LONDON RESILIENCE

preparing for emergencies

Anytown: Final Report

A DEFRA funded project - Community Resilience Funding for Local Resilience Forums in England

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Executive Summary

In 1969 Edward Lorenz described the Butterfly Effect; that there is often a sensitive dependence on initial conditions, and even relatively small changes can result in significant impacts. Similarly, the popular Domino Effect describes a system where a small change causes a sequence of similar change. Both of these ‘effects’ are evidenced in the context of infrastructure disruption, and a number of these are discussed later in this report. These effects can be observed because infrastructures represent highly connected systems upon which many other services rely, therefore disruption can very quickly ripple out from the initiating incident, and have higher order consequences (which may also more significant than the initial incident) across a diverse range of sectors.

Even if designed to be simple, infrastructure evolves towards complexity in response to technological developments, changing user requirements and styles of consumption. This means that reliable analysis in isolation from the environment and other infrastructures is impossible. The many infrastructure interconnections must be considered to develop a global view of the issues. In this report the term interdependencies is therefore used in preference to dependencies as many of the relationships examined show degrees of mutuality rather than isolation.

London Resilience Team proposed Anytown as a tool to help raise awareness of the potential Domino Effect to city systems (the systems that keep cities functioning – emergency services, local government, health services, transport provider etc) resulting from disruption to infrastructure, upon which we are increasingly dependant.

Funding for this project was awarded by DEFRA through the Community Resilience Funding for Local Resilience Forums in England Programme in December 2012.

Each organisation has a tacit knowledge of their own system interactions, however, little has been explicitly documented on these interactions and interdependency between multiple sectors. The work encompassed by Anytown aims to fill these gaps in knowledge, aiding later interpretation by those who have little or no expert knowledge.

Through a series of workshop sessions, research and analysis, data has been collected on the typical impacts arising from disruption to electricity and water supplies, regardless of initiating incident. This report presents the findings of this data analysis, provides a tool which can be used by practitioners to assist business continuity planning and validate assumptions and lists recommendations for the continuation of a project which has significant potential.

Introduction

Problem Space

There is a body of evidence (anecdotes, incident analysis and personal judgement - summarised later) which suggests limited knowledge of interdependencies could present a missed opportunity for understanding and improving resilience. Specific study of infrastructure interdependencies received little attention prior to the 1990s; increased reliance on computerised systems brought this issue into focus in preparation for the "Millennium Bug" contingency planning.

Heightened consideration is reflected in the establishment of National Infrastructure Security Coordination Centre (NISCC) in 1999, becoming the Centre for the Protection of National Infrastructure (CPNI) in February 2007; and increased research funding to universities to investigate infrastructure issues. Increased levels of effort have lead to innovative work however; assessing the interdependency issues has only begun recently.

In chaotic environments, such as emergency response, decision makers need to be able to comprehend a situation and assess the risks and benefits to determine a course of action. Therefore, understanding the dynamics of supporting infrastructures is a key competency. Whilst many interdependencies are intuitive (e.g. phones rely of electricity) comprehensive and detailed understanding is often lacking. Pederson (2006) states this gap in understanding could result in sub-optimal response and coordination between agencies responsible for rescue and recovery.

Infrastructure – Context and Definitions

HM Government (2011) define Infrastructure as the interconnections associated with the supply or receipt of a service on which receiving sectors are reliant. A common property of infrastructures is that they are comprised of complex collections of interacting components, they are complex adaptive systems.

The extent of infrastructure in the UK is vast and has been developed over many decades. In London's case, parts of some infrastructure systems are centuries old. More recently, developments have been seen in information and communication technologies (ICT), including telephone networks, internet access infrastructure and mobile networks, with an even more recent shift to mobile internet. Emerging technologies such as 'smart metering' represent the convergence of different systems and commitment has been made at Government level to significant further investment. It is therefore almost certain that linkages between infrastructures will become increasingly prevalent.

Table 1 illustrates the volume of infrastructure at both a National and London scale. However, it is important to recognise that infrastructure is not homogenous, with centres of population having comparatively more infrastructure.

Infrastructure	National	London
Miles of roads[1]	245,000	9,200
Average train services per autumn weekday[2]	9,700	4,700
Miles of high voltage overhead electricity lines	15,500	[3]EHV - 1,100
Miles of overhead lines and underground cables	500,000	HV - 7,500 LV - 14,100

Table 1: Comparison of UK and London Infrastructure

The UK Government introduced The National Infrastructure Plan (HM Treasury (2010, 2011)) which identified the importance of understanding infrastructure interdependencies in terms of economic growth; and these issues were also highlighted by the Pitt Report following the UK flooding in 2007, which had significant impact on infrastructure.

Infrastructure in the UK is categorised according criticality using the Government "Criticality Scale" (Cabinet Office, 2010). The loss of certain infrastructure nodes (which may be structural or non-structural) would have a major detrimental impact on the availability or integrity of services nationally. These "critical" assets form the UK Critical National Infrastructure (CNI). At the London level, there have been challenges in sharing information relating to CNI, and it anticipated that Anytown will provide a useful opportunity to explain to relevant partner organisations, the benefits of sharing this information.

Project Team

In December 2012, a small project team was formed, lead by London Resilience Team, and supported by UK Power Networks, Thames Water and the London Climate Change Panel. In addition, support was provided for workshop sessions from the Cabinet Office Emergency Planning College through consultants from Training4Resilience Ltd.

Project Aims and Objectives

The project team developed the formal aim of the Anytown project as the "development of a conceptual model to improve the understanding of infrastructure interdependencies by non-experts"

To avoid doubt, this was taken to mean:

- Development of a conceptual model...
    - Complexity of infrastructure makes modelling interactions and processes in detail challenging. Bunza (2007) suggested that they should, therefore, be captured by an appropriate generic model.

[1] Department for Transport (2011a)
[2] Department for Transport (2011b)
[3] Network managed by UK Power Networks, the main supplier to London (incorporates some network assets outside of the Greater London boundary) (2013)

- ...to improve the understanding...
    - Anytown should be used to assist the development of awareness of the issues. It is not intended as a predictive model for specific infrastructure failures.
- ...of infrastructure interdependencies...
    - The model should focus on the consequences to other sectors of infrastructure disruptions. This will allow identification of areas of dependency and interdependency.
- ...non-experts
    - In the context of Anytown, non-experts is taken to mean resilience and adaptation practitioners. Whilst there is potential scope for future development of a public information resource, at this stage the focus has been around providing information to relevant professionals.

Empirical Evidence & Literature Review

Empirical Evidence

There is no shortage of incidents demonstrating interconnectedness with utility infrastructure, and the possible consequences of concurrent or cascading failure. A selection of some of the most notable and recent examples is provided below, highlighting the requirement for greater awareness of these issues.

Manchester Tunnel Fire

In 2004, a fire in a deep level tunnel beneath Manchester city centre caused severe damage to telephony cables, and consequently, major telecommunications disruption in the region. The outage affected an estimated 130,000 homes and businesses including the emergency services. In addition, banks, airlines, mobile phone providers and utility companies reported system impacts.

Hurricane Katrina

Figure 1 is taken from an analysis of dependencies of infrastructure following Hurricane Katrina. Pederson et al (2006) explain "solid lines crossing sectors and connecting nodes [elements of a single system], represent internal dependencies, while the dashed lines represent dependencies…between different infrastructures." For example, a particular connectivity can be seen between the electrical infrastructure, a failure of which had impacts for sewage pumping and communications. This diagram is easy to understand and therefore a useful way of illustrating the presence of relationships between sectors.

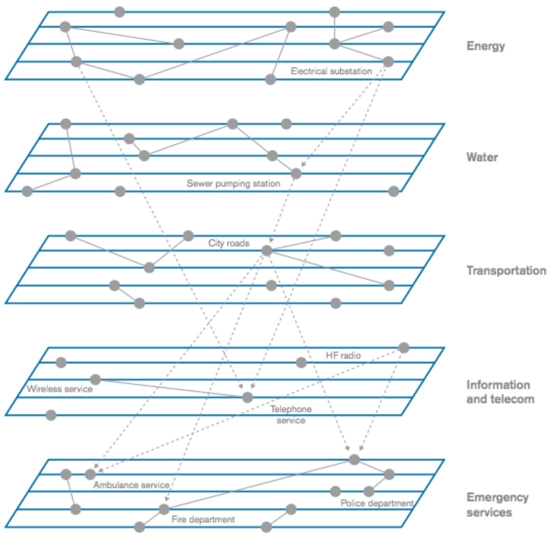

Figure 1: Infrastructure layers and connections (after Pederson et al 2006)

Baltimore Tunnel Fire

The interrelationship between infrastructures and its potential for cascading effects was demonstrated 19 July 2001 following a derailment of a 62-car freight train carrying hazardous chemicals in Baltimore's Howard Street Tunnel, Further to the expected effects on rail network traffic, automobile traffic, and emergency services, this incident caused cascading degradation of infrastructure components not previously anticipated. Specifically, the tunnel fire caused damage to an overlying water main resulting in 20ft geysers and more significantly, localised flooding of three feet in some areas. This flooding affected electricity supplies to 1,200 residences. The derailment also damaged fibre optic cables resulting in disruption to fixed and mobile phones and internet disruption to businesses. The impact of disruption to rail services spread to the Middle Atlantic States and affected coal and limestone deliveries for steel production. This example is used by the Cabinet Office Emergency Planning College in their infrastructure and incident management professional training modules.

Buncefield

A explosions at 06:01 on Sunday 11 December 2005 didn't result in any casualties, is widely recognised as the biggest explosion in peacetime Europe, directly affecting 92 businesses and impacting on multiple infrastructures (energy, transportation and the environment). The incident revealed the significance of information infrastructures as the explosion damaged a number of data centres used in processing of NHS patient records, payroll schemes and data for several local authorities.

UK Floods

Hundreds of thousands of people across England and Wales were affected by flooding during June and July 2007, the most serious inland flood since 1947. In addition to approximately 48,000 households and 7,300 businesses, floods affected infrastructures, such as water and food supply, power, telecommunications and transportation, as well as agriculture and tourism.

In terms of interdependency issues, a good example was observed in Hull, where pumps protecting the city flooded and failed but, and in other locations localised power loss, through flooding, caused pumps to fail and exacerbate flooding further.

Hurricane Sandy

As yet there have been no formal reports into the impacts of Hurricane Sandy in the United States in late 2012, there were many examples of interdependency issues reported in the widespread media coverage. With flooding and high winds damaging power distribution infrastructure, knock on problems were created around the distribution of fuel and use of mobile phones to communicate. These types of consequences were also experienced during the widespread power outages in the north-eastern United States in 2003, a demonstration that despite different causation, there are typical similar types of impact arising from incidents, and therefore considering them generically is a reasonable approach.

Recent Resilience Exercises

In addition to the incidents discussed above, a number of exercises that London Resilience Forum has participated in have also highlighted the need to consider infrastructure more fully.

Date	Exercise	Comment relevant to Anytown
Watermark	Feb 2011	Widespread lack of understanding among the partnership of the status and interdependencies of critical infrastructure
Purple Top	Dec 2011	Limited understanding of the actual / potential consequences of a power outage and the impacts arising from a water supply outage.

Table 2: Selected comments from London Resilience exercises 2004-2011

Literature Review

Several authors cite that normal circumstances can be considered a period of equilibrium. Whilst there are continual changes at a micro level, macroscopically systems function within their expected limits. However, even a slight perturbation outside of those normal limits can have dramatic consequences, as the perturbation is cascaded through interdependent and connected infrastructures.

Helbing et al (2006) asserts that most disasters, regardless of cause, have typical impacts including traffic, transportation and supply problems, and impacts on trade. These consequences are the product of more than just the magnitude of the iniating event. Bunza et al (2007) expand on this stating that feedback loops can serve to amplify the effect of any disruption considerably.

Many approaches to infrastructure modelling (as reported in Pederson et al (2006)) are based on network models, which map the physical configuration of the components of a given system. Whilst useful for interrogation of discrete networks, it is difficult to capture dynamic multi-system responses using this topological description.

With increasing urbanisation, it's likely that cities will continue to extend beyond their "ecological hinterland" through dependence on infrastructure. Interestingly, as Rapoport (2011) observes, infrastructure is increasingly hidden (either physically out of sight, or taken for granted by those who use it) which makes formal approaches to consider infrastructure issues all the more important.

Rimaldi (2001) identified six "dimensions" (Figure 2) which exist in normal operations and during times of stress, which can be used to categorise and describe infrastructure interdependencies. The degree to which each of these dimensions exists reflects the degree of interdependence. Four of these conditions (Type of Interdependence, Coupling and Response Behaviour, Infrastructure Characteristics and Type of Failure), are further expanded below.

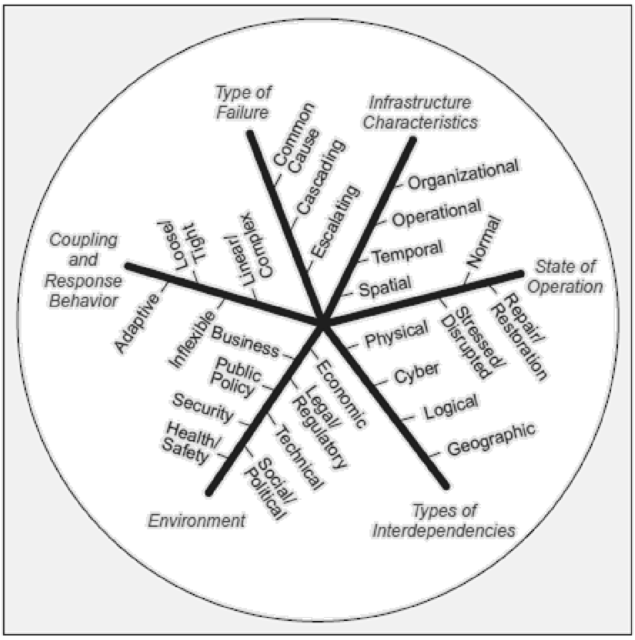

Figure 2: Dimensions of Interdependence (Rimaldi, 2001)

Type of Interdependency

- Physical - direct linkage between two 'agents' such that the output of one is input to the other.
- Cyber -an infrastructure depends upon information from a computer as infrastructure to maintain its operation.
- Geographic - malfunction of one infrastructure can affect the operation of another through proximity, for example a coaxial cable attached to a collapsed bridge.
- Logical - occurs in the absence of physical connections but where the functionality of one infrastructure, say a finance system, is dependant upon the integrity of another, say the computer system.

Coupling and Response Behaviour

- Degree of coupling - Disturbances tend to propagate rapidly through tightly coupled infrastructures, whereas loosely coupled systems demonstrate greater relative flexibility to stressors.
- Coupling order - indicates whether two infrastructures are directly connected to one another or indirectly coupled through one or more intervening infrastructures
- Complexity of the interactions – Perrow (1984) describes a continuum between Linear and Complex along which interactions sit. Linear interactions are those which are predictable and replicable, whereas complex interactions include the impact of feedback loops and emergent behaviour, often unintended by design.

Infrastructure Characteristics

- Spatial scales - range from individual parts, to the whole system, to the wider structure composed of interdependent infrastructures and even the wider environment
- Temporal scales - infrastructure dynamics span a temporal range from milliseconds to years. Anytown looks at the temporal range of hours-days which reflects system operations.
- Operational factors - include how the system works and responds and covers operating procedures, training, business continuity and contingency plans
- Organisational characteristics – includes aspects such as ownership, regulatory environment, corporate policies and motivations and the effects of global socio-economic factors

Types of Failure

- Cascading failure - occurs when a disruption in one infrastructure causes disruption or failure in a second infrastructure
- Escalating failure - occurs when an existing disruption in one infrastructure exacerbates an independent disruption in a second infrastructure.

- Common cause failure - occurs when two or more infrastructure networks are disrupted at the same time

The two other dimensions which Rimaldi (2001) cites influence interdependence include, State of Operation (which can range from optimal design operation to complete failure with a total loss of service to all users), and Infrastructure Environment (meaning the range of economic , policy, legal, health and safety, technical, security and, socio-political concerns which contribute to the long-term design and operation of the infrastructure). These have not been expanded on in this report as they are deemed to be less critical to the scope of the Anytown project at this stage.

Borg (2005) takes a slightly less comprehensive view, illustrating three types of relationships exhibited within and between systems. Where two or more paths run in parallel there is a degree of redundancy, and therefore if one path is compromised the total process will continue (a). Where one process is dependant upon many preceding processes, disruption to an initial process can cause impacts for others; the well-known cascade effect (b). However, if a single process is crucial to all subsequent processes, and compromise will halt the whole system (c).

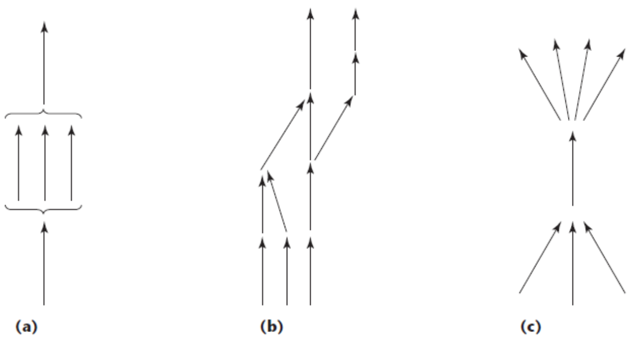

Figure 3: System relationship typology (Borg, 2005)

Discussion of Research

It should be apparent from the presented empirical and academic evidence that comprehensive analysis of interdependencies is a daunting challenge. This was recognised by the Anytown Project Team and used to guide the development of project assumptions and limitations to ensure project manageability.

Currently, interdependencies are managed through the development of close working relationships; with corporate governance and independent regulation serving as the principle mechanisms for managing risks. However, obligations under the Civil Contingencies Act and Climate Change legislation are moving towards additional holistic risk assessments, which is a positive development. In some industries, professional forums (such as, Energy Networks Association and WaterUK) are used to share information and develop sector-wide response plans. Exercises involving infrastructure providers have also been carried out locally and nationally, with learning influencing the development of future activity. However, overall, the focus is largely on business continuity planning, frequent risk assessment and investment in back up systems and security measures at the organisational level. Issues of security, commercial confidentiality, and also trust, appear preclude full information sharing in respect of interdependencies.

A better-developed awareness of infrastructure interdependencies should enable more informed decisions to be taken and provides a baseline understanding for a more sophisticated examination of infrastructure interactions.

Many authors cite examples of incidents exhibiting interdependence issues. Several provide simple models to articulate the broad linkages, and a small number have developed more complex models which are limited to analysing the interaction between two infrastructures. No evidence has been found by the Project Team of any studies or examples of holistic, macroscopic views of the type Anytown attempts to provide.

In addition to just describing that nature of interactions, it should also be possible to estimate the typical time at which certain consequences are likely through spreading of perturbations within a causality network. This approach has been previously suggested (Helbing (2006)), but the Project Team couldn't find any evidence of it being implemented. Anytown therefore aims to develop existing work by contributing to increased understanding of interdependencies and more anticipative, rather than reactive, disaster response.

Methodology

Research

Project Team members collated empirical evidence and published literature which was reviewed before any work was initiated. This provided all members with a common understanding or terminology, approaches and latest developments within the field. In addition, the London Climate Change Partnership were aware of some applied approaches in Canada, which were shared with the Team to inform project delivery meetings.

One of the key questions to be addressed in the initial stages of the project was “how much of the real-world should be modelled?” There is a continuum of possibilities of model fidelity and the project team agreed that the outcome of the project should strike a balance between model fidelity and ease of application.

In accordance with the funding stipulations, the outcome of the project needed to be suitably generic that it could be shared with other Local Resilience Forums. The decision was therefore taken that rather than use a physical location, Anytown would be a fictional and abstract, multi-dimensional, geographical and jurisdictional place. It is worth noting for clarity, incident boundaries in Anytown are not necessarily congruent with this abstract space (meaning that incidents can occur outside of Anytown with the potential to impact Anytown). The generic approach also allowed an exploration of the issued without the impediment of local knowledge, reputational damage and established protocols. It was a useful way to ‘level the playing field’ and ensure that the views of all participants were accorded equal weight.

Workshop Planning

Scenarios were developed in consultation with electricity and water providers to ensure realism within the abstract environment. These fictitious networks had sufficient realism without ‘distractions’ on being as complex as real-world networks.

Two workshops were then held on 20 and 21 February 2013, with participants drawn from industry, academia and government agencies (a full list of workshop attendees is provided at Annex XXX). Across both workshops, there were 103 attendees from 54 different organisations. So that issues could be explored in sufficient depth, the participants were grouped into a number of thematic tables. Sector-based were used , to allow full discussion within sectors of how consequences of an initiating incident could propagate, and in addition, avoided the effect of having particularly dominant or knowledgeable participants, as levels of awareness were broadly similar on each table.

Mind mapping software was used to record the conversations on each of the facilitated tables. This was on display to the table participants and allowed them to provide any additional context or clarity to the recorded notes. In hindsight, for more rigorous interpretation of the feedback, transcription of each table’s discussion would have been helpful to add additional information.

Each workshop considered the same scenarios at the same time, which allowed a degree of cross-validation of the two workshops with similar comments being recorded at both sessions. Regular plenary feedback sessions allowed the sector information and impacts to be reported to the whole delegation, for consideration in the next phase of the interactive sessions.

The workshop sessions were extremely well received by attendees and have gained traction with wider resilience community. The project outputs discussed will be trialled later in 2013 with a pan-London strategic level exercise; however, the Project Team has already received expressions of interest for future adoption for a variety of real world implementations.

Analysis

Data, information and knowledge captured at the Anytown workshops were analysed to produce two models of Infrastructure Interdependency.

Workshop Findings & Discussion

Annex A provides the summary points raised during the discussion at both workshops.

Figure 4 presents two visualisations from the discussion at both Anytown workshops of the impacts of Electricity disruption; a mind map (a) and an onion-skin diagram (b) (these are reproduced at a more readable size in Annexes to this report). Similar diagrams are in production for disruption to water supply, however these are not included in this report due to time limitations. A number of the disruption to water supply aspects were captured through the electricity scenario (as one consequence was a disruption to mains and domestic pumping capability) however, a number of separate water considerations did arise and these diagrams will be included in an update report once available.

Figure 4a shows the consolidated and structured feedback from the two workshop sessions, ordered by sector and then order of impact, with the higher order impacts closer to the initiating event in the centre of the diagram. It can be seen that different sectors experience different levels of consequence at different stages, and from the workshop discussion, this is largely as a result of internal business continuity arrangements. Where organisations have alternatives, such as standby generators, there is a degree of flexibility and continuity before impacts are experienced (presuming that alternative measures are initiated and effective). However, it can also be seen that there is a difference between sectors, with some sectors being more dependant than others as a result of their function. Whilst Figure 4a is useful for interrogation and provides much of the additional discussion and context from the workshops, it is complex and daunting for those not used to reading mind maps.

Figure 4b therefore has been developed to highlight key aspects emerging at the Anytown workshops as aspects which were most significant. The concentric circles capture the ripple effect showing spreading consequences from an initiating incident. During the workshops, this emerged as a useful metaphor in describing chains of causation. Based on the information presented to the Anytown workshops, it wasn't possible to elucidate all of the timings at which certain consequences may result, and in any case, there are a number of variables which would affect these timings. For instance, one timing which was captured related to cessation of Underground transport; this was estimated at 5 minutes, but at a more granular level time for trains to stop would be influenced by factors such as current train velocity, track gradient and weight, so 5 minutes was used as an estimation of the maximum time train travel would continue.

In comparison with Figure 2 (which articulated broad relationships) both of the Anytown workshop visualisations provide a model which is more detailed yet still useable by non-experts. Displaying information in this way which makes it accessible increases the likelihood that it will be adopted and potentially repurposed by organisations in the future.

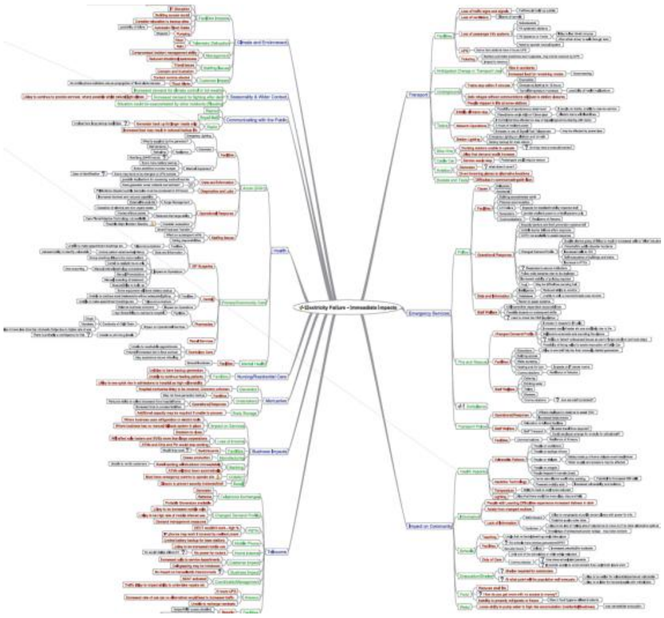

Figure 4a: Mind Map of the Anytown workshop relating to Electrical Supply Failure Scenario

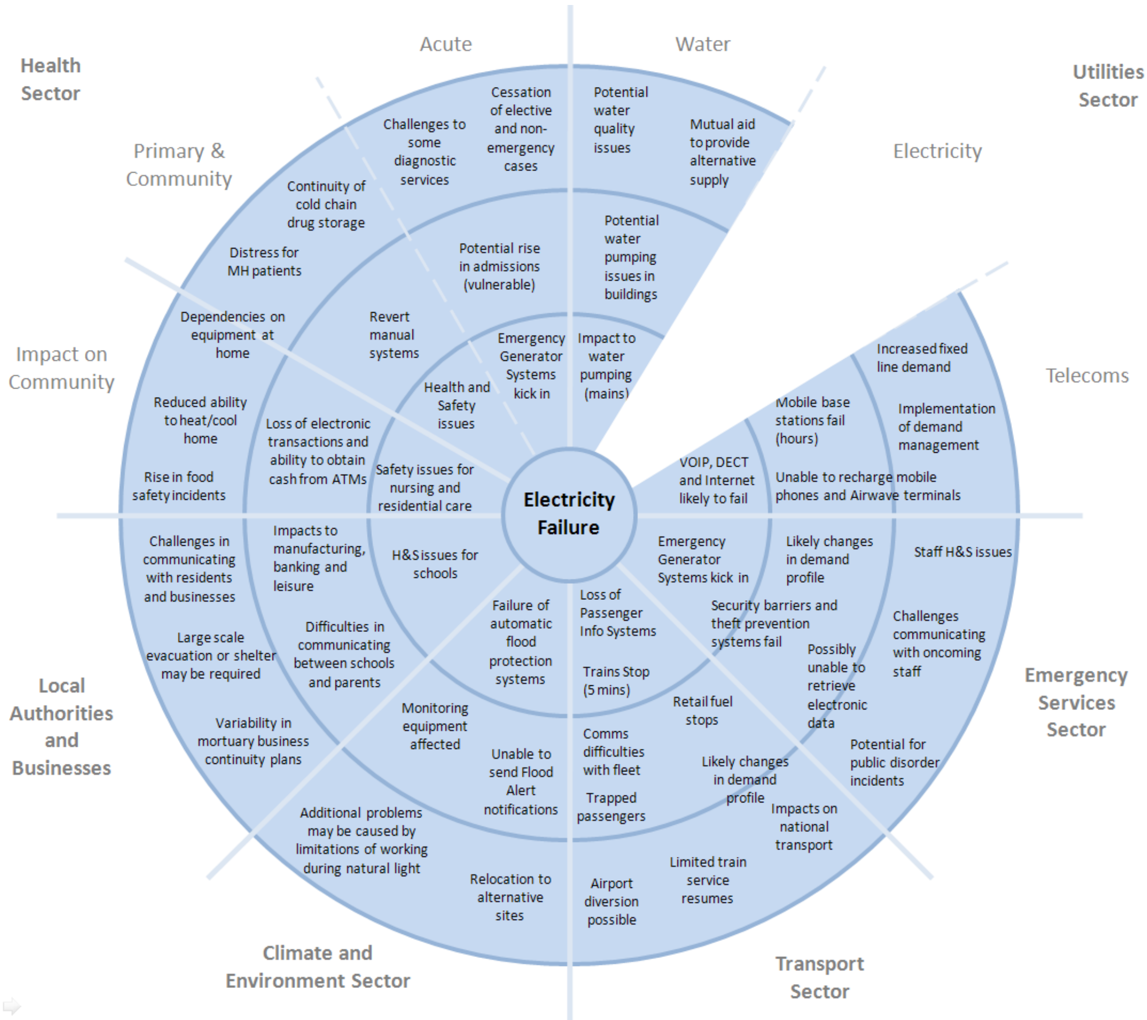

Figure 4b: Onion-skin diagram of Anytown workshop discussions relating to Electricity Supply Failure

Strategic decision makers in London (and anecdotally, elsewhere in the UK) have requested a 'map' of Critical National Infrastructure, so that in the event of an incident they can appreciate the impacts of disruption. Utility companies have routinely explained that in addition to inadequately reflecting network complexity (self healing abilities etc.) the resultant document would have a security classification which would limit how it could be shared or used. Therefore, whilst network operators have maps of their assets, a combined topographical 'CNI map' is thought not to be possible nor adequately serve the purpose for which it would be intended. In addition, many Local Resilience Forums are now considering the identification of 'critical local infrastructure' as those assets which, should services be disrupted, would cause significant impact at the local level yet do not meet the criticality scale.

Considering the complexity of displaying CNI, the display of this more locally significant infrastructure would add additional levels of complexity and make any such maps complicated to interpret. The Project Team therefore propose that decision makers should have good general awareness of interdependencies between, and consequences of infrastructure disruption; but that specific knowledge of network distribution be provided at the time of an incident by the most relevant organisation(s).

Greater sharing of information would derive benefits including reduced duplication of work, greater transparency between sectors, improved basis for training, capability validation and a reduced demand on exercise scenario generation through a pre-existing list of typical consequences.

The work reported by Anytown could be considered foundational in understanding consequence and interdependency issues from a resilience and adaptation perspective. Given further development this work could be developed to bring additional benefits of data sharing to assist risk assessment, capability development, training and decision support tools as well as inform longer term adaptation and sustainability decisions.

Linking Interdependency & Climate Change

Changes in climate (as described in the latest Intergovernmental Panel on Climate Change (IPCC) (2012)) could affect infrastructure in several ways. It is therefore vital to have a good understanding how infrastructure systems relate to each other so that the full range of consequences of climate change can be properly captured.

As the Anytown project, at this stage is limited to an investigation of electricity and water infrastructures only some of the predicted implications for these systems have been included, however climate change is also anticipated to considerable affect other sectors.

The IPCC (2012) have also recognised the need to ensure infrastructure resilience to natural disasters, and acknowledge the challenge of interdependencies and network scale.

Effect	Electricity	Water
Structural	As a result of sea-level change, increased precipitation or storm surge likelihood, power stations or other facilities in proximity to rivers or on the coast could be flooded Flooding could affect the fuel supply infrastructure Drought could threaten the supply of cooling water to power stations Discharged power station cooling water into reduced flow watercourses could cause ecological problems High temperatures could reduce transmission efficiency Increased frequency of storms could lead to more transmission shorting as lines touch Increased likelihood of damage to wave and wind generation systems in extreme or stormy conditions	Changes in rainfall patterns will lead to reduced supplies from reservoirs and river flows, Increased rainfall intensity will lead to increased water pollution incidents Increases in the intensity of severe rain events will lead to increased frequency and severity of flooding, which could damage both water supply and waste systems Saline intrusion into coastal aquifers and sewers as a result of coastal flooding and sea level rise Higher mean water temperatures affect biological treatment processes and drinking water quality in distribution networks. Increased evaporation will lead to reduced yields from reservoirs, lakes and rivers
Non Structural	High demand in summer created by the use of air conditioning has already created problems due to excessive strain on the grid	Hotter, drier summers will lead to changes in customer demand

Table 3: Summary of impact of climate change on infrastructure (Engineering the Future 2011)

Conclusion and Recommendations

In the past, infrastructure systems have been managed as if they were wholly separate systems. However, increasingly, urban systems are being managed as ecosystems (not only does this appear to be more sustainable, but also more efficient). When faced with uncertain challenges, Xu et al (2011) states that cities need to understand the processes and linkages between individual components within cities, similar to food chains in ecology. In nonlinear systems (such as urban areas) it is difficult to predict which small perturbations may yield disproportionate impact; hence there is a need for contextual knowledge. Providing higher-level awareness of complex infrastructures requires architecture which can balance cognition and the complexity of combining multiple interconnected events dispersed in time and space.

Infrastructure networks exhibit a non-linear growth processes; initially developing slowly, but typically followed by surges of intensive growth and a final point of saturation until some innovation prompts further growth or retro-fitting. The infrastructure systems considered by Anytown (electricity and water) could be considered to be well developed, however changes to resource supply and demand , in addition to technological developments mean that these infrastructures are still evolving today. Keeping up with this evolution is another benefit to the development of a suitable generic model such as Anytown.

Whilst the primary concern of infrastructure operators will remain what is within their sphere of influence we're increasingly seeing network convergence and therefore having knowledge of causal chains will help predict and prevent secondary effects. Further, the ongoing development of 'smart' infrastructures makes them increasingly operationally interdependent. This is especially important in the face of changing climatic conditions which could increase the frequency, intensity or duration of a range of phenomena which can impact on infrastructure systems.

Interdependency is inevitable; you're only as strong as your weakest dependency. All organisations and even communities directly, should therefore review whether their weak points are internal/external and develop methods to reduce the impact this could have.

Human built infrastructure interfaces with the natural environment. While the Anytown workshops did not specifically reveal dependencies between natural and artificial systems, they did highlight that interdependencies have a degree of seasonality, in that they are either quicker to occur or occur more frequently during different weather conditions/at different times of the year. Other studies however, have demonstrated this human-environment connection more explicitly (i.e. link between ground surface permeability and drainage capacity). Further, to provide evidence in support of Wilde's (2008) assertion that the failure has socio-technical, as well as structural, roots, it may be necessary for lay participation in any future evidence gathering.

Anytown set out to generalise from the specific and to offer suggestions for future research and investigation; it was not intended to be a detailed analysis, which would need comprehensive and interdisciplinary participation from a wide range of fields. Whilst Anytown has taken a step towards Helbing's (2006) recommendations to articulate the likely time at which typical consequences may occur, it is subject to a number of limitations. In addition, for detailed analysis, additional viewpoints and interdisciplinary skills are required, in addition to commitment and honesty from partners to contribute to the process. Partitioning into discrete systems is convenient for a variety of reasons, however it's apparent that to make further progress better understanding more refined assumptions on interdependency is needed. The Project Team have considered how, with further investigation and modifications to the methodology used, it could be possible to develop an all-encompassing model of how infrastructure is interconnected and likely 'flash to bang' of the typical consequence ripples, which would support increased awareness amongst decision makers, practitioners and even members of the public.

The modelling produced by Anytown is, of course, an approximation and only as good as the data on which it is built. Despite the excellent feedback from the Anytown workshops, challenges of scale and complexity of involved systems, and evidence deficit (many anecdotal examples, but under- or poor-reporting of real-time or post-event analysis) are real. One further observations from this study is that there should be some systematic attempt made to collect consistent data to aid the assessment of the impact of incidents and identify learning.

Recommendations

The Anytown concept will be used at a learning event in July 2013 by London Resilience Team, and will be used in other future work, with some organisations having already expressed an interest in the outcomes.

However, the Project Team has also suggested a number of recommendations, learning from the process and suggesting how this important work may be continued.

1. Than Anytown model clearly articulates the consequences of infrastructure disruption and should be shared with relevant organisations to assist their own local planning. Specifically, organisations should consider whether
    a. Risks and points of weakness (both internal and external to the organisation) have been identified
    b. Existing business continuity arrangements adequately capture and are prepared for the consequences of infrastructure failure
2. The development of the Anytown concept should be continued to provide an holistic model which improves generic understanding of all types of infrastructure failure. Specifically this could be achieved by
    a. Additional project resource commitment (time and funding to be made available for the ongoing development of the model presented to date)
    b. Inclusion of wider consultation with stakeholders (this should be multidisciplinary and involve relevant researchers)
    c. Variety of initiating incidents (telecommunications, transport, cyber/data etc)
    d. Increased consideration of the non-structural impacts and consequences – such as those issues experienced by the community, business sector or the economy more broadly
    e. Clearer data to be collected on phasing and timing of likely impacts to provide higher quality data for modelling
    f. Consultation with non-urban areas to ensure the Anytown model takes account of specifics
3. A possible next step for Anytown would be to develop stronger visualisations, or even the development of an immersive and interactive learning environment, which would help knowledge acquisition.
4. Additionally, whilst in this context, Anytown has been developed for use by the practitioners, there is also a possibility that this sort of information could be used directly by the public.
5. Collection of consistent data from relevant (international) incidents to enable further analysis on the likelihood and severity of typical impacts – this could be used to develop a more precise model, which was not possible with the current data available.

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Annex A – Consolidated Workshop Report

This document consolidates the discussion from the two Anytown workshops held at City Hall on 20 and 21 February 2013. It is intended as a summary of the discussion only. The workshops were facilitated by Matthew Hogan (London Resilience Team), Beverly Osborne (Training4Resilience) and Adrian Seward (Training4Resilience).

Energy

- Energy is critical to all infrastructures, and is closely coupled with telecommunications infrastructure for network monitoring and management.
- Power generation is dependant on water as is the health and hygiene of staff in energy installations.
- Some energy installations are sensitive to flooding.
- The energy sector is also has interdependencies with transport for supplies of raw materials and access to facilities.

Water

- The treatment, storage and distribution of potable water has a strong dependence on energy (electricity), accounting for up to 4% of UK energy usage.
- Systems to manage treatment and distribution are also dependent on energy and IT.
- As with the energy sector, water is dependant on transport for raw material transport and maintaining staff access.
- All sectors are dependant on water for health and hygiene.

Transport

- Transport is dependent on supplies of energy for its operation and on IT for complex transport management systems.
- Transport infrastructure can suffer physical damage during incidents which is a particular risk in locations sensitive to flooding.

Health

- Has strong dependencies with energy, water and telecommunications for the delivery of routine and critical services.
- Well developed business continuity arrangements exist, however have, in the past, shown inadequacies
- In general, providing business continuity measures are effective, significant impacts of utility disruption in the Health sector do not begin to appear directly until several hours into the disruption.
- However, a number of other sectors, and the changed demand profile of the emergency services could bring impacts to parts of the Health system more rapidly
- In addition, the same communication challenges around getting information to both the public and staff groups are faced

Business

- Immediate reaction likely to be closure of premises as the vast majority would be unable to operate without electricity, although some have business continuity plans or manual arrangements which could be used
- Impacts to retail, banking, manufacturing
- ATMs reliant on power and long term widespread disruption to the availability of cash could be significant for a variety of reasons

Local Authority and Voluntary

- Significant challenges with communicating with the public (especially Vulnerable Groups)
- Some services can tolerate outages without significant impact, however social care much more reliant on utilities (directly and indirectly) which could have implications for Health Sector

Emergency Services and Military

- Generally have high levels of resilience and well developed business continuity plans
- However, should incidents be protracted (48 hours onwards) then impact more likely to be identified. Arrangements that this impact affects non- critical services first where possible.
- Opportunities to review arrangements and ensure business contingency plans could be operational without key utilities
- It was suggested that changes in behaviour could affect the demand levels of all emergency services. Anecdotal evidence in support of this was discussed.

Telecommunications

- Many attendees has little knowledge regarding the levels of resilience offered by the range of communication technologies (e.g. some are content that having multiple mobile phone providers affords a degree of resilience, not recognising that there could be a common cause disruption such as loss of power to a mobile phone base station, which would affect both providers)
- ICT is completely dependent on the availability of energy to adequately function. Transport is necessary to enable engineers to access and fix damaged or malfunctioning installations.
- If communications fail, it is not possible to alert support services to the failure, making adapting or fixing the network particularly difficult.
- Smart grids, smart buildings etc increase the interdependencies on energy and ICT, and also increase potential vulnerability to cyber attacks.
- Diversity of systems can provide resilience, e.g. access to a range of telecommunications service suppliers. However, there have been occasions when major network issues have impacted other providers.

General Interdependency Issues

- A systems approach to infrastructure as whole is needed, which allows understanding and management of interactions between infrastructure elements.
- The lack of easily comprehended data about infrastructure is a constraint, knowledge and understanding is seen as a major issue.

- Lack of clarity on the contingency arrangements for staff unavailability (this was identified by causes such as school closures, inability to refuel cars, inability to communicate with staff; as well as other risks not discussed at Anytown such as Pandemic Flu)
- Whilst the ability to share data across sectors may be beneficial, producing a single view of interdependencies saves effort . However needs to be balanced with security considerations.
- The Climate Change Act 2008 requires most, but not all sectors, to identify the risks arising to their businesses from climate change. However, those sectors without reporting responsibilities (including IT) are likely to comply through internal business continuity practices.
- Since different sectors report to different regulators, which makes establishing a cross-sector view complex.
- Regulators focus is largely on increased efficiency and cost reduction, which may act against building resilience into infrastructure.
- Public expectation regarding infrastructure services levels and 'uptime' is increasing and being factored into business development. As a result, any reduction in service levels will have disproportionate consequences and changes in the level of service (e.g. the likelihood of a power cut) will need careful management.

Annex B – Anytown Workshops Slides

Anytown Workshop

20th February 2013

City Hall, London

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Agenda for the Day

Time	Activity
09:00	Arrive and Coffee
09:15	Welcome and Introduction
10:00	Phase 1 – Initial Electricity Failure
10:45	Coffee
11:00	Phase 2 – Continued Electricity Failure
13:00	Lunch
13:45	Phase 3 – Electricity Rota Disconnects
14:30	Coffee
14:45	Phase 4 – Water Failure
15:45	Next Steps
16:00	Depart

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Why Commence the Anytown Project?

- Complex and cascading disasters are becoming increasingly common
- Exercise and incident debrief reports note that there is a lack of awareness regarding the interdependency of infrastructure, sectors, organisations and policy
- Training and exercising budgets are being reduced due to current austerity measures

The Anytown Vision

- To create a model which demonstrates typical interdependencies of a generic urban area. This will support a range of applications such as:
  - A training and decision support tool for strategic decision makers
  - A resource to further explore understandings of interdependency and contribute to risk assessment work
  - A tool to predict change in impact as a result of climate change
  - An information tool to assist community resilience and business continuity initiatives

Generic vs Specific

- A generic environment allows us to explore the issues without the impediments of:
  - Local knowledge and history
  - Reputational damage or concern
  - Unique, specific factors that only affect that one area/building/organisation
  - Established protocols and procedures

It **always** floods in that street!

Don't worry, the local ….. will deal with that

It **never** floods in that street!

Our company would never allow that to happen

We're OK – we have a ………..

That could **never** happen to us!

These sorts of comments prevent us for exploring the "What If ...." question

It **always** floods in that street!

Don't worry, the local ….. will deal with that

It **never** floods in that street!

Our company would never allow that to happen

We're OK – we have a …………

That could **never** happen to us!

These sorts of comments prevent us for exploring the "What If …." question

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The Law of Unintended Consequences

- Widespread school closures (e.g. pandemic flu) – dramatic increase in absenteeism from work from the health sector as 30% of the health and social care workforce is likely to be the main carer for dependent children
- UK Border Agency raid a home care agency and close it down – a women in her 80s, left at home without medication, food or water for 9 days, dies

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Workshop 'Rules'

- Do
  - Reflect on personal and professional experiences
  - Focus on impacts and consequences
  - Give us your suggestions for Anytown
- Don't
  - Fight the scenario
  - Try to manage the incident – this is not an exercise!

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Welcome to Anytown

- Anytown is located in the UK and has a population of approximately 50,000 (the age distribution is typical of a developed nation, and it's population is clustered based largely around levels of affluence and cultural pooling)
- Transport Modes: Road, Rail, Underground, River, Bike Hire, Cable Car, Airport
- Education: Schools, colleges, university
- Healthcare: GPs, dentists, opticians, pharmacies, urgent care centres, DGHs, Trauma and specialist facilities, mental health facilities
- Emergency Services: police, fire, ambulance
- Government: parliament, government offices, VVIPs
- Business: Banking, Retail, Tourism, Manufacturing Industry (including COMAH site)
- Infrastructure: Sub stations, telephone exchanges, water pumping, sewage system, mobile phone network, TV and Radio (Production and Broadcasting)
- Local Authority Services: Street Cleansing, Licensing, Street Trading, Transportation and Highways, Community Safety, Parks and Leisure, Children and Family Services, Adult Social care, Housing and Homelessness

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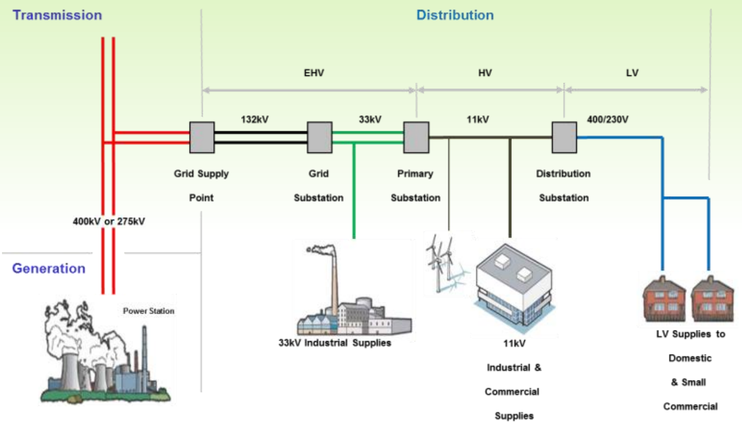
ANYTOWN WORKSHOP STEP 1

Complete failure of the electricity supply from Anytown Grid Substation

Anytown Electricity Supplies (1)



Anytown Electricity Supplies (2)

- Electricity supplies to Anytown are supplied from Anytown Grid substation.
- Anytown Grid substation supplies 4 main substations in the North, South, East and West.
- High Voltage circuits radiate from these main substations and criss-cross the surrounding areas with distribution substations at intervals down their length. These distribution substations supply customers in their immediate vicinity at low voltage. The majority of the these High Voltage circuits have interconnections with other High Voltage circuits from the same main substation and some links to adjacent main substations both within Anytown and to main substations in the surrounding area.

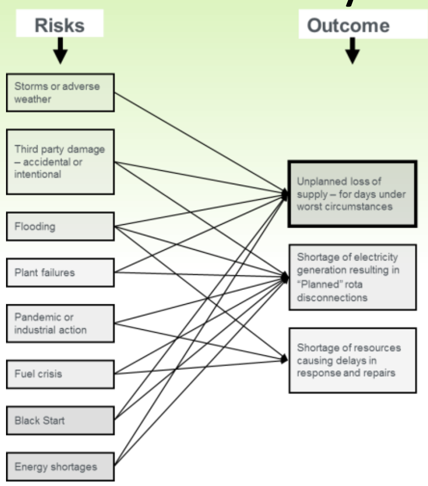
Anytown Electricity Supplies (3)

- High Voltage Supplies provided to:
  - Shopping Centre (West Main Substation)
  - Railway tracks (Grid Substation)
  - Water Treatment Works (West Substation)
  - Sewage Treatment Works (East Main Substation)
  - Telephone Exchange
  - Anytown TV and Radio Transmitters
  - Anytown Council Town Hall
  - High Rise Buildings
  - Anytown District Hospital (South Main Substation)
  - Other large commercial or industrial users

Anytown Electricity Supplies (4)

- Low Voltage Supplies provided to:-
  – Anytown Railway Stations
  – Mobile Phone Masts
  – Radio Anytown Studio and Transmitter
  – Anytown TV Studio
  – Care homes
  – Shops, offices and domestic properties

Key Risks for Electricity Industry



Initial Electricity Failure

- Day: Monday
- Time: 10:00
- Incident: Complete failure of the electricity supply from Anytown Grid Substation (therefore there is no “mains” electricity supply in Anytown)

- Task: What are the **most likely** immediate impacts of power failure for a **generic** organisation such as yours; and the infrastructure you are responsible for?

Electricity Failure + 1 Hour

- Day: Monday
- Time: 11:00
- Duration of Power Outage: 1 hour
- Statement: *Engineers are working as quickly and as safely as possible to restore electricity supplies to customers in Anytown. A fault on the electricity network interrupted power supplies to customers in the town at 10.00am today. We are sorry for the inconvenience caused.* ***Power is unlikely to be restored before 14:00*** *A further update will be provided at 14:00*

- Task: What are the **most likely** actions that a **generic** organisation such as yours will take at this point? What risks can you identify/highlight at this stage?

Electricity Failure + 4 Hours

- Day: Monday
- Time: 14:00
- Duration of Power Outage: 4 hours
- Statement: *We understand how difficult it is when homes and businesses are without power. We are working as quickly and as safely as we can to restore supplies and apologise for the continuing inconvenience and disruption this power cut is causing.* ***Power is unlikely to be restored before 08:00 on Tuesday****. A further update will be provided at this time. Please follow the Power Cut advice*

- Task: What are the **most likely** actions that a **generic** organisation such as yours will take at this point? What risks can you identify/highlight at this stage?

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Electricity Failure + 22 Hours

- Day: Tuesday
- Time: 08:00
- Duration of Power Outage: 22 hours
- Statement: *We understand how difficult it is when homes and businesses are without power. We are working as quickly and as safely as we can to restore supplies and apologise for the continuing inconvenience and disruption this power cut is causing.* ***Power is unlikely to be restored before 10:00 Wednesday****. A further update will be provided at 08:00 Wednesday. Please follow the Power Cut advice.*

- Task: What are the **most likely** actions that a **generic** organisation such as yours will take at this point? What risks can you identify/highlight at this stage?

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Electricity Failure + 46 Hours

- Day: Wednesday
- Time: 08:00
- Duration of Power Outage: 46 hours
- Statement: *We understand how difficult it is when homes and businesses are without power. We are working as quickly and as safely as we can to restore supplies and apologise for the continuing inconvenience and disruption this power cut is causing.* ***Power is unlikely to be restored before 10:00 Saturday****. A further update will be provided at 08:00 Thursday. Please follow the Power Cut advice.*

- Task: What are the **most likely** actions that a **generic** organisation such as yours will take at this point? What risks can you identify/highlight at this stage?

Electricity Failure – Rota Disconnections (1)

- We understand how difficult it is when homes and businesses are without power. We are working as quickly and as safely as we can to restore supplies and apologise for the continuing inconvenience and disruption this power cut is causing. Work to restore electricity supplies has now reached the stage where we are able to supply some electricity to Anytown. We are going to temporarily restore supplies of electricity to Anytown customers on a rota basis until repairs are completed. This rota will allow all customers to have electricity supplies on a fair basis for periods of three hours in every twelve hours from now on until all repairs are completed.
- When you have electricity please conserve energy where you can, switch off unnecessary lights and appliances to prevent overloading of the temporary supplies.
- If power is out in your area:
  - Unplug sensitive equipment to avoid damage
  - Unplug any heat-producing appliances to reduce fire risk
- If power has been restored in your area:
  - Don't turn on all appliances at once
  - Wait 10 to 15 minutes before turning on appliances and electronics
- It is advisable not to restock freezers until we let you know that all repairs are completed.

Electricity Failure – Rota Disconnections (2)

- Today's rota:
  - From 06:30 to 09:29 we will be able to supply electricity to the Western district of Anytown.
  - From 09:30 to 12:29 we will be able to supply electricity to the Eastern district of Anytown.
  - From 12:30 to 15:29 we will be able to supply electricity to the Northern district of Anytown.
  - From 15:30 to 18:29 we will be able to supply electricity to the Southern district of Anytown.
  - From 18:30 to 21:29 we will be able to supply electricity to the Western district of Anytown.
  - From 21:30 to 00:29 we will be able to supply electricity to the Eastern district of Anytown.
  - From 00:30 to 03:29 we will be able to supply electricity to the Northern district of Anytown.
  - From 03:30 to 06:29 we will be able to supply electricity to the Southern district of Anytown.
- Tomorrow's rota:
  - From 06:30 to 09:29 we will be able to supply electricity to the Southern district of Anytown.
  - From 09:30 to 12:29 we will be able to supply electricity to the Western district of Anytown.
  - From 12:30 to 15:29 we will be able to supply electricity to the Eastern district of Anytown.
  - From 15:30 to 18:29 we will be able to supply electricity to the Northern district of Anytown.
  - From 18:30 to 21:29 we will be able to supply electricity to the Southern district of Anytown.
  - From 21:30 to 00:29 we will be able to supply electricity to the Western district of Anytown.
  - From 00:30 to 03:29 we will be able to supply electricity to the Eastern district of Anytown.
  - From 03:30 to 06:29 we will be able to supply electricity to the Northern district of Anytown.
- The times shown in the rota are approximate. We'll try to switch the supply off and on as near as possible to them, but we may have to change them for safety or operational reasons.

ANYTOWN WORKSHOP STEP 2

Complete failure of the water supply from Anytown Water Treatment Works

About Water

- Water is fundamental to life – every plant and animal needs it to live
- The human body is 70% water, the brain up to 85% water
- A person can live for weeks without food, but only days without water
- Water is not only used for drinking, but for preparing and cooking food and for hygiene purposes in and around the home
- It is also used watering gardens, cleaning, agriculture, power generation, recreational purposes, industry and more

The Water Cycle

Anytown Water Network

- Water is pumped from source to Anytown water treatment works to be cleaned and disinfected
- It is transported across Anytown in large diameter mains which are called Trunk or Transfer mains
- Smaller, distribution mains carry water from local storage reservoirs to streets
- Supply pipes transport water from streets to individual properties in Anytown

Anytown Water Network (2)

- Anytown Water company is responsible for the supply network up to the boundary of the property. Beyond that point it is the responsibility of the customer
- Water supply is heavily dependent on electricity for pumping generally and specifically to Anytown's higher elevation locations

Anytown Water Network (3)

- Should the mains water supply fail, water companies must have plans in place to provide water by alternative means (bottles / static tanks / tankers)
- A minimum of 10 litres of drinking quality (Potable Water) will be provided per person per 24 hour period
- The size of the population water companies must plan for varies but a generic figure could be 15,000 people within 24 hours and 25,000 within 3 days
- An outage to larger populations would constitute a civil emergency, and would lead to a multi-agency response
- Bottled water may only be provided to vulnerable people. This could include nursing homes.
- The general public would be expected to collect water from collection points in their own vessels. This water would need to be boiled.
- Hospitals should have their own business continuity plans but they may be supported by tankers

Initial Water Supply Failure

- Day: Monday
- Time: 10:00
- Incident: Complete failure of the water supply from Anytown Water Treatment Works

- Task: What are the **most likely** immediate impacts of water failure for a **generic** organisation such as yours; and the infrastructure you are responsible for?

Water Supply Failure + 1 Hour

- Day: Monday
- Time: 11:00
- Duration of Water Supply Failure: 1 hour
- Statement: *Customers in the Anytown area may be experiencing an interruption to their water supply or low pressure. Our engineers are on site and working to resolve the problem. We expect water supply services to be restored to normal within the next 3 hrs.*
- *We are very sorry for any inconvenience that this disruption to service may have caused.*

- Task: What are the **most likely** actions that a **generic** organisation such as yours will take at this point? What risks can you identify/highlight at this stage?

Water Supply Failure + 4 Hours

- Day: Monday
- Time: 14:00
- Duration of Water Supply Failure: 4 hours
- Statement: *Customers in the Anytown area may be continuing to experience an interruption to their water supply or low pressure. Our engineers are on site and working to resolve the problem. We expect water supply services to be restored to normal* ***within the next 18 hours****.*
- *We are very sorry for any inconvenience that this disruption to service may have caused.*

- Task: What are the **most likely** actions that a **generic** organisation such as yours will take at this point? What risks can you identify/highlight at this stage?

Water Supply Failure + 22 Hours

- Day: Tuesday
- Time: 08:00
- Duration of Water Supply Failure: 22 hours
- Statement: *Customers in the Anytown area may be continuing to experience an interruption to their water supply or low pressure. Our engineers are on site and working to resolve the problem. We expect water supply services to be restored to normal* ***within the next 24 hours****.*
- *We are very sorry for any inconvenience that this disruption to service may have caused.*

- Task: What are the **most likely** actions that a **generic** organisation such as yours will take at this point? What risks can you identify/highlight at this stage?

Water Supply Failure + 46 Hours

- Day: Wednesday
- Time: 08:00
- Duration of Water Supply Failure: 46 hours
- Statement: *Customers in the Anytown area may be continuing to experience an interruption to their water supply or low pressure. Our engineers are on site and working to resolve the problem. We expect water supply services to be restored to normal* ***by 10:00 Saturday*** *.*
- *We are very sorry for any inconvenience that this disruption to service may have caused.*

- Task: What are the **most likely** actions that a **generic** organisation such as yours will take at this point? What risks can you identify/highlight at this stage?

ANYTOWN WORKSHOP

Next Steps

Next Steps

- What we need from you
  - Completed feedback forms as you leave
  - Any other comments by next week
- What we'll be doing next
  - Synthesise comments from today and tomorrow
  - Project report prepared by 31 March
  - Future development

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Annex C – Workshop Attendance

Wed 20 Feb 2013

Table	Participants
Climate and Environment	8
Emergency Services	7
Transport and Telecoms	8
Health	7
Local Authority and Business	7
Health, Voluntary and Military	7
Telecoms	7
Sub Total	**51**

Thurs 21 Feb 2013

Table	Participants
Climate and Environment	8
Emergency Services and Military	7
Transport and Telecoms	8
Health	7
Local Authority and Business	8
Health and Voluntary	7
Health	7
Sub Total	**52**
Anytown Workshops Total	**103**