sup>
Middle management/PATM	14.6	6.0 <sup>b</sup>
Skilled	72.4	4.7 <sup>c</sup>
Unskilled	11.8	3.7 <sup>d</sup>

<sup>a</sup> Obtained from qualitative interview participants.

<sup>b</sup> Calculated from average monthly salary of employees working in following departments: communications, corporate responsibility, finance, human resources, information technology, legal, school, and technical services.

<sup>c</sup> Calculated from average monthly salary of employees working in following departments: administration, environment, health & safety, and supply chain.

<sup>d</sup> Calculated from average monthly salary of employees working in following departments: estate, maintenance, port, mine, rail, security, and transport

Based on the distribution of workforce and hourly wage rate across employment category (Table 9), the costs of lost productivity (termed as relational costs) was in the range of USD 0.78 million to USD 1.30 million.

***Other costs items***

Qualitative interviews investigated whether there were additional costs of the outbreak from shut-down, transport costs, insurance payment, and supply chain items attributable to the EVD outbreak. The responses of key ArcelorMittal staff suggested no additional costs were incurred from any other items in addition to those already included in this analysis on inside the fence preventive measures, construction, salaries, donations and relational costs.

The total preventative costs of the outbreak incurred by ArcelorMittal were mainly driven by direct costs and relational or productivity costs as reported in Table 10. The total preventative costs of outbreak were in the range of 10.58 million USD to 11.11 million USD.

**Table 10. Total costs of preventive measures**

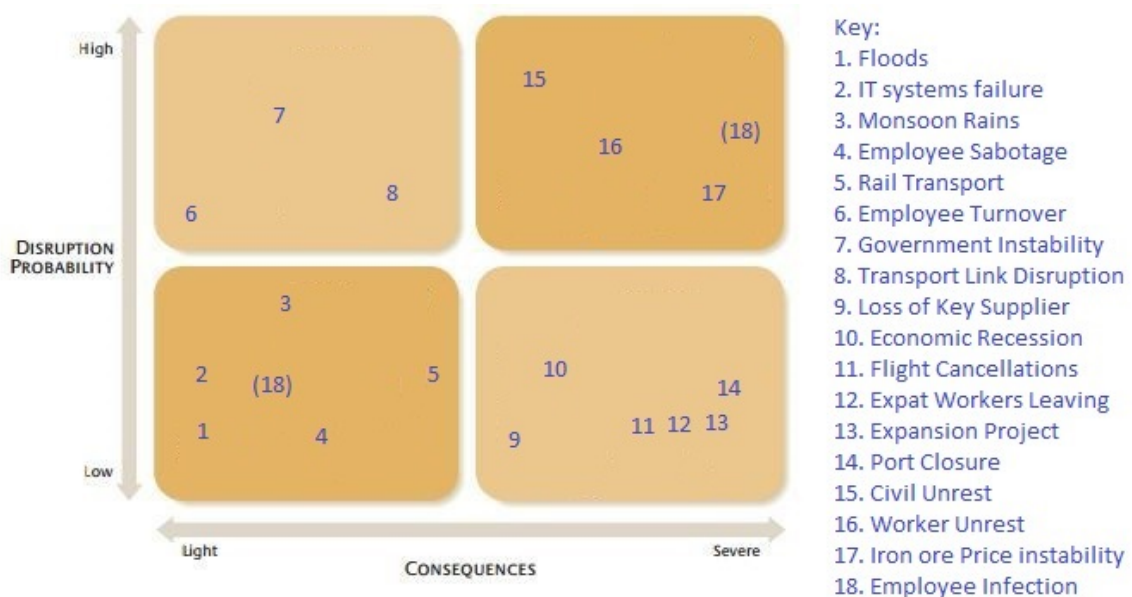
	<b>Estimated USD (in million)</b>
<b>Within the fence preventive measures</b>	3.29
<b>External donations</b>	1.27
<b>Construction related</b>	1.56
<b>Salary</b>	2.41
<b>Evacuation of non-essential staff</b>	1.27
<b>Relational</b>	0.78 to 1.30
<b>Total costs</b>	<b>10.58 to 11.11</b>

The overall direct costs of preventative measures adopted within the fence share about 80% of the total costs incurred. The share of external donation supporting humanitarian response was about 12% of the total costs followed by 7-12% of relational costs.

#### 4.5 Vulnerability and Risk perception of AM employees in FGDs

##### *Vulnerability Maps from FGD and GMBs*

The FGDs and GMBs were conducted with relevant stakeholders in the system – the first FGD was held with contractors working on the expansion project and the other group was made out of finance and risk management staff. The GMBs were conducted with senior management. Participants in all groups had worked during the outbreak and were asked to list and rank the main vulnerabilities faced by the mining firm. The contractors were able to provide their point of view as those working with the mining firm on the various projects related to the expansion project as well providing additional services on site. This led to the production of a consolidated vulnerability map which was discussed near the end of the focus group discussion. The vulnerability maps produced were compiled and validated in the final workshop with members of the senior management and the final map is provided below in **Figure 21**. Note that several items were omitted by the senior management as those items were considered sensitive to their business processes and only that information which could be openly shared was allowed to be represented in this final vulnerability map.



**Figure 21. Vulnerability map (source: FGDs and Validation workshop)**

The vulnerability map confirms, to some extent, the findings of the interviews conducted previously on what were the most vulnerable functions of the firm – in section 4.3. Although those questions were framed primarily with an EVD outbreak in mind and were asked without the consideration of the probability dimension as with the focus group participants they still largely conform to views of the participants in focus groups. The vulnerability map was a useful addition to the data collection process in that helped the researcher initiate a discussion and frame how resilience of the firm can be increased in relation to those vulnerabilities identified here. Note especially the position of employee infections as this was a source of debate among participants in the FGDs. This was resolved when two points were identified for infections – one for outbreaks of EIDs like malaria and yellow fever which were frequent but of less consequence and the second point for EIDs like Ebola which if present in the populace presented a high probability and high consequence to the operations of the firm. This high probability of Ebola infection was probably cited due to the close proximity of the timing of the study to the actual full blown epidemic in 2014 which extended well into 2015. Otherwise it was argued by some participants as a rare event.

#### ***Mind maps and Mental Models***

Another output from the GMBs was the development of mind maps. The participants were asked to map out the expected medium to long term impacts of the outbreak on Liberia in general and their firm in particular. This mind map, show below in **Figure 22**, represented the view of the senior management of AM London at the time of the peak outbreak. It is presented here solely as the view of the seven senior management members present who all worked during the outbreak period.





Finally, another interesting finding from the GMBs was how the firm believed its continued operations contributed to overall community resilience. **Figure 23** on next page shows how senior management envision the economic contribution of the AML operations contribute directly through tax revenues and indirectly through income generation on the local community and its resilience. The senior management of AML considered that preventive actions taken by them had a larger overarching impact on the city and the region they were operating in. For industry that has a large contribution to the overall GDP of Liberia, if these enterprises are resilient they could potentially have a large impact on disaster resilience if coordination between the private and public sectors could be done.

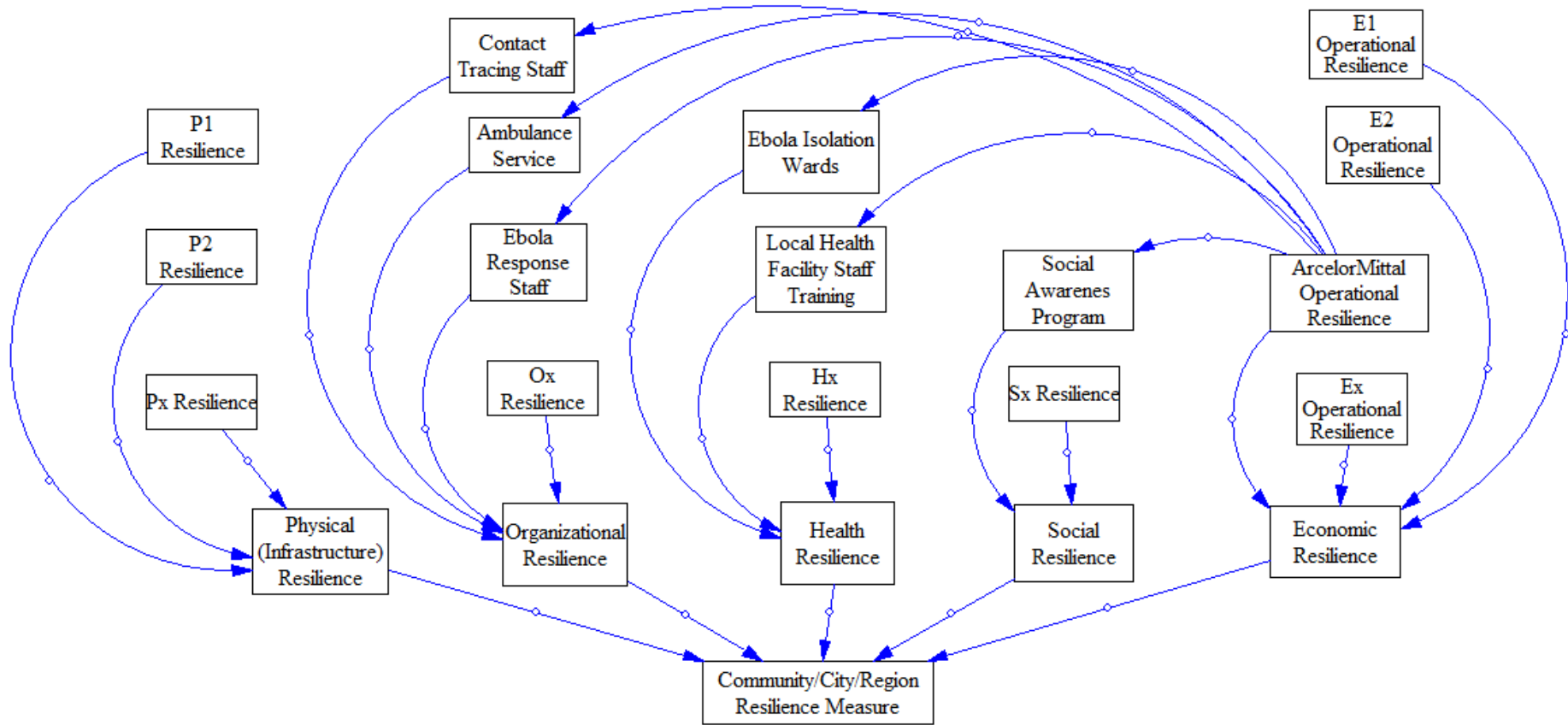
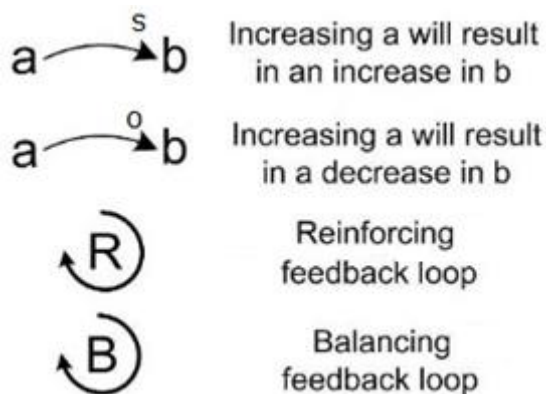


Figure 23. Mental model of AML operations and impact on community resilience (source: senior management FGD)

### ***Causal Loop Diagrams of Risk and Resilience Attributes***

Conceptualizing the boundaries of the system, conditions, consequences and characteristics of the outbreak through interviews and focus groups allowed the study to develop a series of interconnected causal loop diagrams (CLDs) which together set out a hypothetical system map for the response of the company and the wider local system (i.e. including other stakeholders in the system: suppliers, Government, workers and other extractive firms) to the EVD outbreak. This involves identifying the direct and indirect impacts of an action and representing them as a network of interactions – the terminology used here is outlined in Figure 24 below.

**Figure 24. Terms used in the CLDs to denote relationships**



Please note when reading the diagrams that an 'S' is described as an influence going in the 'same direction' and can be either positive or negative, i.e. an increase in 'a' will result in an increase in 'b' or alternatively a decrease in 'a' will lead to a decrease in 'b'. Equally an 'O' indicates an influence going in the 'opposite direction' and could start with an increase or decrease in 'a' leading to 'b' moving in the opposite direction. Also please note that reinforcing loops can either be a positive or negative whilst a balancing loop will be goal seeking or stabilizing. These diagrams are discussed in the sections below. The marked connection points in each diagram show variables which appear in more than one diagram – the diagrams have been separated to aid communication and understanding of the key sub-systems. They should all be thought of as linked elements in the wider system of causal relationships.

Key elements of the total cost to the firm of the EVD outbreak are shown here as they relate to the causal links in the system. It is important to note that this section represents the impact of the outbreak on risk perceptions at the time of the outbreak in 2014 – exploring some of the motivations behind the expenditures made on preventative measures (and external donations). These figures represent a snapshot of how the outbreak may have been perceived by senior management at the time when in September 2014, the Centre of Disease Control (CDC) had predicted 1 million infections by the end of the year (CDC, 2014). In interviews, respondents have indicated that this uncertainty may have significantly contributed to the overall cost itself. This section does not attempt to quantify those costs, merely to identify the sources of cost in relation to the actions taken across the wider system to reduce the impact of the crisis on the company's performance. Note also that this does not set out to be a comprehensive analysis of every causal link across the whole of the company's operations. It forms an initial, high level analysis of the functions explored in the interviews.

As mentioned previously, this is a retrospective research study and the firm had continued production throughout the challenging period (Fry, 2014) so this section will look at the actual and perceived risk in the system at the time of the disruption (2014-15) and how that impacted decision making in the firm, for example the preventative measures considered and selected. This section attempts to show some of the causal connections between some of the resilience attributes discussed in Chapter 2 and the mental thinking of senior management behind the decision making process at the firm during the disruption.

### ***Actual and perceived risk***

The series of loops shown in Figure 25: The impact of EVD outbreak on the system – shows how causal relationships relating to actual risk and risks perceived by key stakeholders describes the response of the key system stakeholders to two connected but non-identical factors:

- The actual risk of an outbreak of Ebola in a location with a direct impact on the stakeholder's interests
- The level of risk perceived by the stakeholder to apply to their interests at a given time

Separating actual and perceived risk is crucial to understanding the behaviour of the system. It provides the climate in which stakeholders acted (or did not act) to develop and operationalise a response to the EVD outbreak. It is arguable that most of the activity that took place across the system, and therefore most of the cost of the response, was in relation to heightened perceived risk, as opposed to the actual proximity of the EVD outbreak to the stakeholder's interests.

Examples of reinforcing loops (denoted by R in the diagrams) consisting of both perceived and actual risk include:

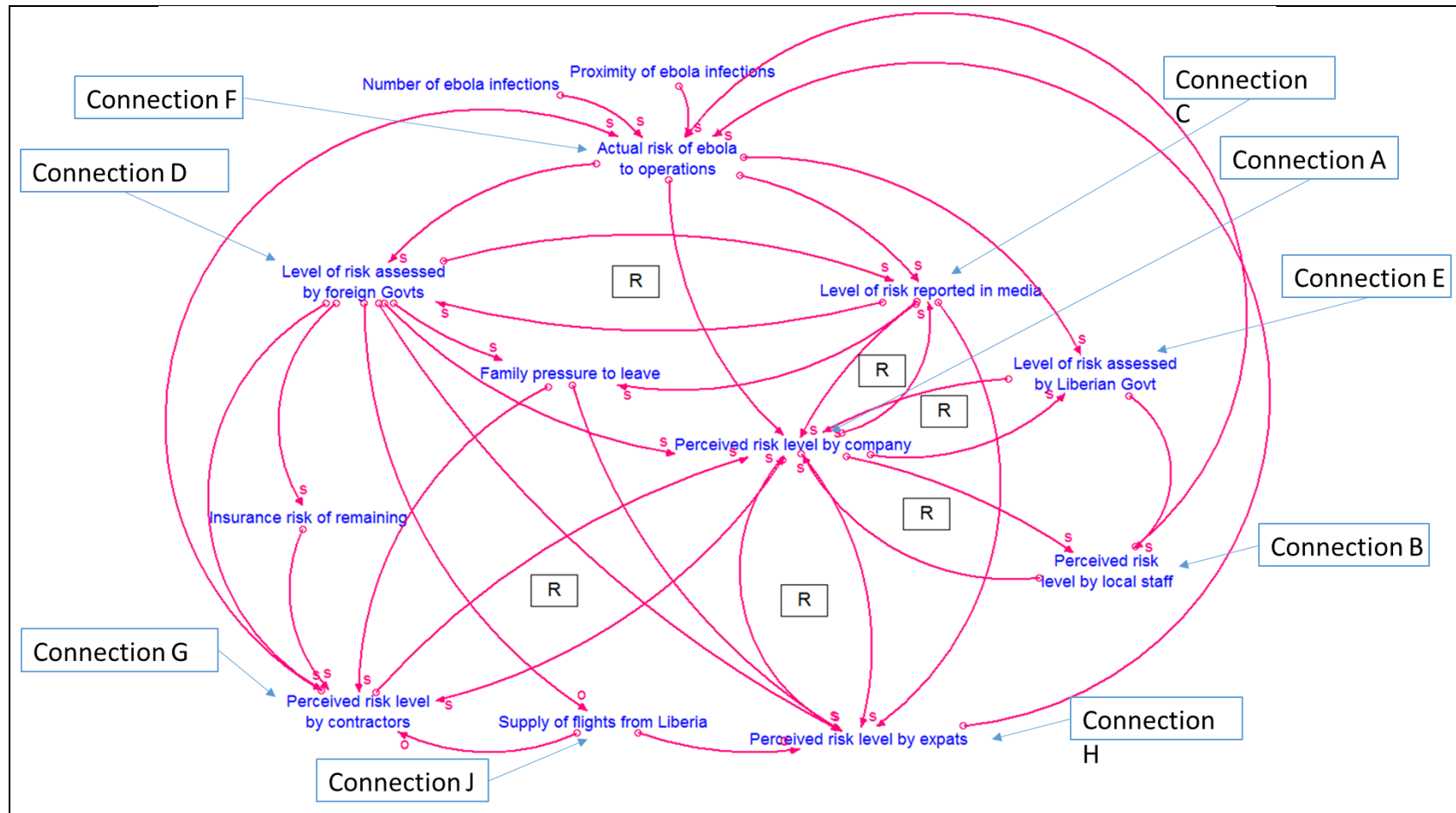
- The relationship between pressure from expatriate workers' families to leave Liberia and foreign Governments' risk assessments is labelled in Figure 10 as Connection D. Family pressure, as noted in the interviews, was influenced both by media reporting (itself a response to the risk perceived by media sources) and by their Government's risk assessments. These risk assessments in turn were a response to actual assessed risk but also, given the difficulties in accessing reliable information about spread and prevalence, a response to perceived risks to the relevant country's nationals as reported in the media, and influenced by pressure from families of expatriate workers.
- The relationship between the level of risk perceived by sub-contractors and the level of risk perceived by the company is depicted in Figure 10 by Connection G. Interviews and FGDs with contractors indicates that as contractors started to take actions to withdraw (in response to withdrawal of their insurance cover contingent on Government risk assessments) the perceived risk to the company's operations increased. This increased both actual and perceived risk to the company's operational capacity. The increase in perceived risk to the company would, with no intervention, be likely to cause a further increase in the level of risk perceived by the contractors.
- Connection E shows the relationship between the levels of risk perceived by the company and the Liberian government. It would probably be expected that any firm's perception of risk will be influenced by the risk assessment of the Government of the country in which it operates. Another point raised by

respondents was that risk perception was also influenced in part by what they called “home” governments where they themselves were based (shown as perceived risk by expatriates) and also where the firm/organization was based. However, in this case, the significance of the company’s operations as a proportion of national GDP meant that it is likely that the company’s perception of risk also influenced the Government’s perception of risk (and therefore its actions in calling for aid and assistance – potentially increasing the media’s perceived risk, foreign Governments’ perceived risk and the company’s perceived risk).

As these examples demonstrate, this part of the system shown in **Figure 25** is composed of a number of interlocking reinforcing loops, leading over time (without external interventions) to a ‘panic system’ with perceived risk to all stakeholders rising exponentially, even if actual risk is not increasing. These causal loops may also be thought of as relating to the various relative resilience attributes or components of the firm, with these resilience components having an impact on each other over time. Resilience as a driver of response to disruption is explored more fully a conceptual model in section 4.7 of this study.

As mentioned earlier, **Figure 25** shows some of these relationships as perceived by the employees of AM in a causal loop diagram (CLD). This CLD is then divided into individual sections and discussed in subsequent CLDs (**Figure 25** to **Figure 29**) to provide clarity and detail. Please note that although Figure 25 only shows a number of positive feedback loops each reinforcing the other – the other sections below consider feedback in the system that may have an influence on this ‘runaway’ perception of risk. The sections, for example on communications and preventative measures or health prevention activity, indicate how those functions may play a role in either moderating or minimizing the behaviour shown in below in Figure 25. These CLDs will explore key resilience attributes as specified in the theory and in the literature with reports from interviews and focus group discussions. Here we consider what role these attributes may have played in reducing the risk perception and contributing to the resilience of the firm or enterprise during the disruption.

Figure 25. The impact of Ebola on the whole system – causal relationships relating to actual risk and risks perceived by key stakeholders





### ***Risk and Resilience Attribute 1: Corporate Culture and Communications***

The causal relationships identified from the interviews in relation to communications are shown by Connections A, B, C and D in Figure 26 - these are also indicated in **Figure 25** but we explore them in more detail here. Earlier in chapter 2, communications was identified as a key attribute of a resilient enterprise (Sheffi and Rice Jr., 2005, McManus, 2008). The case study looks at the actions taken by the company that included:

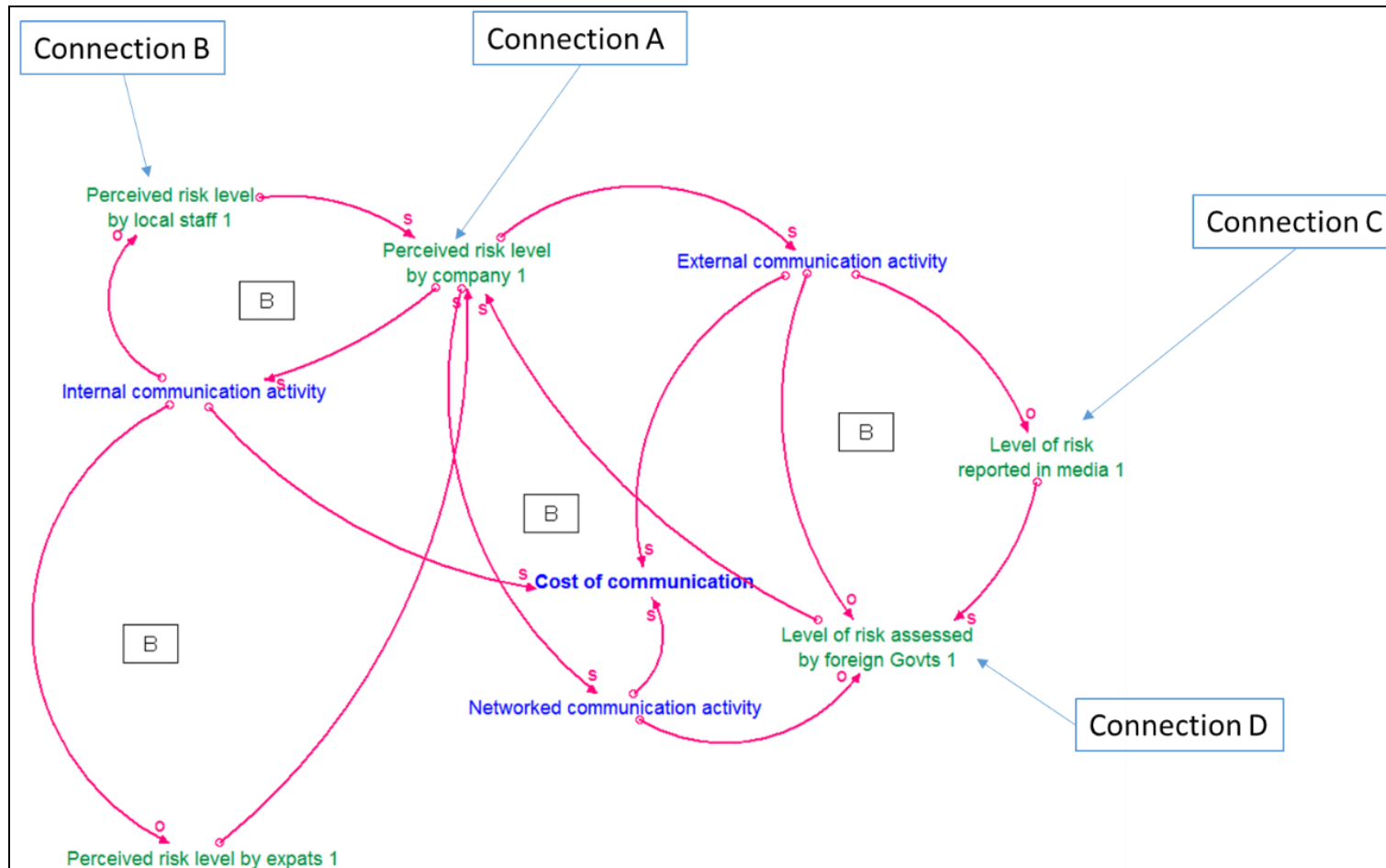
- External Communication by the development of a network of extractive companies operating in the region who have led the efforts in collecting and sharing information amongst its members, and who developed a relationship with foreign Governments and the media called the Ebola Private Sector Management Group (EPSMG). EPSMG originally started among a core group of mining companies in the region, eventually expanded to include over 80 companies dedicated to continued business in the region. The group shared information and best practices (for example, how to set up screening mechanism and what type of information to disseminate) to help support business continuity during EVD outbreak.
- Company-specific external communications (as opposed to the network-wide communications) targeted at communicating the actual impact of Ebola on the company's operations, as opposed to the perceived and (in large part) unrealised potential risk.
- The development and operationalisation of a plan for internal communications aimed at both local and expatriate workers, linked to health prevention activity and addressing perceived risks ('rumours').

These actions provided balancing loops exerting downward pressure on the level of risk perceived by key system stakeholders (i.e. expatriate workers, local staff, media and foreign Governments). The cost of communications, and its relationship to key activities, is shown as the outcome of activity taking place within each balancing loops.

The costs associated with communications include internal communications, like trainings, workshops, information sessions, leaflets and other means of internal communication. This includes external communication to the general public (i.e. posters, leaflets, public health

awareness on radio and TV) and the awareness in the communities both in and around the concessions.

Figure 26. The impact of Ebola on the whole system – causal relationships relating to communications



### ***Risk and Resilience Attribute 2: Preventative measures or Health prevention activity***

The causal relationships identified from the interviews in relation to preventative measures like health prevention activity are shown by Connections A, D, E, F and H in Figure 27.

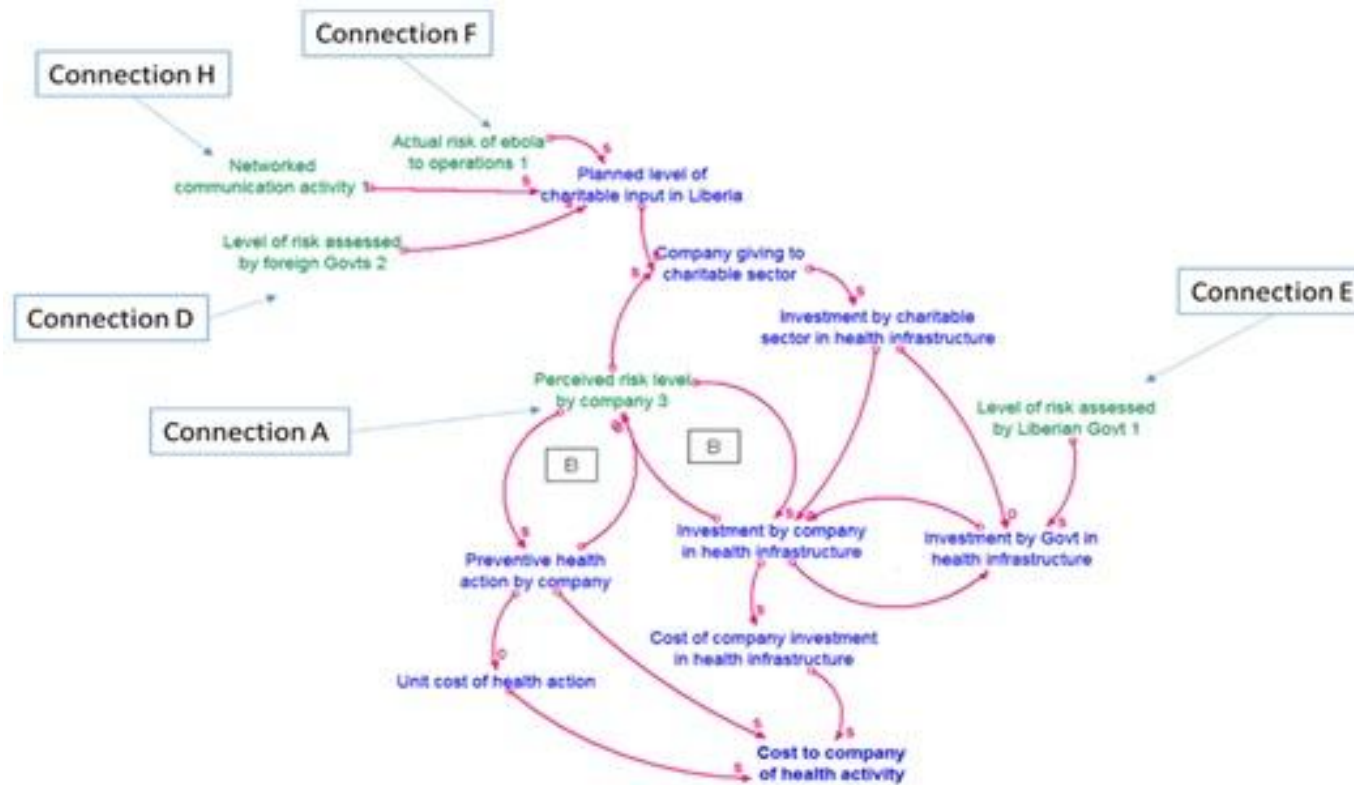
The action taken in relation to health prevention in Liberia included:

- Advice and leadership commissioned from an international expert on infectious disease
- Development of local health infrastructure for workers and the wider community
- Work (including joint work with other companies, co-ordinated through the communications network) with NGOs to deliver targeted support to increase local communities' resilience to the impacts of Ebola.

The balancing loops in this subsystem respond to increased perceived risk to the company by increased action aimed at reducing that perceived risk (which will have a knock-on effect on the perceived risk to other stakeholders, as seen in Figure 10), and therefore on actual risk to operations. Note that the polarity of the loop linking investment by the company in health infrastructure and investment by the Liberian Government in health infrastructure is unclear at this stage and further information and intelligence is needed to understand how, or if, the two are connected. A number of possible scenarios are possible, including:

- As company investment in health infrastructure increases, Government confidence in the benefits and popularity of further investment increases and they become more likely to invest themselves (a kind of 'match funding' approach): this produces a reinforcing loop acting on total health investment in Liberia as a whole
- As company investment in health infrastructure increases, the Government sees less need for it to act ('someone else is taking care of it') and they become less likely to invest themselves: this produces a balancing loop acting on total health investment in Liberia.

Figure 27. The impact of Ebola on the whole system – causal relationships relating to health prevention activity



### ***Risk and Resilience Attribute 3: Flexibility in HR policies and Expatriate workforce and management***

The impacts identified in the interviews of perceived risk amongst expatriates on both short and long term management are shown by a number of factors interacting with Connections H and J in Figure 28. In the short term, action was taken to repatriate staff (with associated costs) and this led to the need to recruit new managers. At the same time, the perceived level of risk had an impact on the potential future attractiveness of the work for expatriate staff (the relationships between perceived risk and family pressures also being relevant here). Interviewees suggested that this would lead in the longer term to changes in the pool of potential recruits to management posts and to a different balance of recruitment from in country sources, as opposed to expatriate workers. This will tend to lead to changes in:

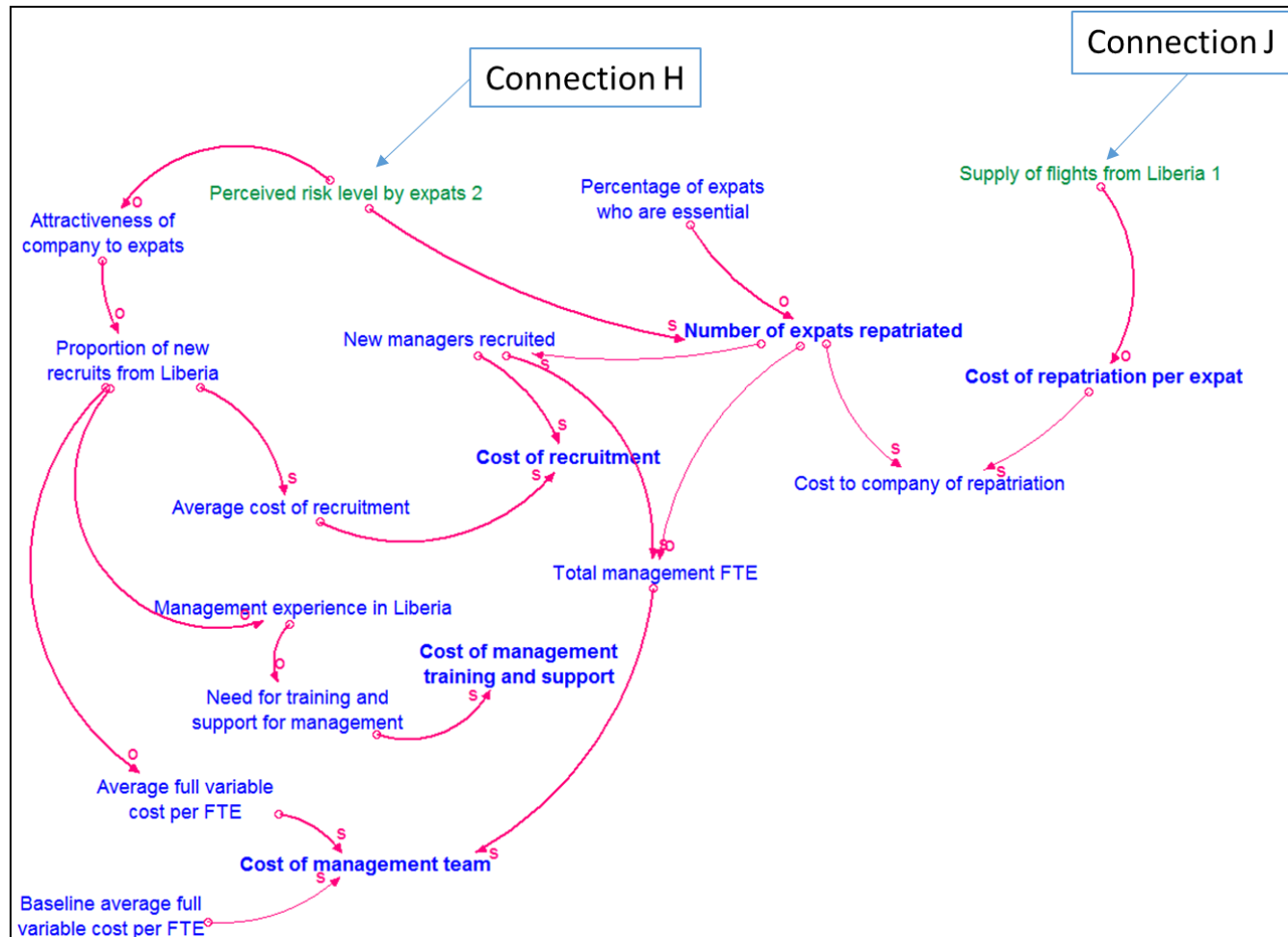
- Ongoing management costs (including for example changes to management structures and Full Time Equivalents (FTE), salary levels, travel expenses etc.)
- Training and development costs for management (skills development, succession planning etc.)

The diagram illustrates how perceived risk by expats (Connection H) and the supply of flights (Connection J) impact the relationship of these sources of cost to the causal links in the system as perceived by the employees. Expat workers have been identified as a major vulnerability of AML and the industry in general. It stands to reason that any expenditure aimed at reducing the risk perception of this cohort will reduce the perceived vulnerability and hence increase overall resilience of the firm.

This discussion touches upon the debate that recruiting local workers and then investing in their training might be a viable option for a resilient enterprise in the long run. If expatriate employees are a vulnerability to mining firms in the region than it stands to reason that investing in developing local capacities of employees might be feasible long run strategy. The objective of hiring local staff is also a running condition of the Mineral Development Agreements (MDA) signed by the firm with the government and it specifically states that a percentage of positions should eventually be filled by local employees rather than expatriates. AML has reported achieving its quota objectives and in principle the firm is on track to work towards higher local representation at all levels including in senior management. For example, in the case study, AML has fourteen senior management

positions in Liberia and seven of them are recruited from Liberia (source: interviews and HR documents).

Figure 28. The impact of Ebola on the whole system – causal relationships relating to expatriate workforce and management



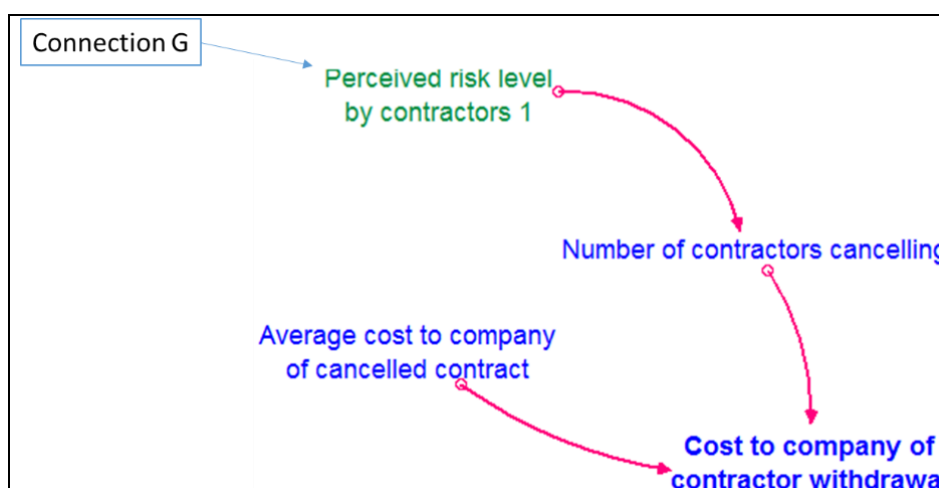


#### **Risk and Resilience Attribute 4: Phase II expansion and Contractor behaviour**

The relationship between perceived risks by contractors and costs to the company, as identified in the interviews, is shown in Figure 29. While this sub-system does not include feedback loops, it records the source of costs to the company in terms of the risk perceived by contractors over time.

Since these CLDs were developed on the basis of a small number of interviews with corporate management staff, they should not be regarded as a comprehensive picture of the full system of causal relationships affecting the impact of the Ebola crisis on the company. However, they do highlight the importance of considering both actual risk and perceived risk in the response of a system to a given disruption such as the outbreak of infectious disease. While the former can be modelled and estimated with some degree of confidence (including through the use of traditional epidemiological models of disease incidence and spread in a geography), the latter is a far more nebulous and unpredictable product of fact, belief, rumour, anecdote and relationships between stakeholders. Understanding the potential impact of perceived risk on stakeholder behaviour (and therefore on stakeholder and whole system resilience) is likely to be of benefit in understanding the type and level of actions required to increase resilience and improve response

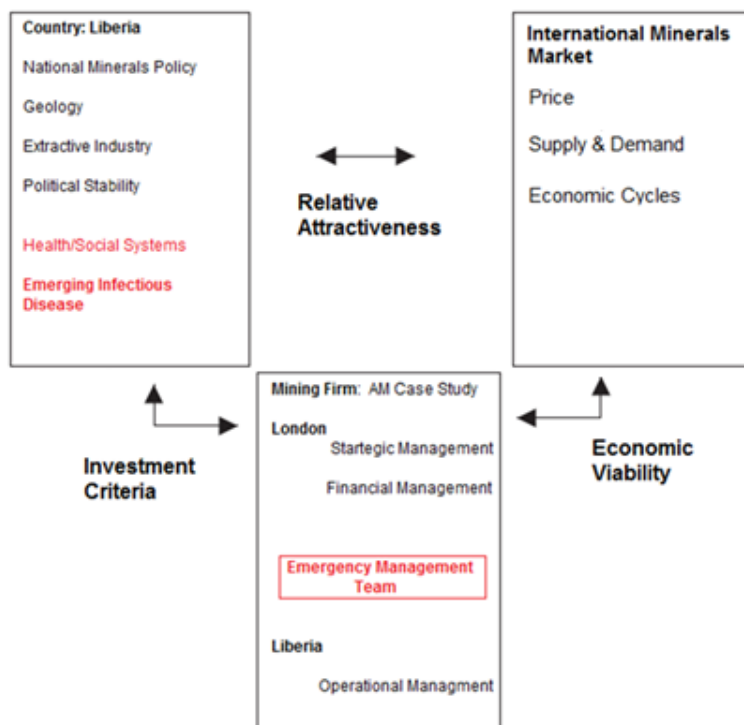
**Figure 29. The impact of Ebola on the whole system – causal relationships relating to contractor behaviour**



**Additional external factors to consider before discussing the model**

Prior to a full discussion on the model this section will identify some elements that are important but external to the consideration of the study. The section uses information and intelligence gained from the literature and validated in interviews to develop a conceptual higher level map of the system and some of the factors playing a role in the decision making of ArcelorMittal. This illustrates a high level view of the structure of the system showing some of the external components and their relationships as perceived by senior management and finance staff in both London and Liberia.

**Figure 30. High level systems map adapted from O'Regan and Moles (2006) and validated by interview data.**



The international market price of iron ore is a key background factor in this study and plays a significant role on many elements of the decision-making process within the firm like production, shipping and expansion in the mining sector. Figure 30 explains the relationship between the international minerals market and the role of prices in making decisions

(O'Regan and Moles, 2006) – this was validated by respondents in interviews as important factors when understanding the timing of the delay and then suspension of the Phase II expansion project. The initial conditions inside Liberia are also relevant to the case study in terms of how they influence the preventative measures considered and adopted and were commented on by the various respondents in the interviews what factors were important prior to the outbreak – and what factors might be important now afterwards -denoted in red. The figure also indicates the boundary of the case study as the mining firm and the two separate locations of the organization at which data was collected - London and Liberia. The study includes those members of senior management from London – who had the opportunity to interact with Liberian counterparts through the specially formed EMTs – and does not include members from other parts of ArcelorMittal Corporate offices in London or any of its other mines and subsidiaries around the world. The model of operational resilience presented in this section looks at the Liberian business unit's ability to maintain operations during the outbreak.

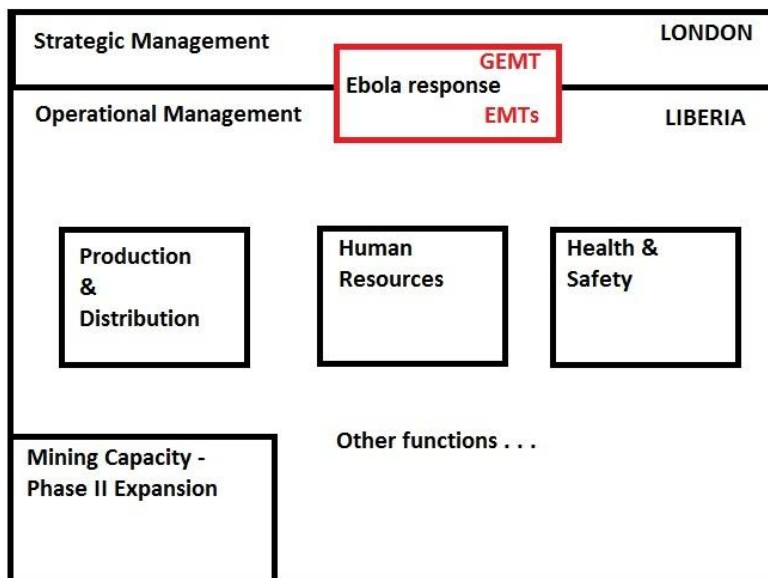
#### **4.6 The system dynamic model of resilience**

This section describes a simple system dynamic model developed to simulate the impact of disruptions/shocks like the EVD outbreak on the performance of on an organisation, focusing on the resilience of an organization in response to disruption. This includes both the elasticity of organisational response to the potential negative impact of the disruption during the period of onset and escalation, and the ability of the organisation to recover once the disruption begins to lessen in impact – the 'recovery phase'. The previous sections of the results have facilitated the team to develop an understanding of key functions within the organization (the ArcelorMittal Liberia system) which contribute to the organization's performance, that were impacted in different ways during the outbreak. The results in the previous section also helped indicate what some of the preventative measures options were, the costs of the preventative measures taken and also what mental thinking might have been behind the decision making by ArcelorMittal Liberia in response to the EVD outbreak in 2014.

### ***Elements and the boundary of the model***

The main elements of the system being considered are illustrated below in Figure 31. The main functions being considered in the model are subsystems within the overall ArcelorMittal Liberia system that were impacted by the EVD outbreak; Production, Human Resources, Health & Safety (medical) and also Mining Capacity (Phase II Expansion). The Global Emergency Management Team (GEMT) based in London and coordinating with the local EMTs are also shown in the figure.

**Figure 31. Elements in the ArcelorMittal Liberia system**



The model has been developed to date as a ‘proof of concept’ to explore the potential value of the approach for strategy and planning within an organisation in the extractive industry. It is not attempting to provide a realistic simulation of the actual size or timing of impact of EVD, or any other type of disruption, on an organisation but rather the likely ‘shape’ of behaviour over time. The model was shared with company representatives and project sponsors at a workshop in December 2016, for discussion and initial testing. This led to valuable feedback on the potential core elements which such a model could include for extractive firms considering future responses to health crises, and this feedback has been included in the sections below.

The prototype model was developed using iThink™ (version 10.1.2). iThink™ (and its sister product, STELLA™) support the development of system dynamic (SD) models. The prototype model runs over a period of 52 weeks (this can be extended in future developments) to simulate the impact of a disruption over a 1 year period. The time period selected was for convenience and simplicity and much longer time periods could be used to explore impacts over the longer term.

### **The conceptual resilience framework in the model**

This section discusses the results from the two group model building sessions (GMB) held with senior management of AML in London held one month apart. In the first GMB definitions and the concept of resilience were fleshed out and the researcher then developed a conceptual model based on this output. The model was then shared in the second GMB session (with the same participants), called the validation workshop, held at the end of the research study.

### ***Definition of resilience***

Several definitions of resilience were considered from the literature (Srivastav and Simonovic, 2014b) and presented to stakeholders at the validation workshop. After careful deliberation the following definition was adapted for the case study and shared with stakeholders at the GMB workshop. The stakeholders strongly felt that resilience is directly related to function of the system or, in other words, the system performance. The definition consists of four elements as follows:

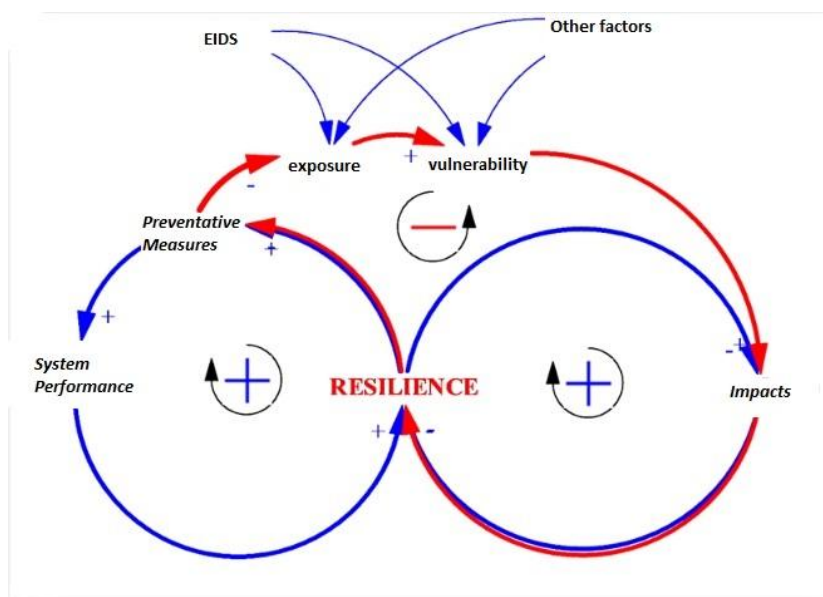
- The capacity of a system, organization, or firm potentially exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure or system performance;
- The capacity to absorb shocks while maintaining function or system performance;
- The capacity to adapt existing resources and skills to new situations and operating conditions; and
- Capacity for collective action in response to extreme events.

The stakeholders had carefully debated on each of the elements of the definition and stated their satisfaction with the above elements in its completeness, especially in relation to AML and the case study. Hence the following definition of Simonovic (2016) was adopted as the preferred complete definition of resilience within the study.

Consolidated Definition: Resilience is the ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a system disruption in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its essential basic functions or system performance (Simonovic, 2016).

### ***Causal Loop Diagram of Resilience***

Participants of the GMB workshop were asked about the relationship between resilience and impacts, also touching on the discussion on the link between vulnerability and adaptive capacity which in our model are the preventative measures. The causal loop diagram is presented below in **Figure 32**. Note also that in this demonstration resilience is linked with system performance, i.e. if the system is resilient then the system performance will not be affected as much by the disruption –see definition above.



**Figure 32. Conceptualizing resilience with stakeholders in first GMB session.**

The diagram shows that if resilience is high then impacts will be low and if impacts are low then resilience will remain high. Another link discussed by the participants was if the organization is resilient, i.e. contains attributes of resilience as discussed in Chapter 2, then it is able to be flexible enough to develop and implement preventative measures that can increase system performance over the long run. This suggests that resilience could be a desirable factor for all business entities in that it can contribute to overall competitiveness.

For our conceptual system dynamic model, the pathways in red was of most interest to the participants as this would help them conceptualize and rank different preventative measures in terms of reducing the disruption impacts.

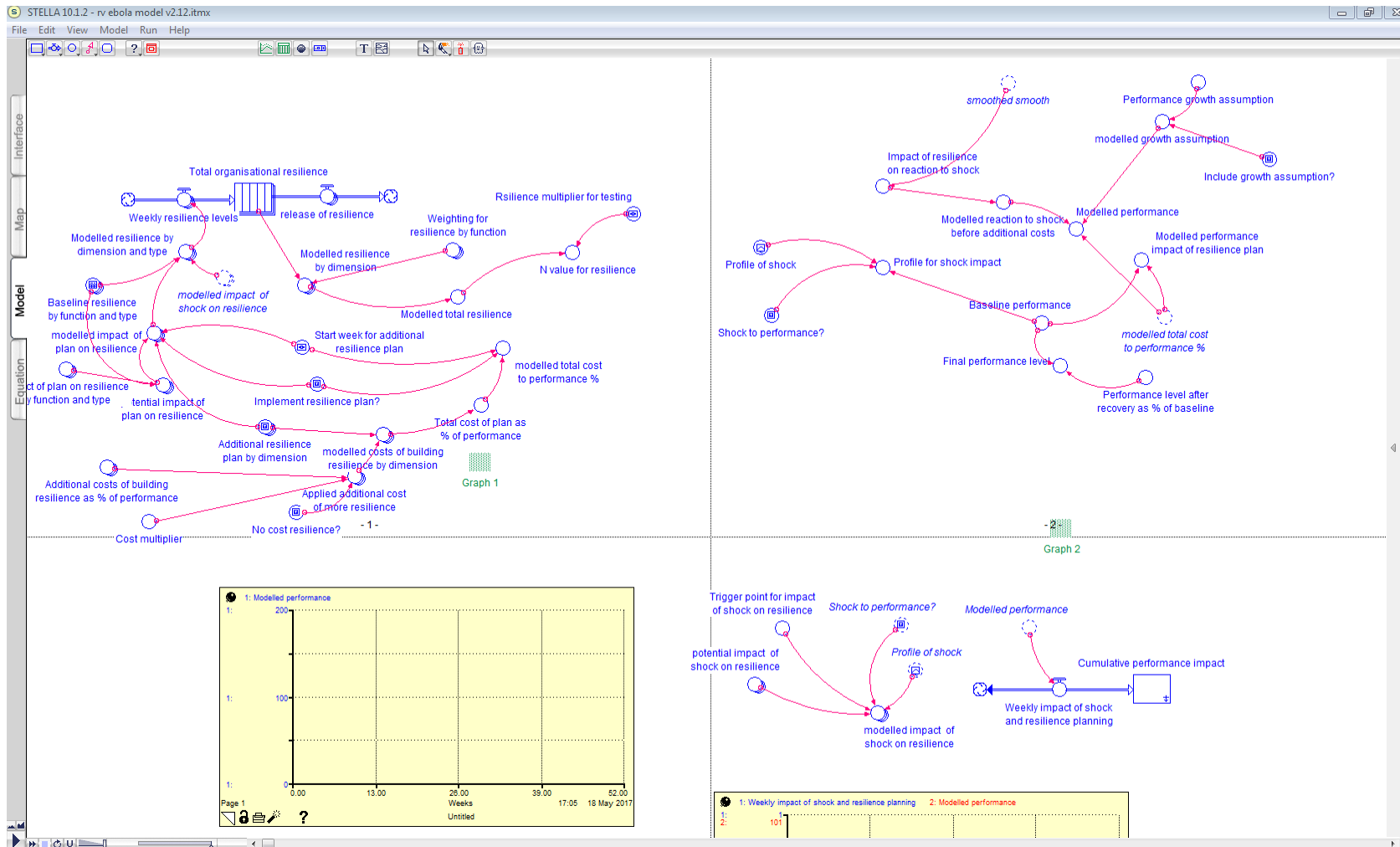
### ***Conceptual Model***

The conceptual resilience model presented here in **Figure 33** was developed based on 1) the literature and theory discussed in chapter 2 and 2) the feedback from the first GMB by members of senior management at AM London.

The model seeks to generate discussion among stakeholders in identifying critical functions of the firm, and then forming a baseline resilience score of those functions. After baseline resilience scores are determined, the model looks at indentifying preventative measures in line with the theory on attributes of resilient enterprises as shown in Chapter 2. As stakeholders discuss the preventative measures, the model ask for inputs on what are the expected effects of these measures with regards to changes in the baseline resilience score determined in the first step. Once the preventative measures have been identified and their additions to the base line score are determined, a new resilience score is generated based on these improvements. The model then reruns the same disruption, conceptually showing how preventative measures can make system performance of the firm more resilient to disruptions. The remainder of this section looks at covering this process in more detail with examples from the workshop shown for clarity.

The process of going through the conceptual model with stakeholders was found to be useful in itself, as it generated the sort of discussions among participants that informed the researcher of the thinking and logic behind decision making of senior management in crisis or disruption, especially with regards to resilience and preventative measures.

Figure 33. The conceptual model in Stella.





### ***Key functions***

As the first step, stakeholders are asked to define the base line resilience of their organization. To do this they were asked to identify critical functions of the organization from a list of pre-generated critical functions. The model uses these functions to illustrate the relationship between resilience of sub-systems and overall organisational resilience. The functions on the list were derived from the the vulnerabilities identified during the interviews and focus group discussions, particularly the vulnerability mapping exercise.

Generally these functions might also be of general relevance to any enterprise or business organisational unit involved in production or service provision. For example, in this case study the following functions were identified by the participants from the list provided to the participants:

- Production
- Mining Capacity Expansion
- Human Resource Management
- Health and Safety

Each was given equal weighting within the model, although this need not be the case as typically different functions will have different levels of contributions to the overall firms output or performance. For simplicity and clarity, in this conceptual model they were given the same weight.

Each of those components can in turn have critical subcomponents which are defined by stakeholders more familiar with each component and subcomponent. At the highest level the model incorporates high level functions and a lower level may focus on one particular aspect of the organization most vulnerable to a shock or disruption.

### ***Feedback – key functions for extractive industries***

It is important to note here that for most participants this was the first instance of using systems analysis and the session was a good introduction to systems thinking for all of them – especially as a way of thinking for a corporate team. The participants quickly saw the potential of using the approach to other aspects of their work and were enthusiastic in the application of the method to the case study. Hence in feedback from the group, in addition

to the above key functions, the following additional functions were identified and suggested as an improved set of key functions/ sub-systems that could form the basis of a more detailed model for use in the extractive industries:

- Supply chain
- Extraction
- Transportation
- Corporate responsibility
- Local infrastructure (enabling environment)

Each of these could potentially be considered separately for each location in which the firm operates.

### ***The components of resilience – 4R approach***

Each of the components of resilience, called the “the 4 Rs”, developed by (Bruneau and Reinhorn, 2007) and (Srivastav and Simonovic, 2014a) was considered for each of the key functions. In presenting the framework and model to the organisation, the following explanations were used for each component of the 4Rs:

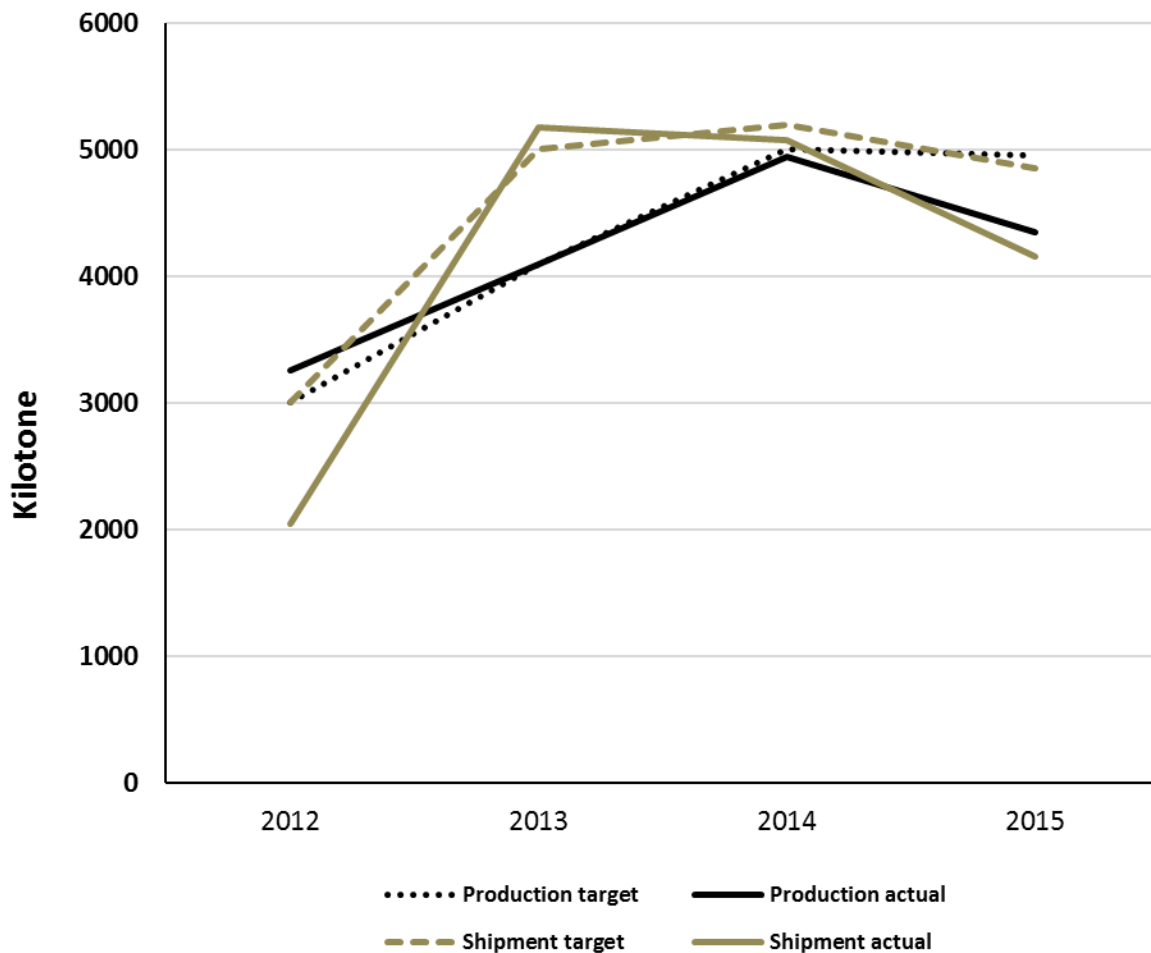
- **Robustness:** How resistant is the function to disruption in the first place? The ability of systems, system elements, and other units of analysis to withstand disaster forces without significant degradation or loss of performance;
- **Redundancy:** How many options do we have for responding? The extent to which systems, system elements, or other units are substitutable, that is, capable of satisfying functional requirements, if significant degradation or loss of functionality occurs;
- **Resourcefulness:** How good are our processes for mobilising our response? The ability to diagnose and prioritize problems and to initiate solutions by identifying and mobilizing material, monetary, informational, technological, and human resources;
- **Rapidity:** How quickly can we mobilise our response? The capacity to restore functionality in a timely way, containing losses and avoiding disruptions.

These four resilience measures were considered by the stakeholders in relation to ArcelorMittal Liberia’s own operational strengths and weaknesses and examples were drawn from the experience of ArcelorMittal Liberia during the outbreak and how certain

preventative measures could change the value of these four component measures depending on the type of preventative measure. The discussion was linked to the attributes of resilient enterprises discussed in Chapter 2. For example if additional inventories of iron ore were to be kept on the Port at Buchanan this would make exporting iron ore more resilient (Redundancy) to transport shocks such as the railway lines being blocked or flooded for a period of time – this would result in a higher score in the distribution network score and hence a higher overall resilience score in the model. Each of the preventative measures considered in the study can similarly have an impact on resilience across the four components (R4). A preventative measure can result in a change in more than one of the 4Rs and not necessarily on only one – these assessments will be made by stakeholders with the necessary expertise and will be based on both qualitative and quantitative assessments in the final model.

System performance could similarly be assessed with multiple measures forming a composite index or be considered in simple output terms. An example of using output as simple measure of performance in our case study can be shown in Figure 34. The figure shows how production during the outbreak period actually met targets as goals were achieved rather than being impacted adversely indicating that production as a critical function was resilient to the EVD outbreak in this case study. A mining firm is a complex organization with many functions consisting of multiple subsystems each having specific goals and targets. If we consider another example of system performance within the Phase II expansion where there were many critical subsystems requiring completion before a set date, like the construction of a large power plant, then that particular critical function might be considered as not resilient if that goal was not achieved in the stated time frame - although how much it was completed in that time frame might be a part of an index that may be a relevant measure of performance for Phase II overall. This may help us understand ArcelorMittal's decision to initially delay and then eventually suspend Phase II – and whether this was due to the outbreak or to the future trend of iron prices or both is something system dynamics modelling can potentially help in understanding. The model could help by isolating the effect of underlying price trends on outputs from the additional potential impact of disruption but this is beyond the scope of the current study.

Figure 34. Resilience of production in ArcelorMittal Liberia case study



The following section provides an overview of how the baseline scores are calculated in the conceptual model used during the validation workshop.

**Baseline resilience scores in the model**

A simple baseline score was allocated to each of R1-R4 for each of the key functions identified initially, as shown below (with low = 1, medium = 2, and high = 3). The low-medium-high scale was chosen for simplicity and clarity as well as its familiarity of senior management members with developing qualitative risk maps using similar scales.

<b>Critical Function</b>	<b>R1 Robustness</b>	<b>R2 Redundancy</b>	<b>R3 Resourcefulness</b>	<b>R4 Rapidity</b>
<b>Production</b>	Low	Low	Medium	Low
<b>Human Resource Management</b>	Low	Low	Medium	Medium
<b>Health &amp; Safety</b>	High	High	High	High
<b>Mining Capacity Expansion</b>	Medium	Low	Low	Low
<b>Supply Chain</b>	Low	Medium	Medium	Medium
<b>Corporate Responsibility</b>	High	Medium	High	High
<b>Local Infrastructure Enabling Environment</b>	Low	Low	Low	Low

**Table 11. Participant inputs to model to determine baseline resilience score.**

A baseline resilience score for each function was calculated by multiplying the baseline scores for R1-R4; the total baseline resilience was calculated by summing those for each function. This baseline score is scaled to give a suitable value for use in the model (i.e. to produce a potential range of periods over which the disruption function is smoothed which produces a realistic pattern of response for organisations in the industry).

### ***Use of resilience scores in the model***

The baseline resilience score is deployed in the model as follows:

An impact function is developed, with the period over which the disruption function (discussed in the section below) is smoothed and applied to baseline performance in proportion to the baseline resilience score: thus a score of 2 will result in a faster response than a score of 4.

A recovery function is also developed, with the period over which the disruption curve is smoothed and applied to baseline performance inversely proportional to the baseline resilience score: thus a score of 2 will result in a slower response than a score of 4. The two functions are combined such that:

- when the trajectory of the disruption is downwards, the impact function is applied
- when the trajectory of the disruption is upwards, the recovery function is applied

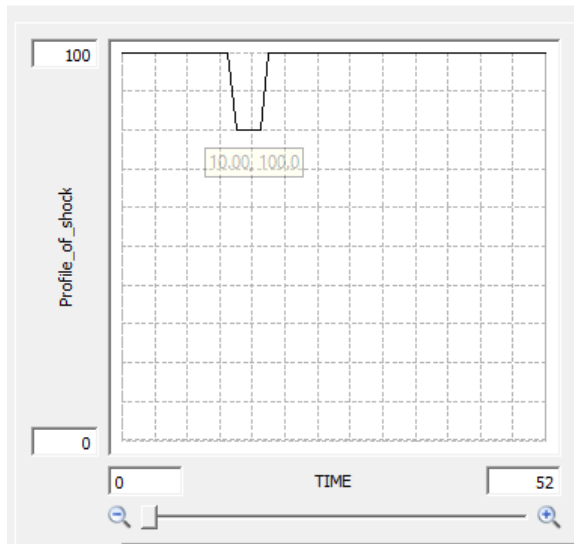
This produces a modelled response to disruption with the following characteristics:

- It will take longer for the adverse impact of a disruption to be seen in terms of performance in a more resilient organisation than in a less resilient one
- It will take longer for recovery from a disruption event to be seen in terms of performance in a less resilient organisation than in a more resilient one.

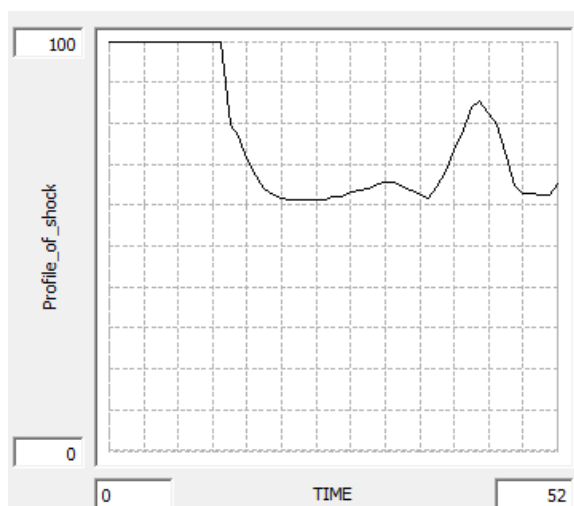
### **Modelling a disruption**

Within the prototype model, crises are introduced via a graphical function which can be understood as representing the potential impact of a sudden event on performance. Alternatively, it can be understood as representing the 'story' of an event in terms of severity and impact.

The two examples below show two possible types of disruption:



This example (used as the default in the prototype model) represents a disruption of relatively short duration, with the potential to cause a 20% reduction in performance at its worst.



By contrast, this example shows a disruption of greater magnitude and duration (with a period of partial recovery) which is not over by the end of the model run.

### Modelling performance

Within the prototype model, default performance is set at a notional level of 100 units per week. This can be understood as representing any key performance indicator (revenue, output) where resilience will have an impact. However, as the model develops it would be possible to develop several performance indicators separately, to enable (for example) the

effect of a disruption on both revenue and output to be modelled separately (and allowing for the effects of market price on revenue to be included, for example).

Within the prototype model, an option allows projected growth to be applied to baseline performance. This could be used, for example, to project the impact of expected rises (or falls) in unit price and thereby to isolate the impact of unit price changes from that of a disruption on overall expected performance.

### **Modelling improvements to resilience: Preventative measures and Resilience Attributes**

The prototype model allows for the impact of projected changes to resilience to be simulated. If the option to change resilience is selected, changes can be made to the resilience rating of any component of the resilience framework. This represents potential actions on the part of the organisation to increase resilience by improved readiness planning. Examples of the changes that could be modelled include:

<b>Change made (Preventative Measures)</b>	<b>Resilience Attribute and Which key functions will be affected?</b>	<b>Which components of resilience will be affected?</b>
Non Essential Staff Policy	<ul style="list-style-type: none"> <li>• Flexibility</li> <li>• It has a potential to impact all functions but not necessarily in the same way (according to interviews)</li> </ul>	<ul style="list-style-type: none"> <li>• R1 (increased robustness as risk of infection is reduced due to less people coming into the workplace, i.e. reduced exposure)</li> <li>• May reduce other Rs in case administrative inefficiencies increase</li> </ul>
Temperature Screening and Fencing	<ul style="list-style-type: none"> <li>• Corporate Culture and Early Detection</li> <li>• Could be any, or all,</li> </ul>	<ul style="list-style-type: none"> <li>• R1 (increased robustness as risk of infection is reduced,</li> </ul>



	functions that take place within physical location of the concession fence	not only from Ebola but others like Malaria as well, i.e. reduced vulnerability by detection)
Emergency Management Infrastructure – Global Emergency Management Team	<ul style="list-style-type: none"> <li>• Corporate Culture and Flexibility</li> <li>• All management functions, Overall decision making</li> </ul>	<ul style="list-style-type: none"> <li>• R2 (increased redundancy if more alternatives are created)</li> <li>• R3 (increased resourcefulness if barriers to action are removed)</li> <li>• R4 (rapidity if resources are more readily available)</li> </ul>
The identification of funds as a dedicated contingency fund for crisis response (ex. GEMT allocated the use of these funds)	<ul style="list-style-type: none"> <li>• Redundancy</li> <li>• Could be any, or all, depending on rules for deployment of the funds</li> </ul>	<ul style="list-style-type: none"> <li>• R2 (increased redundancy if more alternatives are created)</li> <li>• R3 (increased resourcefulness if barriers to action are removed)</li> <li>• R4 (rapidity if resources are more readily available)</li> </ul>
Building health facilities for workers	<ul style="list-style-type: none"> <li>• Early Detection and Redundancy</li> <li>• Extraction and Local management</li> </ul>	<ul style="list-style-type: none"> <li>• R1 (increased robustness as risk of infection is reduced, and impact of</li> </ul>

	<ul style="list-style-type: none"> <li>Local infrastructure</li> </ul>	infections on workforce absence is reduced)
Networking with other extractive firms to share communications	<ul style="list-style-type: none"> <li>Corporate Culture, particularly Communication</li> <li>Corporate responsibility</li> </ul>	<ul style="list-style-type: none"> <li>R2 (increased redundancy as ideas are shared and more options are open to each individual firm)</li> <li>R3 (increased resourcefulness as information is shared and delays to effective action are reduced)</li> </ul>

Currently, the prototype introduces all changes on a single timescale from a chosen start date (week 13 in the default run).

The cost of changes made is defined within the prototype as an ongoing proportion of performance. However, in future model development it would be possible to improve modelling of costs to reflect a more realistic picture by:

- Including non-recurring as well as recurring costs of actions to increase resilience (for example the capital cost of constructing a health facility as well as the recurring costs of operating it)
- Relating costs to performance, so that for example the cost of increasing health provision might be related to the depth of the disruption at any given time (e.g. where infected people receive enhanced support to increase their likelihood of recovery and return to work)

- Including the potential benefits to performance of changes to resilience (for example ongoing cost savings resulting from ‘crisis working’ which drives out inefficiencies and which can be maintained after the disruption is over)
- Modelling underlying trends in expected future performance unrelated to a potential disruption, such as the market price of the extractive product, to enable the impact of this to be explored separately from the impact of the disruption for firms with differing levels of resilience

### **The impact of performance on resilience – a feedback loop**

Within the prototype model, there is an assumption that operating below baseline performance will have an impact on future resilience. This is to replicate the erosive effect of persistent ‘crisis working’ on morale and performance. This creates a (small) reinforcing loop within the model, which as with all reinforcing loops can operate in two directions:

- A drop in performance may lead to a fall in resilience away from the baseline level, which will reduce the organisation’s ability to respond to the disruption, which could (depending on the shape of the disruption curve) lead to further drops in performance and/or slower recovery.
- A rise in performance may lead to a rise in resilience (or in this case a return to the baseline level), which will increase the organisation’s ability to respond to the disruption, which could (depending on the shape of the disruption curve) lead to further improvements in performance and/or quicker recovery.

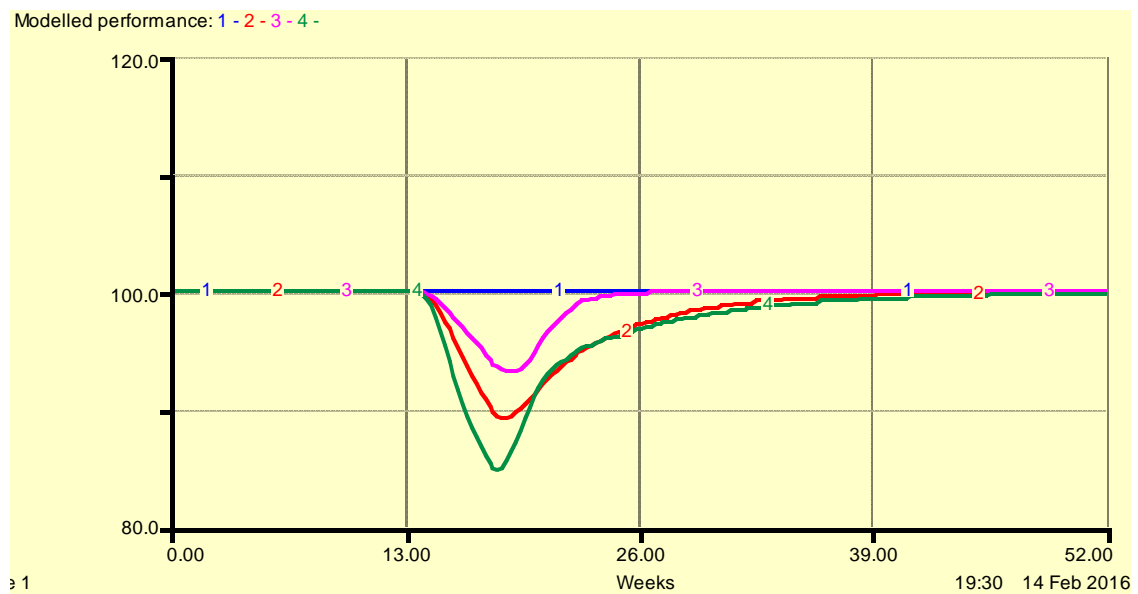
### **Outputs from the prototype model**

It is important to note that the sections below consider simulations based on hypothetical data and not actual data and do not represent predictions – although the assumptions of some of the values used as data in the simulation might be based on qualitative indications from the interviews, focus groups or workshop. The figures below are not predictions or projections of future performance or output of ArcelorMittal Liberia, or any other firm, but of a hypothetical mining firm facing a shock.

## Comparing baseline resilience

Using the modelling approach and baseline assumptions discussed above, the potential impact of disruption on organisational performance for three organisations with different levels of resilience is shown in Figure 35.

**Figure 35. Projected organisational performance response to disruption with variation in resilience: weekly performance levels**



Line 1 = baseline without disruption

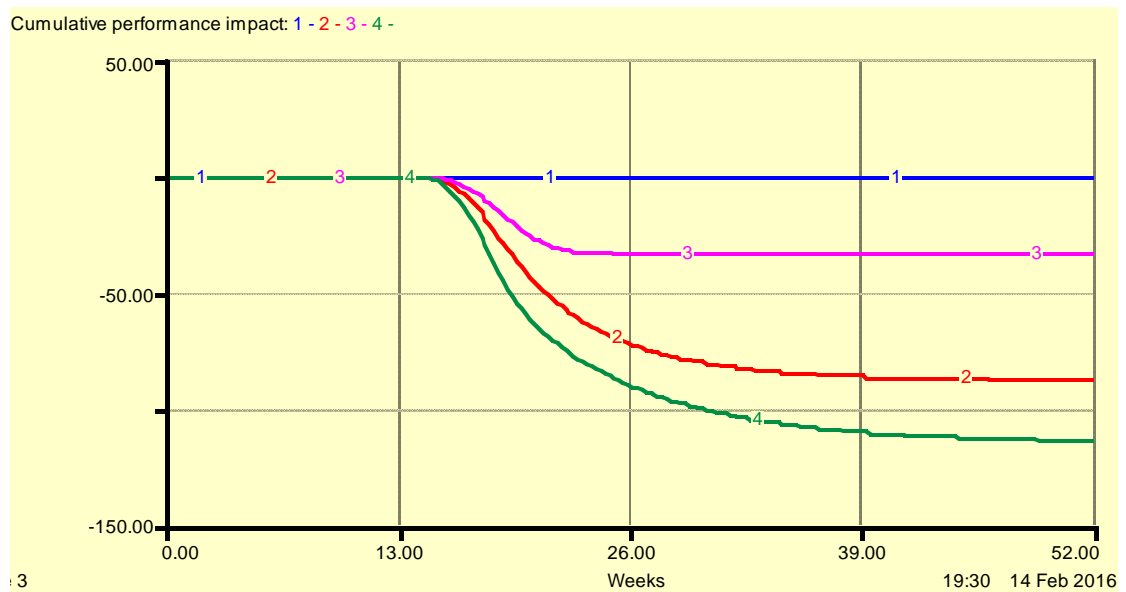
Line 2 = projected performance with disruption and default resilience score

Line 3 = projected performance with disruption and 2 x default resilience score

Line 4 = projected performance with disruption and 0.5 x default resilience score

The cumulative impact of the disruption over the 52 week period is shown in Figure 36 (NB the actual disruption risk begins in week 13 and is over by week 19).

**Figure 36. Projected organisational performance response to disruption with variation in resilience: cumulative performance**



Line 1 = baseline without disruption

Line 2 = projected performance with disruption and default resilience score

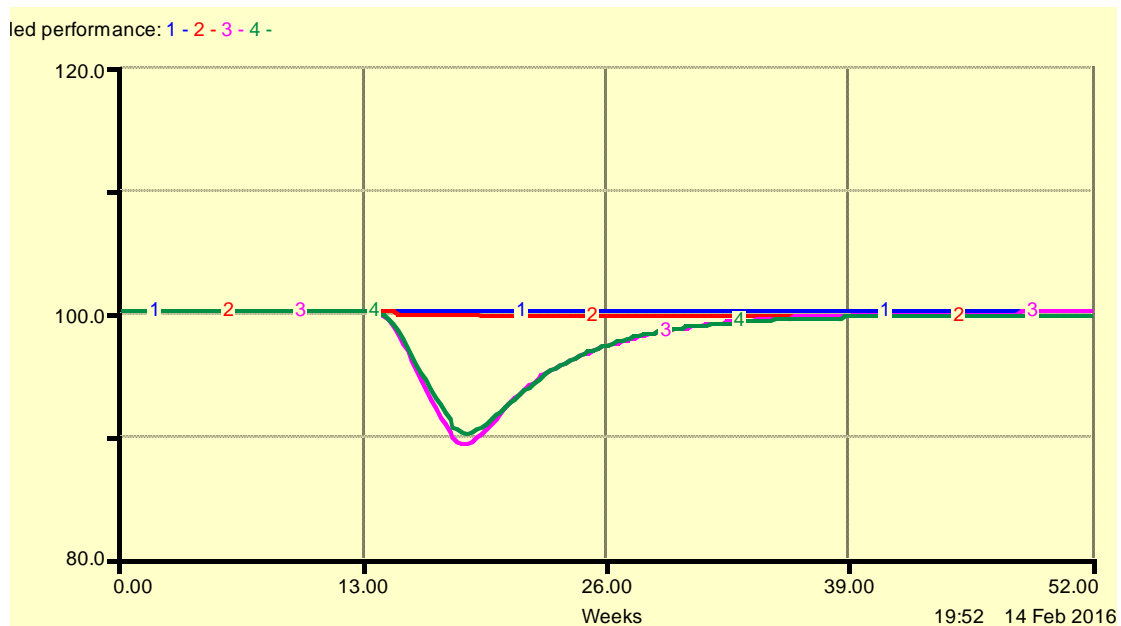
Line 3 = projected performance with disruption and 2 x default resilience score

Line 4 = projected performance with disruption and 0.5 x default resilience score

### Modelling the impact of increasing resilience

Figure 37 shows outputs from the prototype model with the default resilience score when a resilience plan is implemented. The plan targets selected areas of the resilience framework (in this example, production: R1, R3 and R4 and management: R3). An ongoing cost is incurred, equivalent to a total of 0.3% of baseline production.

**Figure 37. Projected organisational performance response to disruption with application of a resilience improvement plan: weekly performance**



Line 1 = baseline without disruption

Line 2 = projected performance with no disruption and resilience plan from week 13

Line 3 = projected performance with disruption and no resilience plan

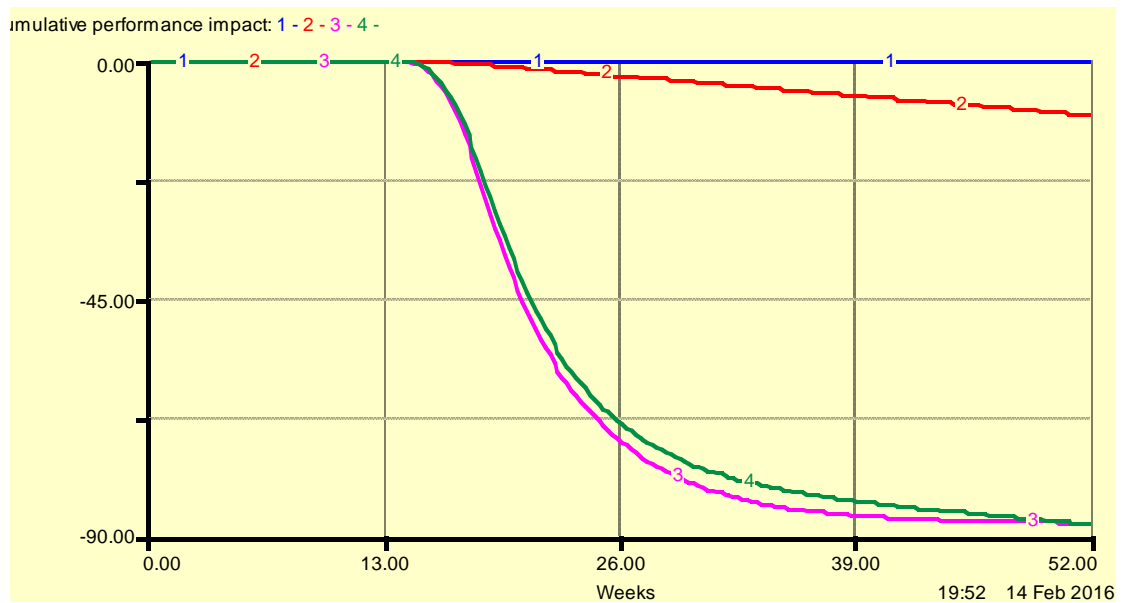
Line 4 = projected performance with disruption and resilience plan from week 13

The ongoing cost of the plan can be seen in the difference between lines 1 and 2, and thus if no disruption occurs the organisation's performance is poorer with the additional resilience developed under the plan. However, the difference between lines 3 and 4 show the impact of the plan on performance if a disruption occurs. In this case the cumulative effect of the plan over a year is neutral, shown in Figure 38 -the costs of the plan is now matching the 'savings' the plan has made to performance through an increase in resilience.

The balance between plan costs and benefits will be dependent on:

- The profile of the disruption
- The areas of the framework that the plan affects, and the impact on their individual levels of resilience
- The timescale for implementation of the plan (NB this could vary for each element)

**Figure 38. Projected organisational performance response to disruption with application of a resilience improvement plan: cumulative performance**



Line 1 = baseline without disruption

Line 2 = projected performance with no disruption and resilience plan from week 13

Line 3 = projected performance with disruption and no resilience plan

Line 4 = projected performance with disruption and resilience plan from week 13

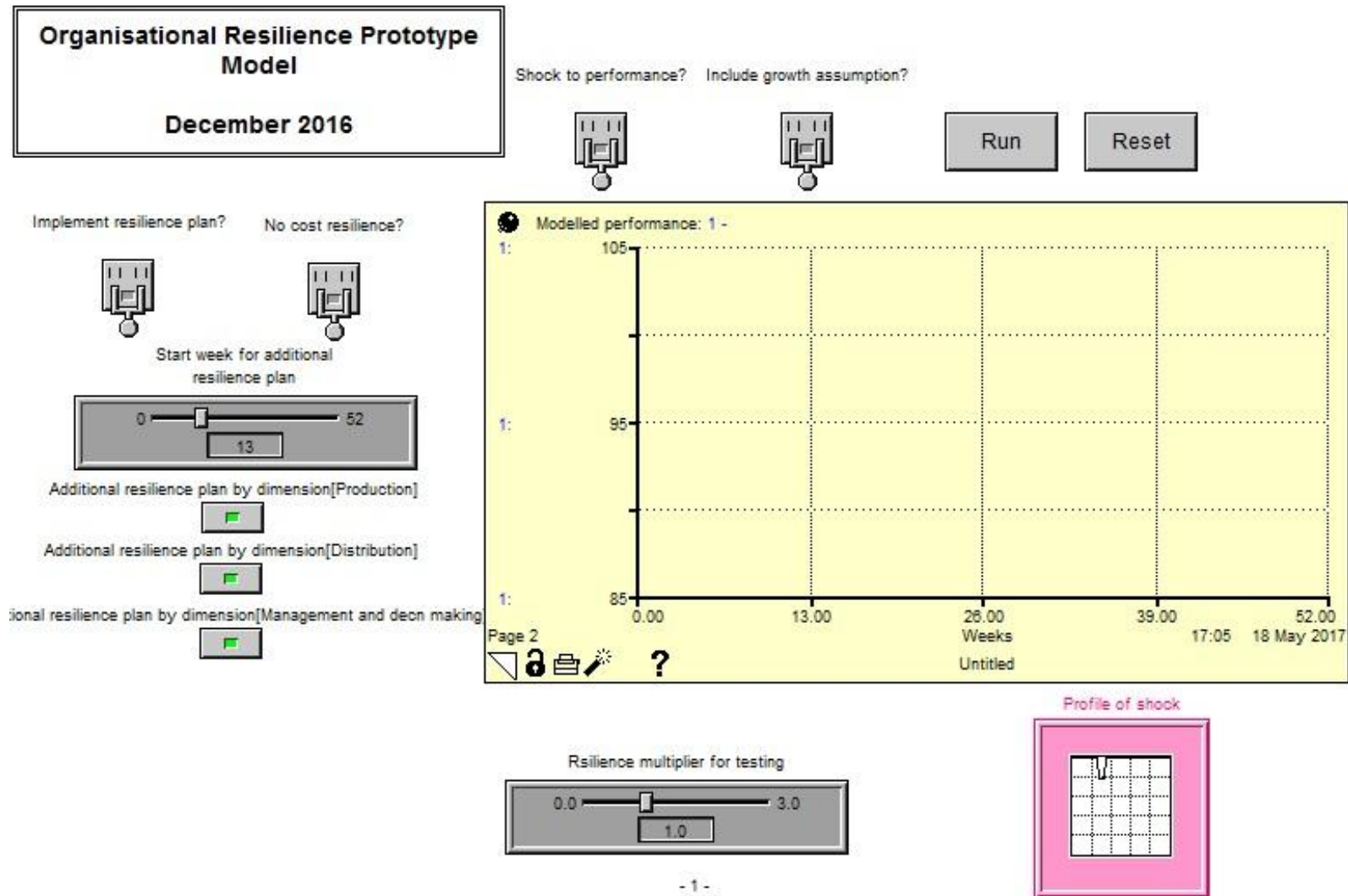
### Workshop Example

Figure 21 to Figure 24 have demonstrated the conceptual model as it has been designed with the impact of changing resilience scores and the introduction of a cost function. The following example demonstrates how it was used in the workshop with participants to illustrate how an improvement in one of the resilience attributes translates into an improved resilience score and how that impacts on system performance.

**Figure 39** shows the general user interface (GUI) developed in Stella for use by participants at the validation workshop. The GUI has several features that including the ability to define a disruption, allow the user to run a baseline scenario as well as implement a resilience plan. The user can also indicate the date at which the resilience plan is implemented as well as a general cost function as explained above.



Figure 39. The General User Interface developed by the researcher for use by participants at the validation workshop.



The GUI proved to be very useful in involving the stakeholders in the workshop and allowed the participants to “game” their decisions regarding potential resilience plans as demonstrated below.

The resilience input screen shows the “back end” of the model - showing the scores as inputted for the baseline resilience.

Figure **40** to Figure 42 illustrate the process of getting participants to enter scores for a proposed resilience plan and their perceived impact on the resilience score using the low-medium-high scale discussed earlier.

Figure 40. Baseline Resilience score as determined by the participants

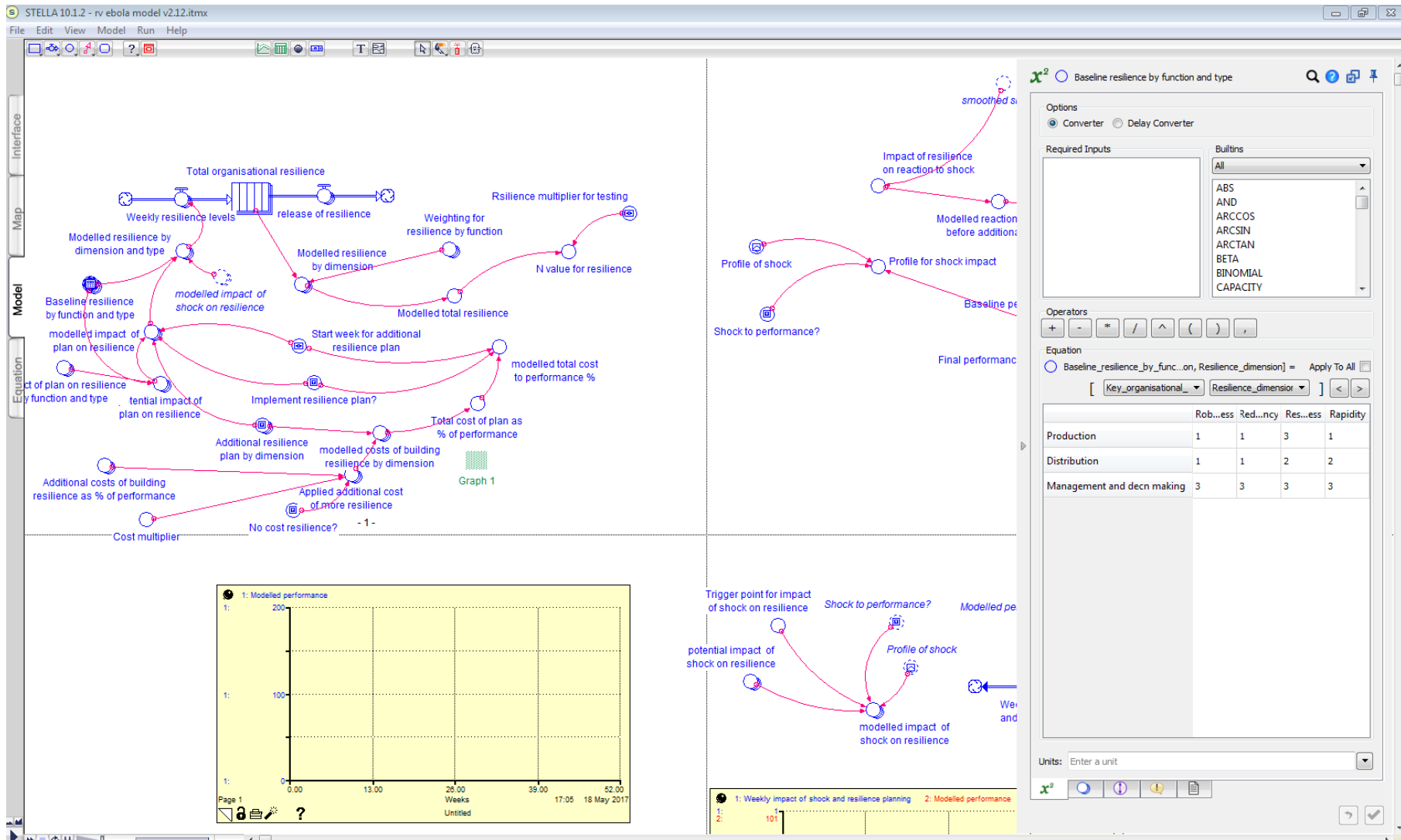
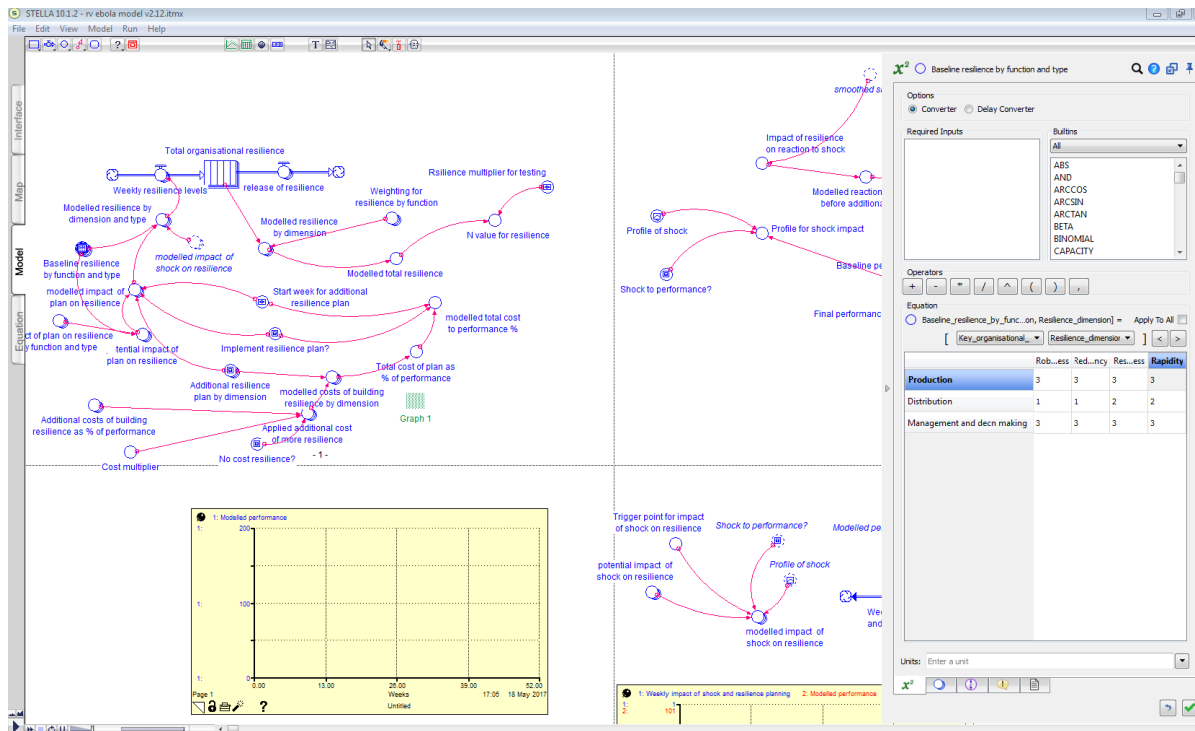


Figure 41 – Introduction of preventative measures improving on resilience score (Production function selected)



**Figure 42. A close up of the two resilience tables used to input a) Baseline and b) a new resilience plan to be implemented**

	Rob...ess	Red...ncy	Res...ess	Rapidity
Production	1	1	3	1
Distribution	1	1	2	2
Management and decn making	3	3	3	3

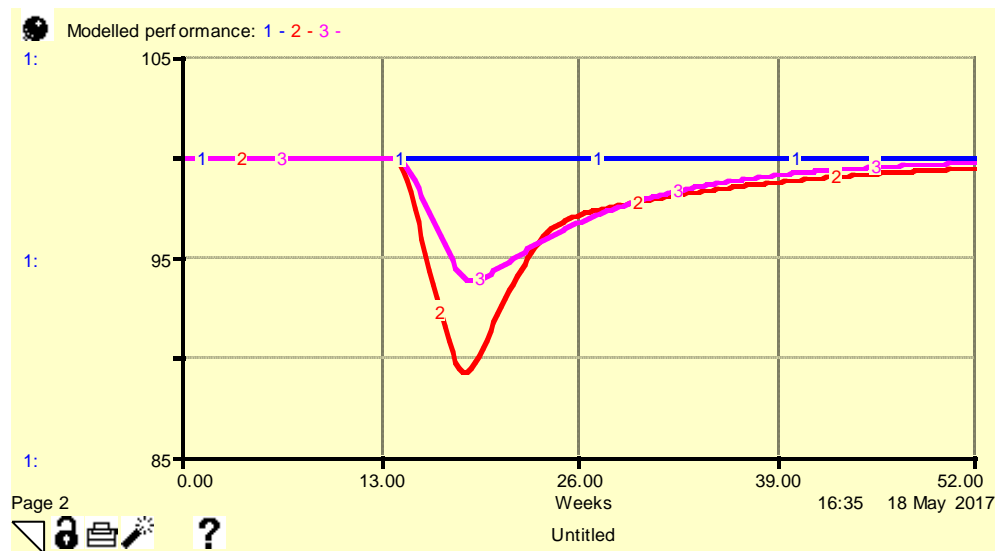
	Rob...ess	Red...ncy	Res...ess	<b>Rapidity</b>
<b>Production</b>	3	3	3	3
Distribution	1	1	2	2
Management and decn making	3	3	3	3

(a)

(b)

The model was then run at the baseline resilience without disruption, baseline resilience with disruption and then, finally, implemented resilience plan with disruption as shown below.

**Figure 43. Projected organisational performance response to disruption with application of a resilience improvement plan: weekly performance**



Line 1 = baseline without disruption

Line 2 = projected performance with disruption and default resilience score

Line 3 = projected performance with disruption and implemented resilience plan with cost

**Figure 43** shows outputs from the prototype model with the default resilience score (as calculated by table a in **Figure 42**) and when a resilience plan is implemented (as calculated by table b **Figure 42**). The plan targets selected areas of the resilience framework - in this example, participants chose to improve the resilience of production: R1, R3 and R4 as shown in

**Figure 41.** This indicates that the participants chose to implement preventative measures targeted at the production process making it more resilient overall. Implementing a plan thus causes the disruption to have a smaller impact on the system performance despite the cost of the plan. This conceptually demonstrates the thinking behind the preventative measures, the resilience attributes and the respective functions it targets in the model. This model can, if further developed with additional inputs from the stakeholders, provide a framework to rank and cost preventative measures and their perceived impact on system performance over time.

### **Workshop feedback**

Feedback to the prototype model at the workshop included the following headline messages:

- This approach has potential value as a tool for exploring the projected impact of different types of disruption on the organisation, and as such can support planning that is not overly focused on one type of risk
- The model needs to reflect the organisation's key functions and it would be necessary to identify and agree these instead of assuming that a 'one size fits all' model can work for all organisations in an industry. However, the list of key functions shared by the participants (mentioned above) provides a reasonable starting point for organisations in the extractive industry, subject to local variation.
- In most cases, local infrastructure may not be susceptible to change through one organisation's resilience plan, although it will have an impact on the organisation's ability to respond to a disruption. It would therefore be treated within the model as a fixed component of organisational resilience (and would, for example, permit the impact of a given resilience plan on operational performance to be compared between two locations where local infrastructure was the only source of difference in baseline resilience). However, there are cases (such as the study site) where the firm is itself a major component of local/ community infrastructure, and resilience planning could include actions with a real and sustainable impact on local infrastructure.



- The participants were interested in developing the tool in the future to link preventative measures with system performance and community resilience as well. Developing a feedback model at the community level was beyond the scope of this study.
- The participants expressed an interest developing a larger community model that could help demonstrate the general economic impact of the AML's activities on the local community which was outside the scope of this study. This interest was expressed by members of the corporate responsibility and sustainability department.

## **4.7 Summary**

Chapter 4 discussed the results of the research process where we analysed the case study to detect the presence of the resilience attributes identified in Chapter 2. As indicated in the interviews the study found that these attributes were present and contributed to the resilience of the firm but these were present in different forms.

The study identified the presence of systems for early detection, redundancy in human resource use and to some extent supply chains, flexibility in management and a corporate culture that took new emerging threats to its operations seriously. The perception of risk and its impact on resilience was also discussed and the costs of the preventative measures taken was estimated.

The outcomes of the FGDs, GMBs and the validation workshop were discussed resulting in mind maps and the formulation of the conceptual model of organizational resilience and how participants considered the use of the model in their organization.

In the next section, the results of this chapter will be summarized the principal findings of the research. The chapter will also indicate the strengths and limitations as well as the key lesson and recommendations from the study. Finally, the chapter concludes with indications for the extension of the present study in to potential future work that might be useful for several different stakeholders.



## **CHAPTER 5      Discussion and conclusions**

### **5.1. Introduction**

The sections in Chapter 2 discuss the main paradigms affecting disaster research and the themes in the literature concerning resilience theory in general and organizational resilience research, in particular, followed by bringing the research into context of the by restating the aim, objectives and the research question.

Chapter 3 covered the methods and methodology used in complexity science research and chose a systems approach to address the research question. The single holistic case study approach was discussed in relations to systems thinking and was chosen as the most suitable method given the objectives of the research.

In Chapter 4, the results and analysis were presented of the case study. The main attributes of a resilient enterprise were found, the chronology of events and sequence of preventative measures was revealed and the costs of those measures was documented. Finally, the conceptual model of organizational resilience was developed and validated through a workshop with stakeholders.

Based on the findings of Chapter 4, this chapter draws conclusions and provides a final discussion on the thesis. The achievement of the aim and objectives will be first covered followed by the discussion on the strengths and limitations of the research. This will then lead to a brief discussion on key lessons and recommendations and finally ending with the scope for future research.

### **5.2. Achievement of Objectives**

This research on organizational resilience was conducted using a systems approach to understanding the impacts of a disaster. To achieve this, the following objectives were identified:

- 5) To identify the common attributes of a Resilient Enterprise and recognize if those attributes were present or not in the case study firm**
- 6) To document the chronology of events and preventative measures/actions taken by the firm during the disruption event**
- 7) To estimate the cost of preventative measures taken by the firm during the disruption event**
- 8) To develop and validate a conceptual model with stakeholders that can be used to assess how various preventative measures (and attributes) could be used to enhance resilience**

The subsequent sections will synthesize the findings of the research against the objectives initially formulated above.

### **5.2.1. Objective 1: To identify the common attributes of a Resilient Enterprise and recognize if those attributes were present or not in the case study firm**

The presence of resilience attributes and the impact of preventative measures on resilience of a mining firm during the 2014 EVD outbreak has been analysed using a systems approach. The case study was based on the experience of ArcelorMittal Liberia. The qualitative approach examined the perception of employees/contractors of the firm regarding the chain of events during the outbreak and the channels through which costs of preventing the outbreak were incurred. The qualitative results show that despite initial gaps in knowledge and awareness of EIDs like Ebola, ArcelorMittal Liberia was able to rapidly access expertise and put into place a number of preventative measures that primarily focused on inside the fence risk mitigation. This indicated that it had the capacity of early detection and was flexible enough to respond quickly to the situation. The ability to quickly adapt infection control measures and to internalize them into existing health and safety mechanisms meant ArcelorMittal Liberia was better prepared in June 2014 when the outbreak entered urban areas than it was in March 2014 at the outset of the outbreak. This was due to the presence of the right corporate culture of health and safety which utilized the knowledge of experts to develop and implement new preventative measures. These preventive measures including screening, fencing, education and awareness and was complemented by an appropriate risk communication strategy to protect employees and operations while maintaining business continuity against the threat of the outbreak. The analysis identified the presence of systems for early detection, redundancy in human resource use and to some extent supply chains, flexibility in management and a corporate culture that took new emerging threats to its operations seriously strongly indicating the presence of the resilience attributes identified in the literature.

### **5.2.2. Objective 2: To document the chronology of events and preventative measures/actions taken by the firm during the disruption event**

The crisis was dealt with by a dedicated 'emergency management team' consisting of senior management in both London and Liberia, which enabled ArcelorMittal Liberia to make pragmatic decisions as promptly as possible again emphasising the presence of a corporate

culture willing to allow decision making at lower autonomous levels. The firm started responding to the outbreak by protecting its employees and business operations, then expanded their response to support the communities, government and non-governmental organisations indicating an emphasis on both internal and external communication at all levels. The success of the firm in its immediate response to keep operations free from Ebola and continue operations has enabled it to support humanitarian response in the wider community showing that a resilient enterprise can contribute actively to the resilience of the community and the country at large as well. ArcelorMittal Liberia has conducted many Ebola initiatives around community awareness, screening, contact tracing and used its machinery to construct external Ebola treatment centres, and building health system capacity of the local areas, which were struggling to deal with the crisis. The firm has taken the initiative to form the Ebola Private Sector Mobilization Group (EPSMG), which provided a single point of contact for private firms to interact among themselves and to collaborate with government and non-governmental organisations in supporting humanitarian response during the Ebola crisis.

The chronological sequence of events that took place during the disaster event was shown against the magnitude of the Ebola epidemic (in Figure 17) and this contributes to the understanding of the response of the firm with respect to the timeline of events. The timeline of the ArcelorMittal Liberia response demonstrates that the firm was engaged in prevention, building and strengthening critical EVD outbreak control infrastructure within the concessions and the wider community when they were needed most at the peak of the outbreak; well before the international community's response. ArcelorMittal initiated the EPSMG and had actively collaborated with public-private partnerships to help overcome the crisis. The EPSMG initiated by ArcelorMittal has participated in international advocacy for a global response to the Ebola outbreak and the mobilisation of in-country resources to support humanitarian and healthcare efforts, for which ArcelorMittal has been recognised by the Clinton Global Initiative for its swift, collaborative, and effective response to the Ebola crisis in West Africa (Clinton Foundation, 2015).

The operation and production of ArcelorMittal Liberia was resilient despite not getting much of a lead time prior to the disruption event because of the way the outbreak spread in

Liberia. The “quiet” time between the initial disruptive event in March 2014 and the time of the full impact of the outbreak in July-August 2014, as reported by some of the respondents, was time ArcelorMittal Liberia used effectively to bring infection control systems into place in their health and safety structure. By adopting preventative measures early, the firm was in a position to continue production with more confidence and this enabled the firm to signal its commitment to stay and continue its operations to all stakeholders in Liberia.

### **5.2.3. Objective 3: To estimate the cost of preventative measures taken by the firm during the disruption event**

Timely and coordinated preventive measures adopted inside and outside the ArcelorMittal Liberia territory had costs attached to them. The actual costs of preventive measures and reduced productivity incurred by ArcelorMittal Liberia were in the range of USD 10.58 million to USD 11.11 million. The largest cost was generated from preventive measures on health outlays and other containment measures implemented on the mining concessions and the community. The second largest costs were incurred from additional salary payments and evacuation of non-essential staff, followed by Ebola related direct construction costs, external support towards Liberia’s efforts to contain, treat and eradicate Ebola, and reduced productivity due to the EVD outbreak. The respondents in the qualitative interviews identified Phase II expansion as the largest costs’ impact of the EVD outbreak on the firm, followed by preventive measures, external donations, consultant fees, ETU construction, and hazard pay. In the quantitative costing the researcher was unable to estimate the costs associated with phase II expansion, however for the other items listed, the actual costs incurred largely conform to the perceived costs. The analysis of the cost of the preventative measures to the mining firm are a significant contribution to the field and will be of interest to stakeholders involved in emergency response, EIDs, Ebola, corporate health and safety, corporate responsibility and other private and public organizations working in the sector and area.

#### **5.2.4. Objective 4: To develop and validate a conceptual model with stakeholders that can be used to assess how various preventative measures (and attributes) could be used to enhance resilience**

In order to define and understand the whole system relevant to ArcelorMittal Liberia's actions in response to the Ebola outbreak, the key concepts of actual and perceived risk were identified, and this formed the basis for the development both of the conceptual resilience model and the prototype systems model. Where traditional epidemiologically-based models of disease spread have focused on actual risk, the introduction of the causal loops relating to perceived risk for key stakeholders both inside and external to the company were crucial to an understanding both of the system behaviour during the outbreak, and to assessing the organisation's response in terms of its impact on the system.

The conceptual model of organizational resilience was used to show the impact of preventative measures on organizational resilience over time and allowed for a detailed discussion on what those measures were and what were considered during the time period and how those could be modelled in the approach. The use of the model highlighted the need for flexibility in defining the key functions relevant to the company. These will be specific to the organisation, the location, and (to some extent) to the nature of the potential disruption against which resilience is being assessed. This flexibility should improve the applicability of the framework as a practical tool to support planning. The validation of the model by senior stakeholders indicated the value of conceptualizing organizational resilience using simulation methods like system dynamics and indicates future scope for expanding the model.

### **5.3. Implications for theory and practice**

From a systems perspective, the identification of the potential impact of local or national infrastructure on an organisation's resilience (and on its potential options for improving resilience) is also critical. In the case of AML, due its size and its importance at the national and local levels as an inward investor means that its actions can also have a meaningful

impact on infrastructure – in other cases, organisational response planning will not affect infrastructure, but it should still be taken into account in assessment of resilience.

The pattern of expenditures on preventative measures suggests a greater focus, and perhaps confidence, on “in fence” measures such as perimeter fencing, temperature screening and enhancement of internal medical facilities. It is interesting to note these measures also have multiple benefits and not only those related to Ebola in that they can contribute to overall security as well as additional benefits of monitoring employee health. The firm had noticed a drop in security related incidents due to tighter security and fencing and the medical staff had noticed a drop in flu rates as well as early detection and treatment of malaria and yellow fever among employees. Although most employees reported a general level of satisfaction at the level of support and the measures employed by the firm during the outbreak, some did criticize the building of an Ebola Treatment Unit at great expense. The argument that was put forward, mostly by Liberian employees, indicated that this money could have been better spent elsewhere for instance on the local health facilities.

As part of the Mineral Development Agreement (MDA), firms such as AM have to spend on a number of “out of the fence” social sector projects, for example schools, hospitals and other community facilities, in the areas of the concessions. Since operations began in 2007, AML has been running these facilities as their legal obligations as well as through several outreach programs as part of their corporate responsibility and sustainability (CR&S) department activities.

International health response agencies, such as the WHO and USAID, have been trying to make the investment case for long-term investments into local health systems rather than the quick and short term (often more expensive) reactive responses that typically take place in response to an outbreak (MARSH, 2007). Of the estimated USD 10.58 million to USD 11.11 million AML spent during the 2014-2015 period only USD 1.27 million was spent on the community directly. Of the remaining amount it is reasonable to assume that some of that benefits from expenditures on preventative measures also trickled out to the community, such as the communication programs launched for the families of employees and also the externalities gained by local



health facilities from interacting with international consultants but an exact figure would be hard to assess.

It can be argued that AML had to spend a lot more money in the short run for a rapid increase in their organizational resilience (perceived or actual) and its was a reactive response to the crisis. Alternatively, a longer term sustained strategy for greater contributions and investments in the local health sector, as argued by USAID and WHO, would add to the resilience of the local communities and AML's own workforce and hence the overall economic resilience of its business operations. This proactive approach may prove to be more beneficial in the long run but more tools are required that could provide the evidence base for such long term investments.

During the GMBs and the validation workshop, participants from the CR&S indicated the value of a tool that can help them gauge the contributions of their activities on the communities they were a part of. Although this is beyond the scope of the present study it is a promising future direction of research to explore as this would provide a more robust evidence base for not only international health agencies like USAID and WHO to convince the private sector of greater investments in disaster risk reduction but also for CR&S departments within these large companies to rank and assess their own social outreach programs and their impacts for greater "in fence" and "out of the fence" resilience.

#### **5.4. Strengths and limitations**

The study was faced with a number of limitations. Firstly, the study was carried out in a complex setting where the outbreak was still continuing and the extractive firm was experiencing economic downturn, not only because of the outbreak but also due to falling commodity prices in the international market. Secondly, the study had aimed to collect and analyse detailed resource use and unit costs data but data was not available in as much detail as required. Thirdly, the study wished to capture the effect of outbreak on indirect costs, especially the effect on supply chain items and future expansion projects, but it was not possible to get reliable data within the timeframe of the analysis. Fourthly, the qualitative and system analysis was also limited by managing key respondents time within the timeframe of the study. FGDs and GMBs could not be done to fully validate qualitative

models due to the inability of the researcher and the focal person at the firm to arrange additional FGDs with the relevant people in London and the prospect of conducting FGDs in Liberia over Skype or other remote access software was not ideal. As mentioned above the research design required an interaction between quantitative and qualitative analysis and this was not possible due to a lack of quantitative data in as much detail as requested. Feedback from quantitative data was required to test the validity of dynamic hypothesis but this could not be done. Data was not available for validation till late in the project. Due to complications in the study setting, the planned sequence of iterative steps of model conceptualization, formulation and validation could not be completed with the optimal level of engagement of all key stakeholders, although this was achieved in part through engagement with the London-based corporate team. Finally, a crucial limitation that affected the research study was that it was originally designed to be a PhD project but due to several mitigating circumstances the research had to be reduced to meet the scope of an MPhil degree requirement. This caused some serious issues as time allocated to collect data was reduced which had an impact on all parts of the research. This also meant that less group model building sessions were conducted than planned as a more extensive modelling framework was envisioned and it could not be implemented in the reduced time frame.

The study's strengths are largely related to its practical applicability in the industry. The study was set in the real world mining firm context. The mixed approach of qualitative and quantitative analysis shows how a crisis or disruption like the 2014 EVD outbreak can impact the complex operations of a mining firm. The views of the experienced mining staff have strengthened the study by providing a balanced and representative view of how an outbreak can affect mining operations, and how future disruptions can be handled. The study developed an innovative conceptual framework of operational resilience that is designed (i) to provide a better understanding of factors contributing to operational resilience of firms in the extractive industry, (ii) to understand how hazards impact on operational resilience, (iii) and for comparison of hazard specific adaptation options, i.e. preventative measures. The framework concept is applicable to a range of situations within and across organisations so that, for example, it can be used to assess resilience and potential response within a single team or business unit, by the organisation at corporate

level, or by a network of organisations in a locality seeking to work together to improve the shared response to future crisis.

The prototype model developed over the course of the project uses the framework as the basis for exploring potential costs and benefits of resilience planning. Even in its current, largely theoretical form, it can support work within organisations on the impact of future crises and the ability of the organisation to respond. As such, it can form the basis of a practical tool for the development of response planning for future health (and other) crises.

## **5.5. Key lessons and recommendations**

The study shows that there was a system in place in ArcelorMittal Liberia for early monitoring of threats like disease outbreaks yet Ebola was identified as a potential EID risk only when it was confirmed in Guinea in March 2014. By then it had already made its way into Liberia. For organizations to be resilient, they need as much lead time as possible before a disruption, in order to develop and implement measures that can help prevent or mitigate the impacts of a disruption on its business activities (Fiksel, 2015). This is especially true for EIDs that can spread in a human or animal population without notice for some time before being detected hence investment in early detection mechanisms is highly recommended.

Private firms in the extractive industry typically have operations in remote locations like the border areas of Nimba County and can play a vital role in the early detection of EIDs if connected to local health systems. This is in the interest of both the public and private sectors to increase preparation time for mitigation strategies that can limit the extent of impact of the disruption (Llamas et al., 2015). The implementation of an EID early warning system would ensure that disruptions to business continuity from EIDs could be minimized. This could only be done if these extractive firms are plugged into local health systems. This requires active public-private collaboration on sharing information towards developing an effective early warning system and consequent control measures for health related emergencies.

The response of ArcelorMittal Liberia was focused on its employees and operations, but it was then expanded to the wider community and eventually to supporting the humanitarian response as well. This was important in building and strengthening the low healthcare infrastructure of Liberia to make a concerted effort to fight Ebola. The resilience of a firm like ArcelorMittal Liberia crucially depends on the risk of EIDs in the community they operate in and the capacity of healthcare systems to handle the health crisis. The support to the wider community and healthcare infrastructure needs continued investment, especially in the face of a possible flare up of Ebola or other EIDs in the future.

It was reported in the study that ArcelorMittal Liberia responded quickly to any information gaps in EIDs that were identified by immediately asking for expert advice on the medical emergency – this proactive approach indicated that systems were in place that could make the information demand quickly and directly with minimal delay. Good emergency management infrastructure enables a rapid and dynamic assessment of risk (Sheffi, 2015b). The study shows that for ArcelorMittal Liberia there was an existing mechanism for response in the form of EMTs put in place in Liberia prior to the outbreak (due to security concerns). This existing infrastructure made linking up with a Global Emergency Management Team (GEMT) based in London relatively easy and with minimal delay. It is recommended that all extractive firms invest in emergency management infrastructure that can quickly be adapted to respond to changing circumstances of a disruption or hazard – especially EIDs.

One of the factors determining operational resilience is the role attributed to communications in corporate culture (Sheffi and Rice Jr., 2005). Effective communications plays a role throughout the risk management process especially when there is uncertainty in outcomes (Srivastav and Simonovic, 2014a) and interview data indicates that ArcelorMittal Liberia effectively used risk communication in the implementation of preventive measures at different levels ranging from community social awareness programs to industry collaboration in the form of the EPSMG and its campaign for a coordinated international response to the EVD outbreak. It is suggested that firms develop training programs in Crisis coordination for Communication departments at both local and international levels that will

improve the ability of firms in the extractive industry to respond to a disruption. Inclusion of ArcelorMittal communication staff to EMTs at the earliest stage is an example of the role effective communication can play in reducing fears of employees in the initial stages of an outbreak.

Firms in the extractive industry know that the most important resource in a mining concession is not the ore but the humans in the system. The study has shown that during the outbreak, ArcelorMittal Liberia decided to immediately adopt disease control measures to safeguard its workforce and incurred significant expenses in bringing in the best experts available to address information gaps that may have existed. The ability of ArcelorMittal Liberia to rapidly internalize recommendations from experts into their health and safety (H&S) culture and communicate those across the organization is perhaps one of the reasons many of the respondents felt the concessions were the safest place in all of Liberia during the outbreak. The creation of an ETU at a significant cost represents a strong commitment on ArcelorMittal Liberia's part to its employees.

## **5.6. Scope for further research**

The cost of preventative actions has been assessed in the study using retrospective data from the firm. While the preventive measures taken by the firm have been vital to protect operation and maintain business continuity, it was not possible to evaluate the effectiveness of the measures retrospectively. Further research is required to assess the effectiveness and cost-effectiveness of different preventative measures.

Due to limitations in the study setting the indirect sources of impact could not be covered. Studying disruptions like the EVD outbreak would need researchers to examine the impact of the outbreak on supply chain management data, which could be addressed in detail with data at the firm level. Further research also needs to investigate the impact of disruptions like the EVD outbreak by estimating the relative impact driven by the outbreak itself and the effect of exogenous commodity prices (e.g., the effect of declining iron ore price in the current study context).

There is a need for quantitative assessment of hazard impacts on these large firms and analyses of various adaptation options. This study has developed an original operational resilience assessment framework, through synthesis of existing models in the literature and through group model building sessions directly with stakeholders, based on system dynamics simulation. This framework can be used to identify the most significant factors affecting operational resilience and to understand and develop hazard specific adaptation measures for large firms in the extractive industry. This work could be extended to include community level impacts.

The prototype model could be developed in a number of directions in the future. Quantification of preventative costs would enable the costs of a range of planned actions to be compared over time, and (as discussed above) this could be separated both from the underlying impact of market forces or planned trajectories in organisational performance and from the costs associated with a range of crises. It would also be possible to develop a more complex approach to identifying resilience in a complex system, linking the resilience of each stakeholder enterprise or firm (which could themselves be complex combinations of business units, locations or functions each with their own assessed level of resilience) through a series of feedback loops, such that a change in resilience of one part of the system would have an impact on the resilience of the whole system and thus on the resilience of the other stakeholders. However, a balance has to be struck between the value of that a complicated analysis through 'modelling of data', and the benefits of simpler, practical approaches based on expert advice and experience which can help organisations improve their understanding of risk, resilience and response.

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**Appendix A: Combined Information sheet, Invitation letter and Consent Form**  
**ADULT CONSENT TO PARTICIPATE IN A RESEARCH STUDY: Human Research**  
**Consent Form**

**STUDY TITLE: Impact of the 2014 -15 West Africa Ebola Outbreak on Organizational Resilience: A Case Study**

**INTRODUCTION**

We invite you to take part in a PhD research study conducted by the \_\_\_\_\_. This research may give us knowledge that may benefit the work of both \_\_\_\_\_ and PARTICIPATING FIRM (PF).

First, we want you to know that taking part in the research is entirely voluntary. You may choose not to take part, or you may withdraw from the study at any time. In either case, you will not lose any benefits to which you are otherwise entitled nor will you otherwise be penalized.

Before you decide to take part, please take as much time as you need to ask any questions and discuss this study with anyone at PM or \_\_\_\_\_, or with family, friends or any of your advisers.

**THE RESEARCH STUDY**

**1. Research Protocol**

You will be participating in an interview as part of a PhD research study to create a preliminary systems model of the operations of PF and how the Ebola outbreak has affected it. You will be asked questions about your professional background, working relationships, role within the safety and risk management activities at PF, and perception of how your role fits within the larger safety and risk management process at PF. This interview should take approximately 1 hour.

**2. Risks/ Discomforts**

Since we will keep your responses confidential, we perceive little to no foreseeable risks to taking part in this Study. However, your participation is entirely voluntary. You may skip over any questions for any reason and you may stop at any time. Your responses will be kept confidential and your name will not appear in any of our final products. When results of the research are reported in final project reports, professional journals, at scientific meetings, or in academic dissertations, the people who take part are not named and identified. Any data used is constructed so as to preclude identifying participants.

**3. General or Participant Benefits**

In general, participants are not paid for taking part in these research studies.

**4. Problems or Questions**

If you have any problems or questions about your Rights as a research participant or about any Research-related concern, contact \_\_\_\_\_ at

[CONTACT INFORMATION IN THIS SPACE]

For more information on this study, please contact the Principal Investigator or the Supervisor:

[CONTACT INFORMATION IN THIS SPACE]

**CONSENT DOCUMENT** - Please keep a copy of this document in case you want to read it again.

**Participant's Consent:** I have read the explanation about this research study and have been given the opportunity to discuss it and to ask questions. I hereby consent to take part in this study.

Signature of Participant

Date

Signature of Principal Investigator/ Witness

Dat

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## Appendix B: Interview Guide for IDIs

Interview guide for Participating Firm (PF) and contractual staff		
Specific dimensions/topics	Questions	Suggested probes
<b>General Section for all</b>		
Introduction/background	<ol style="list-style-type: none"> <li>1. Please indicate what is your designation /department that you belong to and describe the nature of your role in the company as well as your main responsibilities and duties.</li> <li>2. How long have you worked in this company? How long have you worked in the mining industry?</li> <li>3. Did you work in the industry during the current outbreak period? Where exactly and for how long?</li> </ol>	<ul style="list-style-type: none"> <li>- How many countries or sites do you manage?</li> <li>- Is the company centralised or is decision making devolved to the sites?</li> <li>- Did your roles and responsibilities change in any way during the outbreak?</li> </ul>
Risk and vulnerability	<ol style="list-style-type: none"> <li>4. Can you describe any past experiences of disease outbreaks or illnesses in your mines in Liberia or other mining sites where you have worked?</li> <li>5. How serious are these diseases for the company and local communities? Please give examples of their impacts.</li> </ol>	<ul style="list-style-type: none"> <li>- What happened?</li> <li>- What kinds of situations make these diseases more or less likely?</li> </ul>
Systems Affected by Outbreak	<ol style="list-style-type: none"> <li>6. Can you please list, to the best of your knowledge, which aspects of the mining operations were most affected during the Outbreak? (List and rank)</li> </ol>	<ul style="list-style-type: none"> <li>- Production</li> <li>- Mining Capacity</li> <li>- Human Resources</li> <li>- Health &amp; Safety</li> <li>- Why do you think this was the most affected?</li> </ul>



**Section for Staff related to Production at PM**

Production	<ol style="list-style-type: none"> <li>Can you please describe how production was affected during the outbreak? (List and rank if more than one way)</li> <li>What were the added challenges of operating in an outbreak environment?</li> </ol>	<ul style="list-style-type: none"> <li>- Compare to normal operations previous to the outbreak</li> <li>- How was the Production Rate affected? Production Goals? Daily/Weekly/Monthly data?</li> <li>- How were inventory levels affected?</li> <li>- Did this significantly affect order rates/order fulfilments?</li> </ul>
Factors of Production (INPUTS)	<ol style="list-style-type: none"> <li>How were the costs of Production affected?</li> <li>How were supply chains of inputs affected?</li> </ol>	<ul style="list-style-type: none"> <li>- Of local inputs</li> <li>- Of inputs being brought in from abroad</li> <li>- Rental/repairs</li> <li>- Any Critical blockages that were affected for key inputs</li> <li>- Petroleum/chemical products etc.</li> </ul>
Transportation and Shipping (Logistics)	<ol style="list-style-type: none"> <li>How was transportation of iron ore affected during the outbreak?</li> <li>How was the shipping rate affected, if at all?</li> <li>Other aspects of logistics that affected mining operations during the outbreak</li> </ol>	<ul style="list-style-type: none"> <li>- Freight costs</li> <li>- From sites to inventory/warehousing site</li> <li>- Trade restrictions/border crossings etc.</li> </ul>

**Section for Staff related to Mining Capacity at PF (Expansion and Exploration)**

Mining Capacity	<ol style="list-style-type: none"> <li>Can you please describe how in your understanding the mining capacity, or expansion, was affected by the outbreak? (List and rank if more than one way)</li> <li>In your opinion, what effect would the outbreak have on the ability of AM to attract future investment for mining capacity expansion?</li> </ol>	<ul style="list-style-type: none"> <li>- How were expansion goals/ planned capacity additions affected?</li> <li>- How was exploration affected, if at all?</li> <li>- In Liberia</li> <li>- In West Africa</li> <li>- In areas more susceptible</li> </ul>
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to EIDs

3. Capital Expenditures

4. What role do foreign subcontractors play in mining capacity expansion?

- i.e. any up gradation of plant machinery, equipment and/or other capital intensive expenditures affected

Section for Staff related to Human Resource Management at AM

Human Resources

1. What effect did the outbreak have on the human resources available to AM and its mining operations?
2. How did you/your firm mitigate it/cope?
3. Was productivity compromised? If so then at what levels and how?
4. Were there any changes in the decision making structure of your firm

- Number of workers/ level of absenteeism
- What major reasons for absenteeism? transport, fear, taking care of relatives
- Hiring additional workers
- Training
- Increasing workloads/ more overtime
- financial incentives
- productivity
- skilled vs unskilled
- domestic vs foreign
- Senior management productivity/ outbreak response/workloads
- Time allocation being affected vs normal
- Changing roles/shortages of key personnel
- For special areas/locations
- For special types of

	during the outbreak – creation of new roles/departments etc.?	activities
	5. Change in Standard Operating Procedures?	
Section for Staff related to Health and Safety (both AM and contractual staff)		
Health and Safety Systems	<ol style="list-style-type: none"> <li>1. Can you please describe how Health and Safety has been affected, if at all, by the current outbreak? (List and rank if more than one way)</li> <li>2. How has this affected your personal commitment to safety?</li> <li>3. How might have both these factors affected the incident rate of Ebola infections?</li> <li>4. Can you describe any ways you have heard of (or been personally involved in) for preventing diseases that come from animals?</li> <li>5. Are any of these preventive approaches currently being used in your mining areas, in Liberia and elsewhere? <ol style="list-style-type: none"> <li>a. Why or why not?</li> </ol> </li> <li>6. What health services or facilities does PF provide on-site for its employees?</li> <li>7. What additional health services or facilities has PF been able to provide during this outbreak?</li> </ol>	<ul style="list-style-type: none"> <li>- Compared to pre-outbreak period</li> <li>- Management commitment to safety/Time taken to respond</li> <li>- Living under outbreak conditions</li> <li>- Risky behaviour</li> <li>- Rate of other Incidents</li> <li>- Are there any measures that can be taken at the mine itself to avoid outbreaks?</li> <li>- Training activities</li> <li>- Screening</li> <li>- Temp checking</li> </ul> <p>Are there any issues around:</p> <ul style="list-style-type: none"> <li>- Costs</li> <li>- Logistics</li> <li>- Skills</li> <li>- Manpower</li> <li>- Equipment</li> </ul>

8. During the ongoing outbreak has this preventive been scaled up? if so then by how much
9. How effective do you feel are the preventive measures taken by PF?
10. How have these measures affected your morale and of the employees working in outbreak areas?

## Appendix C: Focus Group Discussion Guide

Focus Group Discussion guide for PF staff		
Specific dimensions/topics	Questions	Suggested probes
Introduction/background	<ol style="list-style-type: none"> <li>1. Please indicate what are your designations /departments that you belong to and describe the nature of your role in the company as well as your main responsibilities and duties.</li> <li>2. How long have you worked in this company? How long have you worked in the mining industry?</li> <li>3. Did you work in the industry during the current outbreak period? Where exactly and for how long?</li> </ol>	<ul style="list-style-type: none"> <li>- How many countries or sites do you manage?</li> <li>- Is the company centralised or is decision making devolved to the sites?</li> <li>- Did your roles and responsibilities change in any way during the outbreak?</li> </ul>
Risk and vulnerability	<ol style="list-style-type: none"> <li>4. Can you describe any past experiences of disease outbreaks or illnesses in your mines in Liberia or other mining sites where you have worked?</li> <li>5. How serious are these diseases for the company and local communities? Please give examples of their impacts.</li> </ol>	<ul style="list-style-type: none"> <li>- What happened?</li> <li>- What kinds of situations make these diseases more or less likely?</li> </ul>
Risk Perception	<ol style="list-style-type: none"> <li>6. How likely is it that there might be an incident of a worker infected with Ebola in the next year</li> <li>7. How serious would it be for an employee or a worker to get infected by Ebola in the next year</li> <li>8. How likely do you think it is that an employee or worker will get infected</li> </ol>	<ul style="list-style-type: none"> <li>- In general (London)</li> <li>- Local site (Liberia)</li> <li>- Magnitude question try to get answer in a scale out of 100</li> <li>- Elaborate as much as possible by using “why” when getting a response from the respondent</li> </ul>

	by Ebola in the next year compared to other firms working in the same area		
Current outbreak risk	9. Do you think that people in general are informed and can take actions to prevent getting Ebola?	<ul style="list-style-type: none"> <li>- Locals</li> <li>- Families of employees</li> </ul>	
	10. How many incidents have there been of workers from your firm getting infected during this current outbreak?	<ul style="list-style-type: none"> <li>- General outbreak</li> <li>- Locality (if in Liberia)</li> </ul>	
	11. How severe is this outbreak (compared to any previous ones you may have experienced)?		
	12. What was/is the probability of an employee being infected in this outbreak? A close family member?		
	13. How confident are you that workers in your firm can prevent getting infected by Ebola?	<ul style="list-style-type: none"> <li>- Locals</li> </ul>	
	14. How effective has the government been in addressing the current outbreak?	<ul style="list-style-type: none"> <li>- Families of employees</li> <li>- Subcontractors/foreign workers</li> <li>- Employees in other sectors</li> <li>- Government commitment to safety of citizens</li> <li>- Time taken for response</li> <li>- Response/actions taken</li> </ul>	
	Knowledge and Sources of Information	15. How much do you know about the Ebola virus?	
		16. What are the main sources of information about Ebola and what source to you trust the most? (list and rank if more than one)	
	Systems Affected by Outbreak	17. Can you please list, to the best of your knowledge, which aspects of the mining operations were most affected during the Outbreak? (List and rank)	<ul style="list-style-type: none"> <li>- Production</li> <li>- Mining Capacity</li> <li>- Human Resources</li> <li>- Health &amp; Safety</li> <li>- Why do you think this was the most affected?</li> </ul>

Causal Loop Diagrams

18. Please comment on the CLD diagram(s) that the research team have developed.

Discussion

## Appendix D: Model equations

Stella model equations reproduced below:

$$\text{Cumulative\_performance\_impact}(t) = \text{Cumulative\_performance\_impact}(t - dt) + (\text{Weekly\_impact\_of\_shock\_and\_resilience\_planning}) * dt$$

$$\text{INIT Cumulative\_performance\_impact} = 0$$

INFLOWS:

$$\text{Weekly\_impact\_of\_shock\_and\_resilience\_planning} = \text{Modelled\_performance-INIT}(\text{Modelled\_performance})$$

$$\begin{aligned} \text{Total\_organisational\_resilience}[\text{Key\_organisational\_function}, \text{Resilience\_dimension}](t) = \\ \text{Total\_organisational\_resilience}[\text{Key\_organisational\_function}, \text{Resilience\_dimension}](t - dt) + \\ (\text{Weekly\_resilience\_levels}[\text{Key\_organisational\_function}, \text{Resilience\_dimension}] - \\ \text{release\_of\_resilience}[\text{Key\_organisational\_function}, \text{Resilience\_dimension}]) * dt \end{aligned}$$

$$\text{INIT Total\_organisational\_resilience}[\text{Key\_organisational\_function}, \text{Resilience\_dimension}] = \text{Baseline\_resilience\_by\_function\_and\_type}$$

$$\text{TRANSIT TIME} = 1$$

$$\text{CAPACITY} = \text{INF}$$

$$\text{INFLOW LIMIT} = \text{INF}$$

INFLOWS:

$$\begin{aligned} \text{Weekly\_resilience\_levels}[\text{Key\_organisational\_function}, \text{Resilience\_dimension}] = \\ \text{Modelled\_resilience\_by\_dimension\_and\_type} \end{aligned}$$

OUTFLOWS:

$$\text{release\_of\_resilience}[\text{Key\_organisational\_function}, \text{Resilience\_dimension}] = \text{CONVEYOR OUTFLOW}$$

$$\text{Additional\_costs\_of\_building\_resilience\_as\_}\_of\_performance[\text{Production}, \text{Robustness}] = 0.5$$

$$\text{Additional\_costs\_of\_building\_resilience\_as\_}\_of\_performance[\text{Production}, \text{Redundancy}] = 0.5$$

$$\text{Additional\_costs\_of\_building\_resilience\_as\_}\_of\_performance[\text{Production}, \text{Resourcefulness}] = 0.5$$

$$\text{Additional\_costs\_of\_building\_resilience\_as\_}\_of\_performance[\text{Production}, \text{Rapidty}] = 0.5$$

$$\text{Additional\_costs\_of\_building\_resilience\_as\_}\_of\_performance[\text{Distribution}, \text{Robustness}] = 0.05$$

$$\text{Additional\_costs\_of\_building\_resilience\_as\_}\_of\_performance[\text{Distribution}, \text{Redundancy}] = 0.1$$

$$\text{Additional\_costs\_of\_building\_resilience\_as\_}\_of\_performance[\text{Distribution}, \text{Resourcefulness}] = 0.025$$



Additional\_costs\_of\_building\_resilience\_as\_%\_of\_performance[Distribution, Rapidity] = 0.05

Additional\_costs\_of\_building\_resilience\_as\_%\_of\_performance[Management\_and\_decn\_making, Robustness] = 0.2

Additional\_costs\_of\_building\_resilience\_as\_%\_of\_performance[Management\_and\_decn\_making, Redundancy] = 0.25

Additional\_costs\_of\_building\_resilience\_as\_%\_of\_performance[Management\_and\_decn\_making, Resourcefulness] = 0.05

Additional\_costs\_of\_building\_resilience\_as\_%\_of\_performance[Management\_and\_decn\_making, Rapidity] = 0.15

Additional\_resilience\_plan\_by\_dimension[Production] = 1

Additional\_resilience\_plan\_by\_dimension[Distribution] = 1

Additional\_resilience\_plan\_by\_dimension[Management\_and\_decn\_making] = 1

Applied\_additional\_cost\_of\_more\_resilience[Key\_organisational\_function, Resilience\_dimension]  
= if No\_cost\_resilience?=1 then 0 else  
(Additional\_costs\_of\_building\_resilience\_as\_%\_of\_performance\*Cost\_multiplier)

Baseline\_performance = 100

Baseline\_resilience\_by\_function\_and\_type[Production, Robustness] = 1

Baseline\_resilience\_by\_function\_and\_type[Production, Redundancy] = 1

Baseline\_resilience\_by\_function\_and\_type[Production, Resourcefulness] = 2

Baseline\_resilience\_by\_function\_and\_type[Production, Rapidity] = 1

Baseline\_resilience\_by\_function\_and\_type[Distribution, Robustness] = 1

Baseline\_resilience\_by\_function\_and\_type[Distribution, Redundancy] = 1

Baseline\_resilience\_by\_function\_and\_type[Distribution, Resourcefulness] = 2

Baseline\_resilience\_by\_function\_and\_type[Distribution, Rapidity] = 2

Baseline\_resilience\_by\_function\_and\_type[Management\_and\_decn\_making, Robustness] = 3

Baseline\_resilience\_by\_function\_and\_type[Management\_and\_decn\_making, Redundancy] = 3

Baseline\_resilience\_by\_function\_and\_type[Management\_and\_decn\_making, Resourcefulness] = 3

Baseline\_resilience\_by\_function\_and\_type[Management\_and\_decn\_making, Rapidity] = 3

Combined\_smooth = if (N\_value\_for\_downward\_crisis<N\_value\_for\_recovery)

THEN

(if (Smoothed\_crisis<Smooth\_for\_recovery) then Smoothed\_crisis else Smooth\_for\_recovery)

ELSE

if (Smoothed\_crisis<Smooth\_for\_recovery) then Smooth\_for\_recovery else Smoothed\_crisis

Cost\_multiplier = 0.2

Final\_performance\_level =

Baseline\_performance\*(Performance\_level\_after\_recovery\_as\_%\_of\_baseline/100)

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Production, Robustness] = 1

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Production, Redundancy] = 0

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Production, Resourcefulness] = 1

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Production, Rapidity] = 1

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Distribution, Robustness] = 0

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Distribution, Redundancy] = 0

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Distribution, Resourcefulness] = 0

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Distribution, Rapidity] = 0

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Management\_and\_decn\_making, Robustness] = 0

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Management\_and\_decn\_making, Redundancy] = 0

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Management\_and\_decn\_making, Resourcefulness] = 1

Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type[Management\_and\_decn\_making, Rapidity] = 0

Impact\_of\_resilience\_on\_reaction\_to\_shock = smoothed\_smooth

Implement\_resilience\_plan? = 0

Include\_growth\_assumption? = 0

Indicator\_for\_direction\_of\_shock\_trajectory\_1 = if ((HISTORY(Sample\_crisis\_graph, time-dt)=Sample\_crisis\_graph) and Sample\_crisis\_graph>=init(Sample\_crisis\_graph)) then 3 else if ((HISTORY(Sample\_crisis\_graph, time-dt)>Sample\_crisis\_graph)) then 2 else if ((HISTORY(Sample\_crisis\_graph, time-dt)=Sample\_crisis\_graph) and Sample\_crisis\_graph<init(Sample\_crisis\_graph)) then 1 else 0

Max\_n\_value = 20

modelled\_costs\_of\_building\_resilience\_by\_dimension[Key\_organisational\_function] =  
Additional\_resilience\_plan\_by\_dimension\*(Applied\_additional\_cost\_of\_more\_resilience[Key\_organisational\_function,  
Robustness]+Applied\_additional\_cost\_of\_more\_resilience[Key\_organisational\_function,  
Redundancy]+Applied\_additional\_cost\_of\_more\_resilience[Key\_organisational\_function,  
Resourcefulness]+Applied\_additional\_cost\_of\_more\_resilience[Key\_organisational\_function,  
Rapidity])

modelled\_growth\_assumption = if Include\_growth\_assumption?=0 then 1 else  
Performance\_growth\_assumption

modelled\_impact\_of\_plan\_on\_resilience[Key\_organisational\_function, Resilience\_dimension] =  
DELAY(Implement\_resilience\_plan?\*potential\_impact\_of\_plan\_on\_resilience\*Additional\_resilience\_plan\_by\_dimension[Key\_organisational\_function], Start\_week\_for\_additional\_resilience\_plan)

modelled\_impact\_of\_shock\_on\_resilience[Key\_organisational\_function, Resilience\_dimension] =  
if (Shock\_to\_performance?=1 and  
Profile\_of\_shock<Trigger\_point\_for\_impact\_of\_shock\_on\_resilience) then  
potential\_impact\_of\_shock\_on\_resilience else 0

Modelled\_performance = (Modelled\_reaction\_to\_shock\_before\_additional\_costs-  
modelled\_total\_cost\_to\_performance%)\*modelled\_growth\_assumption

Modelled\_performance\_impact\_of\_resilience\_plan = Baseline\_performance-  
(modelled\_total\_cost\_to\_performance%)

Modelled\_reaction\_to\_shock\_before\_additional\_costs =  
Impact\_of\_resilience\_on\_reaction\_to\_shock

Modelled\_resilience\_by\_dimension\_and\_type[Key\_organisational\_function,  
Resilience\_dimension] =  
Baseline\_resilience\_by\_function\_and\_type+modelled\_impact\_of\_plan\_on\_resilience+modelled\_impact\_of\_shock\_on\_resilience

Modelled\_resilience\_by\_dimension[Key\_organisational\_function] =  
Total\_organisational\_resilience[Key\_organisational\_function,  
Robustness]\*Total\_organisational\_resilience[Key\_organisational\_function,  
Redundancy]\*Total\_organisational\_resilience[Key\_organisational\_function,  
Resourcefulness]\*Total\_organisational\_resilience[Key\_organisational\_function,  
Rapidity]\*Weighting\_for\_resilience\_by\_function

modelled\_total\_cost\_to\_performance% =  
delay(SMTH3(Total\_cost\_of\_plan\_as\_%\_of\_performance\*Implement\_resilience\_plan?, 4, 0),  
Start\_week\_for\_additional\_resilience\_plan)

Modelled\_total\_resilience = SUM(Modelled\_resilience\_by\_dimension[\*])

No\_cost\_resilience? = 0

**N\_value\_for\_downward\_crisis = N\_value\_for\_resilience**

**N\_value\_for\_recovery = Max\_n\_value-N\_value\_for\_downward\_crisis**

**N\_value\_for\_resilience = (Modelled\_total\_resilience/20)\*Rsilience\_multiplier\_for\_testing**

**Performance\_growth\_assumption = GRAPH(TIME)**

**(0.00, 1.03), (1.00, 1.03), (2.00, 1.04), (3.00, 1.05), (4.00, 1.07), (5.00, 1.08), (6.00, 1.10), (7.00, 1.11), (8.00, 1.12), (9.00, 1.12), (10.0, 1.14), (11.0, 1.15), (12.0, 1.15), (13.0, 1.17), (14.0, 1.18), (15.0, 1.19), (16.0, 1.20), (17.0, 1.20), (18.0, 1.20), (19.0, 1.22), (20.0, 1.23), (21.0, 1.23), (22.0, 1.24), (23.0, 1.25), (24.0, 1.28), (25.0, 1.31), (26.0, 1.33), (27.0, 1.35), (28.0, 1.38), (29.0, 1.39), (30.0, 1.40), (31.0, 1.42), (32.0, 1.44), (33.0, 1.45), (34.0, 1.45), (35.0, 1.45), (36.0, 1.45), (37.0, 1.45), (38.0, 1.45), (39.0, 1.45), (40.0, 1.45), (41.0, 1.45), (42.0, 1.45), (43.0, 1.45), (44.0, 1.45), (45.0, 1.45), (46.0, 1.45), (47.0, 1.45), (48.0, 1.45), (49.0, 1.45), (50.0, 1.45), (51.0, 1.45), (52.0, 1.45)**

**Performance\_level\_after\_recovery\_as\_%\_of\_baseline = 110**

**potential\_impact\_of\_plan\_on\_resilience[Key\_organisational\_function, Resilience\_dimension] = if  
Baseline\_resilience\_by\_function\_and\_type<3 then  
1\*Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type else  
0.25\*Impact\_of\_plan\_on\_resilience\_by\_function\_and\_type**

**potential\_impact\_\_of\_shock\_on\_resilience[Key\_organisational\_function, Resilience\_dimension] =  
-0.015**

**Profile\_for\_shock\_impact = if Shock\_to\_performance?=0 then Baseline\_performance else  
Profile\_of\_shock**

**Profile\_of\_shock = GRAPH(TIME)**

**(0.00, 100), (1.00, 100), (2.00, 100), (3.00, 100), (4.00, 100), (5.00, 100), (6.00, 100), (7.00, 100),  
(8.00, 100), (9.00, 100), (10.0, 100), (11.0, 100), (12.0, 100), (13.0, 100), (14.0, 80.0), (15.0, 80.0),  
(16.0, 80.0), (17.0, 80.0), (18.0, 100), (19.0, 100), (20.0, 100), (21.0, 100), (22.0, 100), (23.0, 100),  
(24.0, 100), (25.0, 100), (26.0, 100), (27.0, 100), (28.0, 100), (29.0, 100), (30.0, 100), (31.0, 100),  
(32.0, 100), (33.0, 100), (34.0, 100), (35.0, 100), (36.0, 100), (37.0, 100), (38.0, 100), (39.0, 100),  
(40.0, 100), (41.0, 100), (42.0, 100), (43.0, 100), (44.0, 100), (45.0, 100), (46.0, 100), (47.0, 100),  
(48.0, 100), (49.0, 100), (50.0, 100), (51.0, 100), (52.0, 100)**

**Rsilience\_multiplier\_for\_testing = 1**

**Sample\_crisis\_graph = Profile\_for\_shock\_impact**

**Shock\_to\_performance? = 0**

**Smoothed\_crisis = SMTH1(Sample\_crisis\_graph, N\_value\_for\_downward\_crisis)**

**smoothed\_smooth = SMTH1(Combined\_smooth, 1)**

**Smooth\_for\_recovery = smth1(Sample\_crisis\_graph, N\_value\_for\_recovery)**

**Start\_week\_for\_additional\_resilience\_plan = 13**

**Total\_cost\_of\_plan\_as\_%\_of\_performance =  
SUM(modelled\_costs\_of\_building\_resilience\_by\_dimension[\*])**

**Trigger\_point\_for\_impact\_of\_shock\_on\_resilience = 90**

**Weighting\_for\_resilience\_by\_function[Production] = 1**

**Weighting\_for\_resilience\_by\_function[Distribution] = 1**

**Weighting\_for\_resilience\_by\_function[Management\_and\_decn\_making] = 1**