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Simple Critical Infrastructure Maps

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SCIM

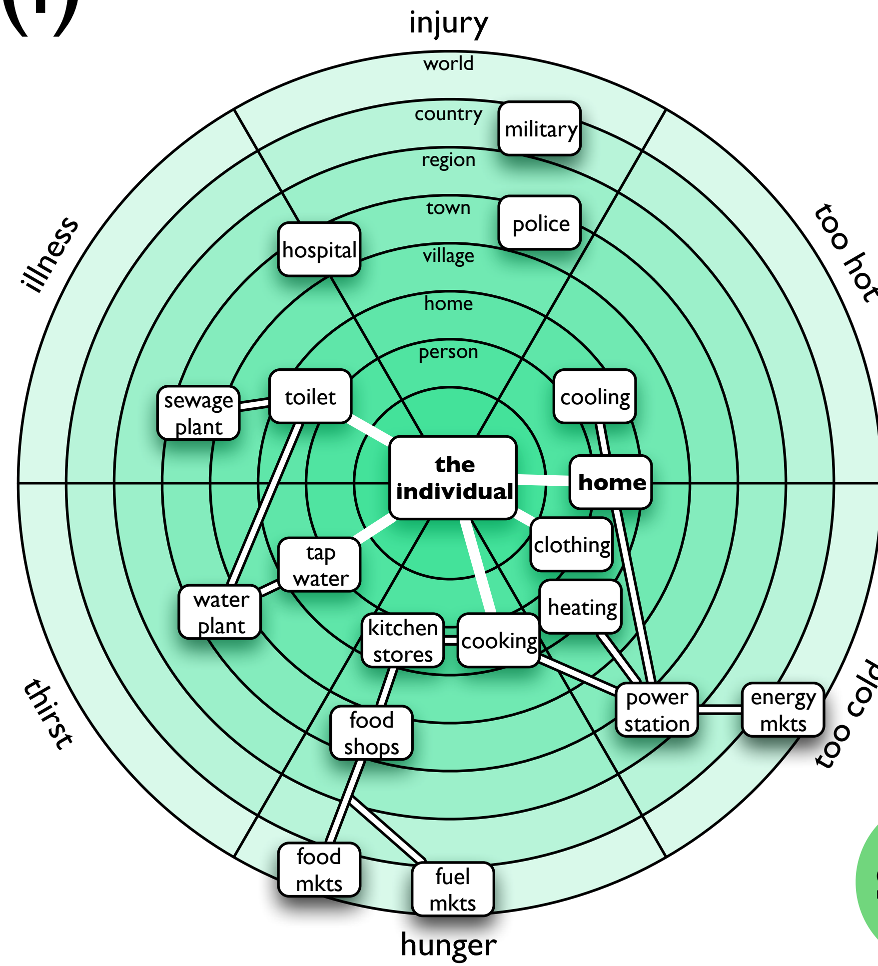
SCIM diagrams (i)

SCIM is a tool for understanding infrastructure resilience in crises.

The *individual* level SCIM diagram, to the right, lets a person map the basic infrastructure systems which are keeping them alive. It maps the *six ways to die* to the various services which mitigate those risks in daily life.

A detailed version of this diagram would include fuel and transport infrastructure, the water and electrical grids and many other details.

Services which are provided nearer to the center of the diagram - closer to the individual level - are typically more robust, as are those with less external dependencies.



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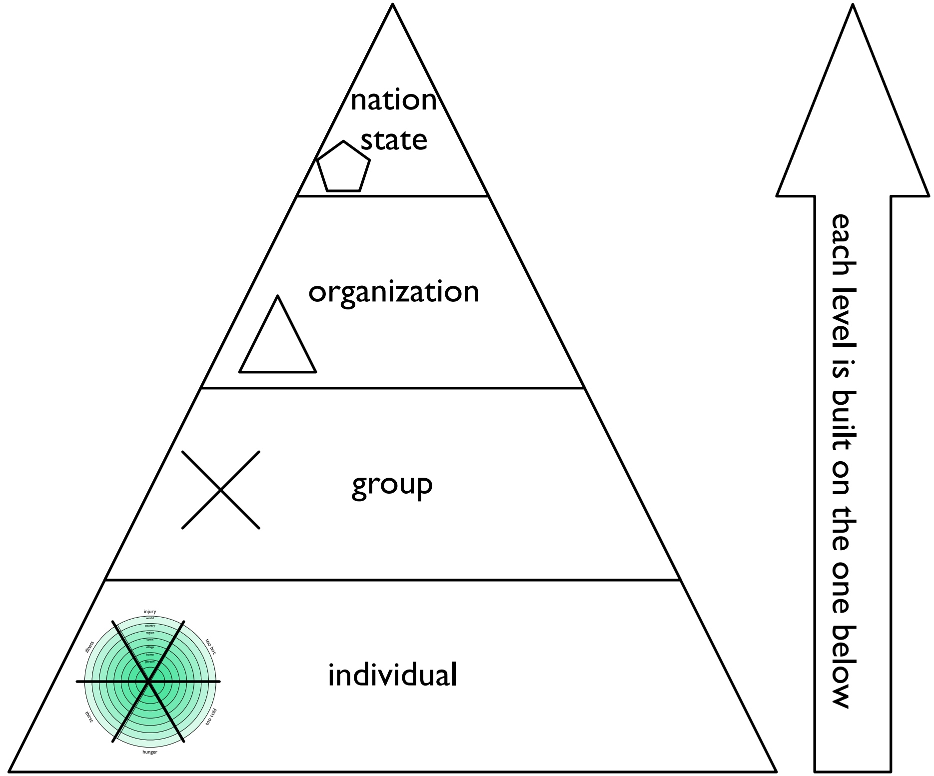
SCIM diagrams (ii)

Infrastructure does not stop at supporting the health of individuals. In the same way that there are a set of basic survival needs for people, there are basic survival needs for groups, organizations and even countries.

A group is formed of individuals. It requires all the same infrastructures that an individual requires, plus a group has additional needs which may also require infrastructure to support them. Organizations are special kinds of groups, and they have additional needs. We will term these needs "infrastructure" because it aids planning but the term is being used loosely.

Finally we will examine the nation state and its "infrastructure."

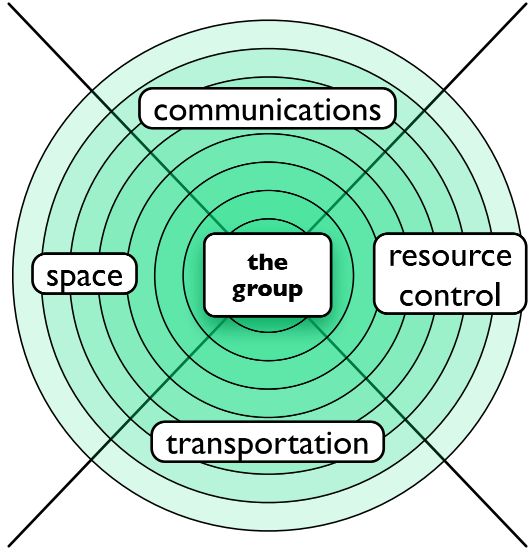


SCIM diagrams (iii)

A *group* is any collection of people. It could be as few as two. Typical groups include families, fellow travelers on a bus or a plane, or any social group.

Groups have complex psychology related to inclusion and exclusion and degrees of allegiance to one group or another. A lot has been written and learned about those matters, and they are beyond our scope here.

However, the simple physical requirements for a group to exist are generally fairly similar. Most groups require these needs to be met to exist and function, requiring additional infrastructure like offices, cell phones, transportation networks and so on.



Each sector represents one area of need. Most groups require function in all areas to continue to exist, although certain groups may be very decentralized or rely entirely on face-to-face meetings.

1. Communications
A group has to be able to pass messages (voice, phones, mail, sms) or it cannot act together.

2. Space
Most groups need places to physically gather, from an office for a company to the local cafe for a set of friends.

3. Transportation
Groups that do not simply stay in one place need to have members leave to do things and return. Walking counts.

4. Resource Control
Shared resources have to be used in a way that lets the group continue to exist.

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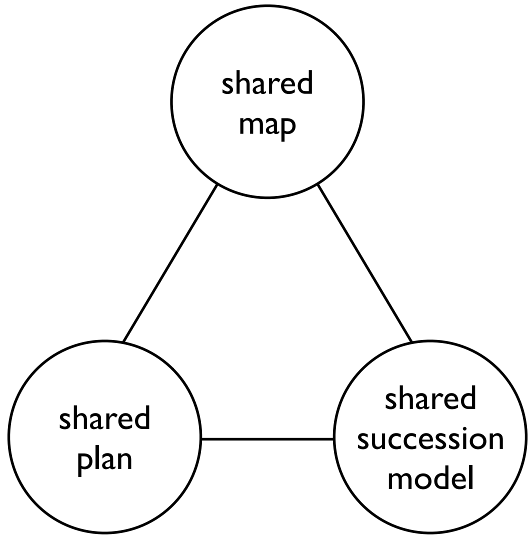
SCIM diagrams (iv)

An *organization* is a special kind of group. Organizations have a purpose beyond the combined purposes of the members. Hospitals, police forces, fire brigades, armies, schools and so on are all examples of organizations.

An organization has all the needs of a group, plus three pieces of "social infrastructure."

This kind of "social infrastructure" is conceptual matter that underlies certain essential functions the organization needs to function.

On a more practical level, organizations often have specific technology needs - electricity to power computers, for example.



A group which has these three additional features can be considered to be an organization, whether or not it has a name or is recognized as one before the crisis begins. In the US, church groups often go through this transition.

1. Shared Map
The people in an organization must share a map of reality - their responsibilities, environment of operation and so on. Some fraying is acceptable, but not much.

2. Shared Plan
Within the context of a shared map, there must be a shared plan, subject to the diffusion of power and responsibility within the organization.

3. Shared Succession Model
Most importantly, if the current leadership of an organization is not performing, there must be a shared model of how to select new leaders. This can be critical in times of urgent crisis.

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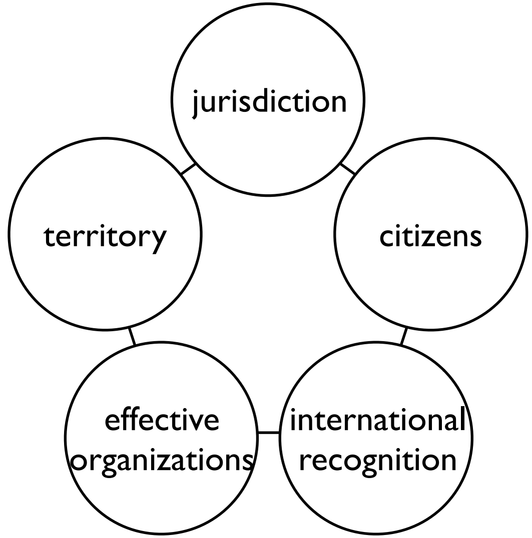
SCIM diagrams (v)

A *nation state* or government is a special kind of social organization which carries vast responsibility and authority. Specific systems and technologies are required to keep a nation state running smoothly. Most of these systems are identical with those required for organizations of other kinds (for example, electrical power and an electoral process.)

Certain kinds of crisis - civil wars, particularly - call into question the infrastructure of state. Inability to identify citizens can lead to drastic problems. Getting clarity on who has jurisdiction over which territories can be another challenge. These functions and others are carried out by the arms of state (police, military and so on) which must be effective organizations in their own right.



These five features of the state loosely define a geographical region (a defined territory) and a list of persons who are under the jurisdiction of that territory. International recognition then follows in most cases.

1. Jurisdiction
The state must provide an effective system of law and law enforcement.

2. Citizens
Certain individuals are citizens of the state, while others are simply visitors. The state must know.

3. Territory
There must be an agreed area in which the state has control.

4. Effective Organizations
Without these, the government cannot do anything.

5. International Recognition
Typically required for meaningful sovereignty.

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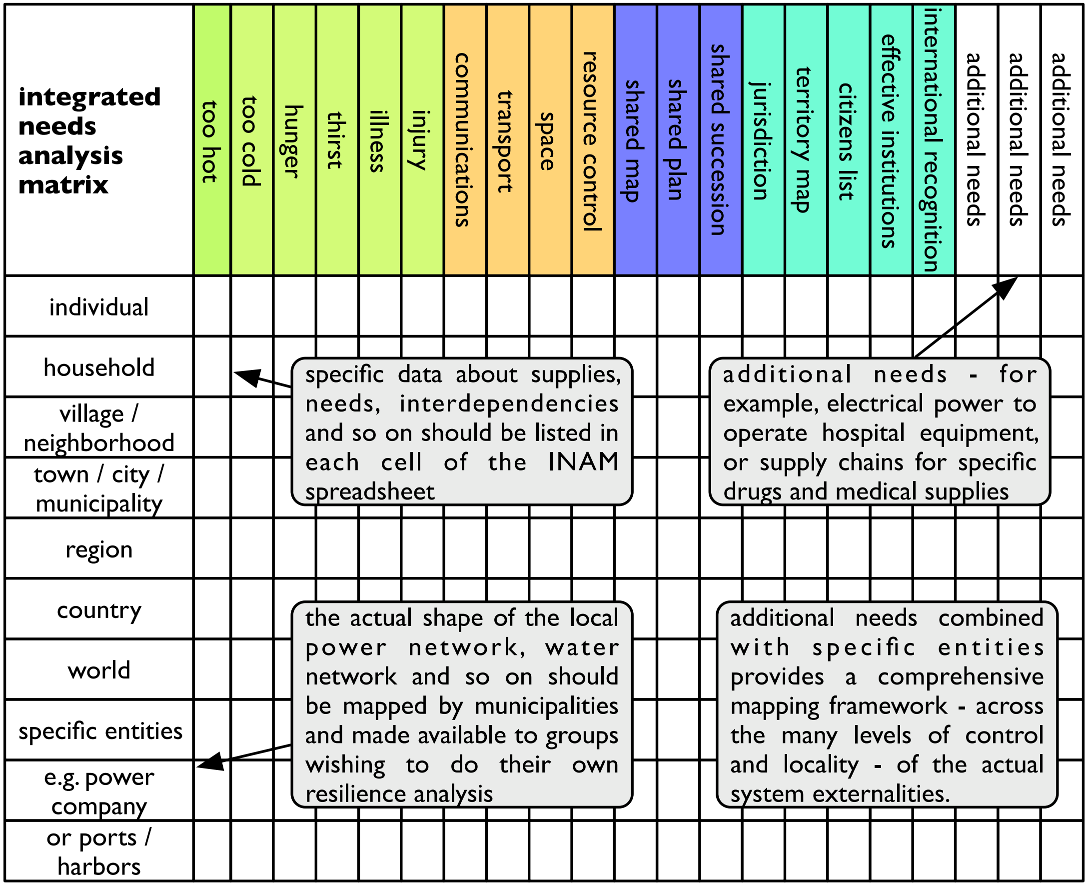
Integrated needs analysis matrix



Simple critical infrastructure maps combine to map, for a given individual, group or situation which critical resources are coming from which institutions and levels of government. For example, a hospital is relying on local police to protect against some kinds of injury risks, on the local power company to provide mains electricity, and on a diesel backup generator and the diesel supply chain for additional power.

These matrices can grow quite large when filled in with accurate information about a given situation, particularly when interdependence is taken into consideration - the power and water companies depend on each other in many cases, for example.

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What is infrastructure?

Unless you are a professional in the infrastructure field, infrastructure's number one job in your life is to be invisible.

The system of pipes and wires which lets your toilet flush and your lights shine, which powers the computer and the stove, is intended to function perfectly 365 days each year, 24 hours each day.

Relatively short outages draw our attention. A quarter second power outage loses work on our computer. A two day water problem due to a burst pipe feels like a return to the medieval age. Infrastructure is universal, invisible and frequently very, very expensive and difficult to repair.

Let's count the infrastructure systems which are in the building you live in. Depending on where you live the exact set of systems you depend on changes, but we will look at the basic set.

Electricity comes from distant generation factories and is carried over a fragile grid.

Drinking water comes from a reservoir or well, and is purified in another factory and piped to you.

Sewage is carried away over a separate system of pipes.

Natural gas, storm water, communications including internet fill out the basic package.

The most essential function of infrastructure is to protect us from the hazards of the natural environment. Heating our homes, providing us with safe water to drink and carrying waste are the most basic functions of the infrastructure systems around us.

Other functions, like providing electrical power to machines and light are primarily quality of life improvements which compliment the basic health-protection services which infrastructure generates.

Infrastructure is a public health system. It is from this perspective we will examine it further.

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Provision, cost and quality (PCQ)

Infrastructure generally has three possibilities. They are:

1. Provision
To make a service (like electricity) available where it was previously unavailable.

2. Cost
To reduce the cost of a service relative to other ways of providing it, like centralized water vs. local wells.

3. Quality
To improve the quality of a service, such as by providing pure water rather than river water.

Good infrastructure makes services seem totally reliable, cheap and perfect. Bad infrastructure is patchy, expensive and of poor quality.

Making essential services like electricity cheap and reliable has very strong economic effects. If every business had to operate a diesel generator during its hours of operation, things would be much more expensive. The air would be filled with smoke, and junk yards would fill with obsolete diesels.

By *centralizing* energy generation, certain kinds of efficiency are created. Coal-fired power stations cause far less pollution than local diesel generators do. Many high-tech power stations working together produce ultra-reliable grid service.

But to get this cheap electricity is very, very expensive. The investment in systems is huge. These costs are met with large, strong economies.

This reduction in service cost by centralization is an example of *economies of scale*. Water, electricity, sewage processing, natural gas provision, even transportation systems like roads and rail have typically been centralized to emphasize the ability of centralized infrastructure to cut the cost of essential services.

In distressed environments, quality is noticed more than cost. Failures in centralized infrastructure expose people to bad drinking water which makes them sick.

Infrastructure failures are usually rare.

Six ways to die (6WTD)

There is a simple way to understand how infrastructure protects health. There are six basic ways in which people die.

1. **Too Hot**
2. **Too Cold**
3. **Hunger**
4. **Thirst**
5. **Illness**
6. **Injury**

In the developed world, nearly all death is from illness or injury. Ordinary diseases like heart disease and ordinary accidents like car crashes are responsible for nearly all death. Injury from violence is rare.

In the developing world, death from hunger and exposure to climate is more common.

Infrastructure affects all of these "six ways to die." There are three basic groupings:

Shelter
protects from Too Hot and Too Cold

Supply
protects from Thirst and Hunger

Safety
protects from Illness and Injury, including security, medical and public health / sanitation services

Transportation, cheap energy, total access to clean drinking water and sanitation, low cost food and many other factors combine to push these basic modes of mortality to very low levels in the developed world.

In the developing world, all of these threats are elevated by a combination of poor physical infrastructure, poverty, and in some areas social instability.

In a crisis in the developed world, in most cases, the short pressures there are put on infrastructure systems do not threaten anyone's life. However, in more severe times of crisis, or in developing world disasters, infrastructure failures can be just as dangerous as the original disaster. Water and sanitation issues are particularly dangerous.

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Who owns infrastructure?

As previously noted, infrastructure is expensive. Making a service like electricity available can be very expensive. One approach to reducing those costs is to build big, efficient systems like power stations. But this requires a large organization to raise the capital required to construct the system, and a long period of stability to pay for it.

Part of the success of the developed world is that it has successfully financed and deployed complex infrastructure systems, making basic services like electricity available, cheap and near-perfect. Every infrastructure service has one or more operators and owners.

Understanding this is critical to knowing infrastructure deeply.

The ownership arrangements around essential services like electricity are often fiendishly complex mixtures of market relationships, law and governance.

A typical arrangement is something like this. A government generates a contract to provide services, operate sections of a national grid. Companies bid to operate local power stations and sell power into the grid. Quality and standards are sometimes set by professional bodies which are not bound to any given nation state. These, plus fuel contracts, transportation contracts, health and safety regulations, anti-trust laws and so on comprise the complex system of ownership which lets you turn on a light switch.

In general, however, there are seven basic levels of infrastructure ownership. They are:

1. **Individual**
2. **Household**
3. **Neighborhood / Village**
4. **Municipality / Town / City**
5. **Region**
6. **Country**
7. **International**

So, for example, often cities own their own water purification systems. Many countries are part of international electrical grids. Household infrastructure is things like solar panels or the very existence of a toilet.

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Centralization and decentralization

Much of the infrastructure we take for granted is highly centralized. One power plant provides energy for half a million people. A grid then farms out this centralized service to the people. Reliability comes from many similar cells all connecting together.

This centralization comes at considerable cost. Although a single large infrastructure resource of this kind can power an entire town, it can take many, many years to build and as long as 30 years to pay for itself. If there is a system failure, the large, single point of failure must be repaired quickly. The cost of maintaining ultra-reliable centralized systems can be very high.

But in stable times, these systems produce incredibly cheap services.

Decentralized infrastructure is the wave of both the past and the future. Old decentralized systems were things like water mills and pit latrines - systems which ran directly from the natural world to provide basic services.

New decentralized infrastructure is systems like advanced composting toilets, solar panels, local water purification like SODIS or SOPAS, wind energy and so on. Note that many decentralized energy systems can be tied together in a grid configuration but it is not always necessary or profitable to do so.

These systems can be purchased a few at a time, upgraded individually and are often quite reliable because they are redundant.

From an infrastructure mapping point of view, the critical distinction between centralized/decentralized systems is *dependencies*. Centralized systems typically have large and complex networks of requirements to operate, but operate at high efficiency. Whether the input is fuel or chlorine or spare parts, it seems that in general the cost of efficiency is complex dependencies.

Decentralized systems typically have few dependencies or none at all, and what dependencies exist are often simple (lubricating oils or distilled water.) This often makes decentralized systems much more trustworthy in a crisis.

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Moving services around

There are four basic ways that services reach end users.

1. **Generate** on site (solar)
2. **Grid** services (power, water)
3. **Deliver** (water, gas)
4. **Fetch** (food, batteries)

Consider drinking water. It can be made available in all four ways.

1. A well can generate it on site.
2. Grid water can come from the tap
3. A truck can deliver water
4. People can bring the water from a well or river nearby, or buy it in a supermarket. Shopping is the usual model for "fetch" in the developed world.

Not all essential services can be created using all four systems.

Natural gas, for example, is seldom generated on site, except in the case of biodigesters. But it can come from the grid, delivery, or fetch methods.

Electricity, on the other hand, can be generated on site using solar, wind or microhydro but is very hard to deliver or fetch except in small quantities using batteries.

Systems which rely on inputs which can be deliverer, stored or fetched are usually more robust than those which are reliant on only grid options. Electricity requires either local renewable generation capacity, or use of diesel generators which convert what can be moved (diesel) into what cannot (electricity) on site.

Keeping essential services available to people in a crisis can require careful thinking about what is essential, and skillful substitution of what is available for what is not.

Local resources must replace resources from the grid. Resources which can be delivered or fetched can be stockpiled in case of supply interruptions. Specific devices, particularly diesel generators, can convert what is available and storable into what is difficult to find. Substitutions like using composting toilets or even basic latrines rather than flush toilets can conserve scarce water resources, if used with care. There is a lot of flexibility.

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Threats to infrastucture

There are six typical "threats" to infrastructure systems. These stresses are not all external.

1. Time and wear
The mechanical components of all infrastructure systems age and break down. Some parts must be replaced every year, others (like sewer pipes) can last hundreds of years.

2. Neglect
Without proper maintenance, including but not limited to repairing time and wear, infrastructure systems fail.

3. System Externalities
Some infrastructure systems need inputs from other systems to operate. For example, power plants need fuel.

4. Operators
Infrastructure systems require skilled operators to run and maintain them. In situations where many people are sick this can cause real problems.

5. Economics
Maintaining and operating infrastructure systems is expensive. Under typical circumstances costs pay for themselves by making essential services available, cheap and reliable, but under tough circumstances there may not be enough money to operate them.

6. Violence
Both terrorism and war often target infrastructure as a way of impacting many people easily.

In the event of failure, infrastructure systems cease to operate. This has three effects:

1. Services become unavailable (provision.)

2. Service prices rise steeply (cost.)

3. Service quality drops, such as dirty water, unreliable electricity and so on.

These changes can have effects ranging from inconvenience through to widespread death. It depends on the degree to which an area requires infrastructure to keep people alive and society stable.

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