Foreign & Commonwealth Office

Disaster Proofing Indian Smart Cities

CLIMATE RESILIENCE OF DIGITAL INFORMATION TECHNOLOGY

ARUP

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This project was conceptualised as a way to share UK technical and design expertise to support the climate resilience of towns and cities in India that are entering India's 'Smart Cities Mission'. India is prone to multiple geological and climatic hazards and as part of the Smart City process Digital Information Technology (DIT) will be deployed widely across a number of towns, cities and states that are located across the many climatic and geological zones of India.

Within cities a key function of DIT will be to ensure 'life-line' functions such as emergency health services, disaster response units continue to function uninterrupted and effectively. Under conditions such as floods, cyclones and extreme heat - DIT itself needs to be robust in order to perform its designed critical function. While the key components of DIT (such as the electronics) are designed for operating in a wide range of weather conditions, the individual components as well the 'systems' are still vulnerable to impacts from weather extremes. This climate performance of systems and components is not always clear to cities and town when they procure DIT.

Such risks to DIT over the full life-cycle need to be planned for its context and mainstreamed within the policy, procurement, design and operations thereby sustaining the confidence of institutions, citizens, investors and manufacturers. Many smart cities that are looking to attract investors and investment will want to ensure that critical and emergency services can withstand climate extremes and any disruption to society and economy is minimised.

As part of this project we have engaged with a number of cities and one of the main outcomes is this guidance document on climate resilience of DIT. We hope, this will be helpful to Smart City planning and procurement teams when selecting and purchasing DIT, particularly for emergency services. It can also be used by those who are developing and innovating products and services for Indian Smart Cities as they will benefit from a targeted overview of what is an appropriate product or service for Indian climatic conditions. We hope to share this guidance widely and continue to update it based on user feedback and changing technology or innovation.

We have focussed on Kakinada and Indore (two cities in different climatic zones) where we received excellent interest, engagement and support from city officials. The guidance can also be a useful for other cities looking to ensure they develop climate resilient emergency services in Smart Cities and the life and work in these cities can go uninterrupted and investment is safe and productive.

We would like to thank the UK Foreign and Commonwealth Office 'Prosperity Fund' for commissioning this project as well as UK Department of International Development (New Delhi) for their enthusiasm for UK expertise to support a key development outcome of reducing risk in Indian Smart cities and enhance climate resilience.

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About this document

In preparing this report, we have drawn upon our experience of specifying Digital Information Technologies (DIT) projects for procurement and deployment, and have looked at potential natural hazards related to climate change, especially those which are projected to increase in frequency and intensity due to climate change.

We think it is important to define what we understand by natural hazards and natural disasters as these are terms that will be used throughout the report:

- Natural hazards are naturally occurring physical phenomena caused either by rapid or slow onset events which can be geophysical (earthquakes, landslides, tsunamis and volcanic activity), hydrological (avalanches and floods), climatological (extreme temperatures, drought and wildfires), meteorological (cyclones and storms/wave surges) or biological (disease epidemics and insect/animal plagues). [1]

- A natural disaster is a sudden, calamitous event caused by a physical phenomenon that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources.

  A disaster occurs when a hazard impacts on vulnerable people. The combination of hazards, vulnerability and inability to reduce the potential negative consequences of risk results in disaster.[2]

  (VULNERABILITY + HAZARD) / CAPACITY
  = DISASTER

From our meetings with city and state officials in India, we have developed an outline understanding of several DIT procurement projects currently underway, including as part of the Smart Cities agenda in Kakinada and Indore; the World Bank-funded National Cyclone Risk Mitigation Project (NCRMP) in coastal Andhra Pradesh; and the development of the new city infrastructure in Amaravati.

This report provides -

- Definitions of DIT infrastructure, systems, services, and components. (Section 2)
- Information on the climate context of India, focussing on Kakinada and Indore. (Section 1)
- Thoughts on the challenges faced in procuring DIT. (Section 3)
- Exemplar clauses and other content for inclusion in performance specifications for Digital Information Technology infrastructure (DIT) in India (Section 4), and a summary checklist. (Section 5)

1. www.ifrc.org/en/what-we-do/disaster-management/about-disasters/definition-of-hazard/

2. Based on www.ifrc.org/en/what-we-do/disaster-management/about-disasters/what-is-a-disaster/

1. Introduction

Natural disasters, triggered by natural hazards related to climate, can occur anywhere in the world, sometimes with limited notice and unexpected consequences. Whenever they occur, the local and national authorities, civil society, the general public and the critical emergency services will rely on Digital Information Technology (DIT). Therefore, DIT must be specified, procured, installed and operated so as to maximise the likelihood that critical functions continue during the disaster event.

1.1 Reliance on DIT

DIT is used at every stage of a natural disaster. If the entire process of disaster management is broken down into four stages, the impact of DIT on each can be considered:

- **Normal Conditions** – During normal conditions, DIT is relied upon to carry out functions preparatory to a natural disaster response. For example, for the maintenance, communication and coordination of contingency plans between the agencies. DIT plays a role in exercises and drills. To prevent climate hazards such as floods and cyclones, becoming natural disasters, weather prediction and early warning systems rely on DIT such as weather sensors, computing resources, and communications networks, which can be dispersed over a wide geographic area. If an early warning system fails during the onset of a climate hazard, the response will be delayed, and opportunities to mitigate the impact and prevent a natural disaster will be lost.
- **Crisis Management** – at all stages of crisis management, communications between teams of emergency services are essential. The responders will need to be appraised of developments – perhaps the road networks are disrupted by evacuations or physical damage; perhaps the weather conditions are expected to worsen. Those coordinating the response need to be kept informed of the disposition of available assets- where the ambulances and sandbags are; how many emergency services personnel are available for duty; where are the populations most at risk of harm? Keeping this information up-to-date and sharing it with those who can act upon it will enviably rely on DIT – to relay information to the emergency services, to receive situation reports and to provide timely advice to the population.

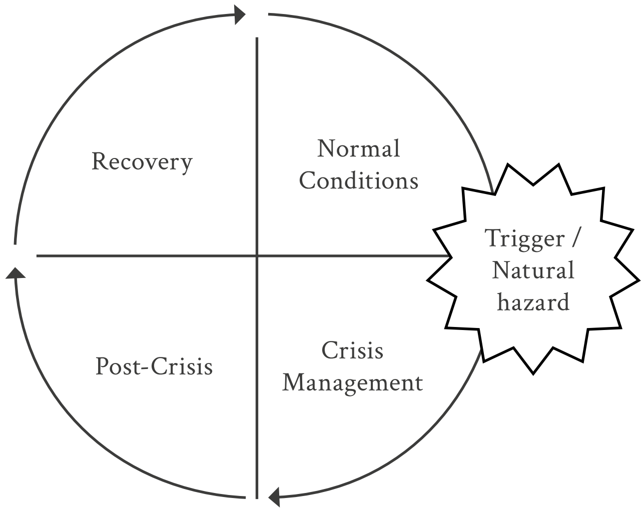


Figure 1.
Disaster Management Cycle (Interpreted from: VOLO 2009)

- **Post-Crisis Management** – as the crisis abates, DIT will be relied upon to gather, interpret and share information on the conditions in the region. Where has the civil infrastructure been destroyed? Where have conditions returned to normal? During this phase, the need for coordination and information sharing continues, potentially between more parties as external aid agencies and relief resources may become more available.
- **Recovery and return to Normal Conditions** – The process of rebuilding, restoring and rehabilitating a community following an emergency or disaster also requires DIT.

In summary, degraded DIT capabilities may paralyze official responses, challenge containment efforts and delay mobilisation of relief and recovery efforts where most urgently needed.

1.2 Susceptibility of DIT

All DIT systems and services rely on physical infrastructure. Nodes like server rooms, antennas and masts, telegraph poles; and links like buried cables, two-way radio networks and broadcast networks are all subject to damage or destruction. When physical infrastructure is damaged, the services they provide are disrupted or degraded. If the physical infrastructure avoids damage, the services may still be placed under strain - each system has a finite capacity, probably sized for normal conditions.

Some examples of events in which climate hazards have impacted DIT infrastructure, systems and services are summarised in Table 1 below.

Within the Smart City Context, it is possible to develop a bespoke metric within the ISO 37120 framework, which measures the resilience to natural disasters arising from climate change. The impact of a DIT intervention on the city's overall level of resilience could then be assessed.

Chennai floods, India 2015	Flooding affected Chennai, coastal Andhra Pradesh and neighbouring areas. Rainfall levels of over 260mm (Chennai airport) and 370mm (Ponneri) were recorded. Severe damage to telecoms infrastructure, lasting many months, prolonging the recovery processes. Bharti Airtel, Idea Cellular and Vodafone India were all affected[3], largely by power cuts and damage to mast structures[4].
Gujarat floods, India 2006	Flood waters peaked at over 6m. Severe damage to electricity and telecoms lines hampered recovery[5].
Indian Ocean Tsunami, 2004	Coastal areas of the Indian Ocean were devastated by Tsunami floods. Areas with best telecoms infrastructure had lowest loss of life, since warnings could be received and some evacuations could take place[6].
Hurricane Katrina, USA 2005	Flood control levees were destroyed, allowing the inundation of large areas of New Orleans. The combination of physical damage (affecting 2000 mobile cellular masts, fixed-line conduits and switching centres) and dramatically increased telephone call volumes – meant that there was no 911 capacity in some parishes for weeks.[7]
West Bengal Drought, 2016	Lack of water leads many power plants to shut down, preventing many communications systems from functioning[8]. Temperatures of 45°C were sustained.

Table 1.
Examples of events in which climate hazards have impacted DIT infrastructure, systems and services

3. Mankotia and Parbat, 2015

4. Indian Express, 2015

5. Bhat, 2013

6. Moss and Townsend, 2005

7. Miller, 2006

8. Burton and Fernandes, 2016

1.3 Climate Variability

India comprises a range of climate zones and is prone to multiple climate hazards. These hazards, when they occur, can result in loss of lives and significant economic damages and disruption. If not adequately planned for and responded to, climate hazards can become natural disasters. Climate change is projected to increase the frequency and intensity of climate hazards and extreme weather events which, if not monitored and prepared for, will cause increasing levels of damage and disruption, particularly in cities. DIT itself must be resilient to the climate hazards they will be exposed to. For example, under conditions such as floods, cyclones and heat waves, it is critical that 'life-line' functions such as emergency health and information and communication services continue to function uninterrupted and effectively in order to prevent a climate hazard becoming a natural disaster.

Climate is an important framework for understanding the risk context as per the international risk management standard ISO 31000 and influences the DIT. The two must remain aligned over time, so it is important a regular review is undertaken to ensure the DIT remains sensitive and responsive to climate changes and their influence on natural disasters.

Climate profiles have been developed for the two cities of interest in this project; These cities are under development as 'Smart Cities' and have different climate characteristics. Kakinada, a coastal city in the state of Andra Pradesh in the East of India, and Indore, an inland city in state of Madhya Pradesh in central India, see Figure 2.

These profiles have identified the climate hazards that need to be monitored in each city and for which appropriate preparation and response plans should be developed to reduce the risk of natural disasters. In addition, these climate profiles should be used during the procurement process of DIT to ensure that the technology selected is resilient to the key climate hazards to which cities are prone.

Figure 2.
Map showing the location of the two cities of focus, Indore and Kakinada. The map highlights areas India that are prone to different types of climate risks

9. http://habitatindia.in/disaster-response/disaster-in-india/

1.3.1 Kakinada Climate: Summary Profile

Table 2 summarises the collected baseline and future climate data for Kakinada. Additional information on the climate profiles for Kakinada can be found in Appendix A.

Climate variable characteristic			Baseline 3	2020s	2050s	2080s
Temperature	Mean temperature	September-February mean temperature (°C)	27.2	This data was not collected.	This data was not collected.	This data was not collected.
	Extreme temperature	March-August mean temperature (°C)	30.7	**31.3 (31.2 - 31.5)[i]** 31.2 (s31.4-31.6)[ii]	31.7 (32.0-32.3)[i] **32.2 (32.5-32.8)[ii]**	32.0 (32.3 - 32.9)[i] **33.3 (33.9 - 34.7)[ii]**
		Annual average maximum daily temperature (°C)	43.6	44.6 (43.9 – 45.8)[ii]	45.8 (45.0 – 57.0)[ii]	47.7 (46.2 – 49.3)[ii]
		Maximum recorded temperature (°C)	56	It is likely that the number of days with extreme temperatures will increase.		
Humidity	Annual average humidity		72%	Data for future seasonal and diurnal variation has not been considered in this study.		
	Annual average maximum humidity		95%			
Wind	Maximum wind speed		47.8 m/s	There is considerable uncertainty in climate change projections for future wind speeds and direction. A number of studies show statistically insignificant variations in wind speed. Hence, major changes are not anticipated in mean wind speeds and directions.		
	Average wind speed		1.8 m/s			
Sea level	Sea level rise (m)		Current sea level was not obtained during this work. Maximum wave heights of up to 3m have been recorded in the past.	0.061 m 0.062 m	0.231 m 0.262 m	0.331 m 0.422 m
Precipitation	Mean precipitation	Winter (December, January, February) monthly average precipitation (mm/month)	18.3	**18.6 (15.8 – 20.2)[i]** 18.3 (17.2 – 21.5)[i]	19.0 (16.7 – 21.6)[i] **20.0 (18.1 – 22.3)[ii]**	20.2 (17.5 -24.3)[i] **22.7 (18.7 – 27.2)[ii]**
		Summer (June, July, August) monthly average precipitation (mm/month)	180.0	**185.6 (171.5 – 193.5)[i]** 183.0 (171.5 – 195.7)[ii]	191.1 (172.9 – 208.4)[i] **195.5 (179 – 219.4)[ii]**	197.3 (178.4 – 213.8)[i] **209.5 (186.8 – 257.2)[ii]**
		Average monthly precipitation during wet season (June-November) (mm/month)	200 (monthly precipitation can exceed 600 mm at times)	Future data was only collected for the months DJF and JJA. The wet season is from June to November so we are not able to provide specific values for future precipitation in this period. We would expect it to be similar to the summer projections.		
	Low precipitation	Dry spells (10+ days with no precipitation)	97 days	103 (83 -114)[ii]	101 (73 – 123)[ii]	106 (86 – 124)[ii]
	High precipitation	Heavy precipitation (>20 mm/day)	16 days	16 (14 – 19)[ii]	17 (16 – 20)[ii]	18 (15 – 26)[ii]

Table 2.
Kakinada climate profile summary

i. Based on Representative Concentration Pathway 4.5 (RCP4.5) – this represents a medium greenhouse gas emission scenario

ii. Based on Representative Concentration Pathway 8.5 (RCP8.5) – this represents a high greenhouse gas emission scenario

iii. This baseline data is based on 30 years of weather data

*Bold indicates the worst case scenario based on a higher greenhouse gas emissions scenario as specified in ref ii.

Where 3 values are given: x (y-z) these present the median estimate, with the 25th and 75th percentile values in brackets.

1.3.2 Indore Climate: Summary Profile

Table 3 summarises the collected baseline and future climate data for Indore. Additional information on the climate profiles for Indore can be found in Appendix B.

Climate variable characteristic			Baseline 3	2020s	2050s	2080s
Temperature	Mean temperature	June-February mean temperature (°C)	24.4	This data was not collected.		
		March-May mean temperature (°C)	30.2	31.3 (31.0 – 31.5)[i] **31.4 (31.1 – 31.6)[ii]**	32.2 (32.0 – 32.5)[i] **33.0 (32.7 – 33.4)[ii]**	32.7 (32.3 – 33.3)[i] **35.0 (34.5 – 36.0)[ii]**
	Extreme temperature	Annual average maximum daily temperature (°C)	43.2	44.3 (43.6 – 45.0)[ii]	45.8 (44.8 – 47.0)[ii]	47.9 (46.3 – 49.4)[ii]
		Maximum recorded temperature (°C)	47.4	It is likely that the number of days with extreme temperatures will increase.		
Humidity	Annual average humidity		52.3%	Data for future seasonal and diurnal variation has not been considered in this study.		
	Annual average maximum humidity		87.5%			
Wind	Maximum wind speed		57.1 m/s	There is considerable uncertainty in climate change projections for future wind speeds and direction. A number of studies show statistically insignificant variations in wind speed. Hence, major changes are not anticipated in mean wind speeds and directions.		
	Average wind speed		4.6 m/s			
Precipitation	Mean precipitation	Winter (December-February) monthly average precipitation (mm/month)	10	9.9 (8.6 – 13.1)[i] **10.7 (9.4 – 12.4)[ii]**	10.6 (7.7 – 12.9)[i] **11.7 (9.3 – 13.3)[ii]**	11.7 (7.9 – 13.7)[i] **12.6 (9.7 – 15.5)[ii]**
		Summer (April-September) monthly average precipitation (mm/month)	150	157.2 (150.5 – 171.1)[i] **159.2 (149.3 – 171.7)[ii]**	169.0 (154.9 – 181.6)[i] **179.1 (158.3 – 193.7)[ii]**	169.7 (155.1 – 193.3)[i] **191.1 (156.6 – 226.2)[ii]**
		Average monthly precipitation during wet season (June-September) (mm/month)	200 (monthly precipitation can exceed 600 mm at times)	Future data was only collected for the months DJF and JJA. The wet season is from June to November so we are not able to provide specific values for future precipitation in this period. We would expect it to be similar to the summer projections.		
	Low precipitation	Dry spells (10+ days with no precipitation)	106 days	114 (90 – 132)[ii]	106 (73 – 143)[ii]	108 (63 – 161)[ii]
	High precipitation	Heavy precipitation (>20 mm/day)	15 days	16 (14 – 17)[ii]	17 (13 – 22)[ii]	17 (12 – 24)[ii]

Table 3.
Indore climate profile summary

i. Based on Representative Concentration Pathway 4.5 (RCP4.5) – this represents a medium greenhouse gas emission scenario

ii. Based on Representative Concentration Pathway 8.5 (RCP8.5) – this represents a high greenhouse gas emission scenario

iii. This baseline data is based on 30 years of weather data

*Bold indicates the worst case scenario based on a higher greenhouse gas emissions scenario as specified in ref ii.

Where 3 values are given: x (y-z) these present the median estimate, with the 25th and 75th percentile values in brackets.

2. DIT Definitions

Many different technologies can be considered DIT. The architecture of DIT systems usually comprises:

- several **components**, some deployed in the field and some at centralised operational facilities;
- **network links** which connect components together;
- **operational facilities** where personnel use, control and operate the DIT; and
- **software-defined rules of action** that provide a degree of automation.

For the purposes of this document, we have defined five elements – Components, Network Links, Operational Facilities; Systems and Software - in the following sections. Figure 3 shows them in context. Examples of each element are described in the figure below.

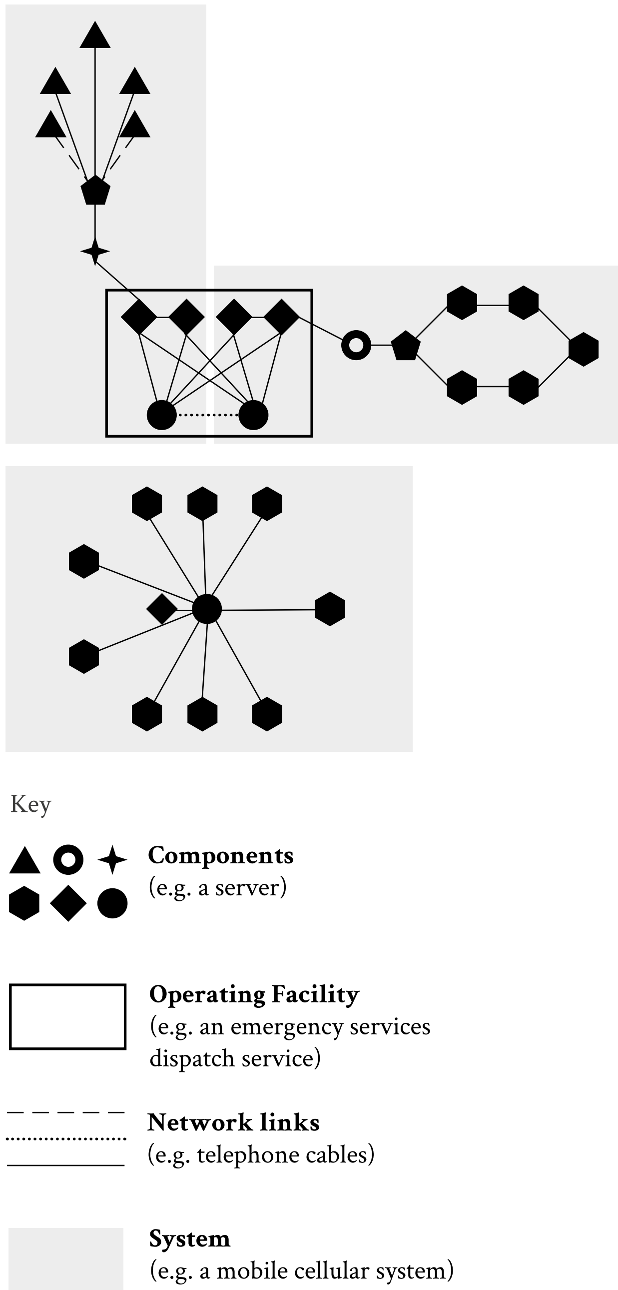


Figure 3.
Components, Network Links, Operating Facilities and Systems

2.1 Components

DIT components are the individual elements that each provide a limited set of capabilities. A component exists at a specific location, and relies on a supporting infrastructure – perhaps electrical power or a Network Link - to do useful work. Components are manufactured to particular environmental tolerances. They might have temperature ranges outside of which they will not operate correctly. They may be sensitive to vibration, ingress of moisture or dust, physical shock or other factors.

Procurement processes for any component must bear in mind the circumstances in which it will be deployed. If it is to be deployed on a column in a public place (as a CCTV camera or cellular antenna might), it will need to be resilient to the expected climate, and to damage by the public. Storage servers will more often be deployed to controlled equipment rooms where their specified temperature range requirements can be met by chillers and access control mechanisms. Some components, like network switches, are available in more-resilient "industrial" or "ruggedized" versions; or in versions that must be carefully handled and deployed into well-managed equipment rooms.

The housing of components in field locations requires careful consideration. Network-related components are often housed in metal roadside cabinets. In regions prone to high temperatures, these housings can allow temperatures to build up; so adequate ventilation must be incorporated.

Examples - DIT Components include –

- a server;
- a network switch;
- a mobile telephone handset;
- a cellular base-station;
- a CCTV camera;
- a climate sensor

See Figure 4

Figure 4.
Components - (Clockwise from Top-Left) a set of Servers, a CCTV camera, a mobile cellular mast with antennas, and a mobile telephone handset.

The process of procuring a component should always begin with developing an understanding of its intended criticality; then understanding the conditions in which it will be deployed and used. Only then can a performance specification be developed.

Case Study

Batteries operate over a wide temperature range as seen in the table below but the charging process is delicate and special care must be taken. Extreme cold and high heat slow down charging so the battery must be brought to a moderate temperature before charging. For best results, charge between 10°C and 30°C .

The recommended storage temperature for most batteries is 15°C (59°F); the extreme allowable temperature is –40°C to 50°C for most chemistries. While lead acid must always be kept at full charge during storage, nickel- and lithium-based chemistries should be stored at around a 40% state-of-charge (SoC). As temperature rises, stored batteries can develop permanent capacity loss.

Battery type	Charge temperature	Discharge temperature	Charge advisory
Lead acid	-20°C to 50°C (-4°F to 122 °F)	-20°C to 50°C (-4°F to 122 °F)	Charge at 0.3°C or below freezing. Lower V-threshold by 3mV/°C when hot.
NiCd, NiMH	0°C to 45°C (32°F to 113 °F)	-20°C to 65°C (-4°F to 149 °F)	Charge at 0.1°C between -18°C or 0°C. Charge acceptance at 45°C is 70%. Charge acceptance at 60°C is 45%.
Li-ion	0°C to 45°C (32°F to 113 °F)	-20°C to 60°C (-4°F to 140 °F)	No charge permitted below freezing. Good charge/discharge performance at higher temperature but shorter life.

Table 4.
Permissible temperature limits for various batteries

10. “BU-410: Charging at High and Low Temperatures,” Battery University, 02 April 2016. [Online]. Available: http://batteryuniversity.com/learn/article/charging_at_high_and_low_temperatures.

2.2 Network Links

Network links are the connections between two components, which could be provided by a wireless radio signal, a fixed copper cable or fibre-optic cable. Systems usually consist of many network links, which connect their components to convey data between them.

Since they connect components across potentially large distances, a network link can be disrupted by physical affects anywhere along their path. A cable link could be disrupted by flooding at any point, and wireless links can be disrupted by physical damage to antennas, radio interference, and sometimes by temporary impositions into to their paths – which could block or reflect signals. Some radio signal types are disrupted by atmospheric conditions too.

All types of network link have characteristics which limit the amount of data they can carry and the time taken to do so. Therefore, as well as the threat posed by physical damage and disruption, network links are also prone to congestion.

Therefore, when considering how to connect two locations together via a network link procurers often specify redundant links (meaning multiple, separate links between two locations), over diverse routes (meaning that the links do not share any part of their path) or via multiple methods (perhaps copper and wireless).

Examples - DIT Network Links include –

- copper telephone cables between an exchange and a residence or business premises;
- fibre-optic communications cable between a data centre and a business premises;
- a point-to-point microwave link between two emergency services depots;
- a mobile cellular link between a weather sensor at a remote location and a provider's nearest base station

Figure 5.
Network Links - Copper Telephone Cables (bottom) and Microwave Dish for a point-to-point link (top)

2.3 Systems

A **system** is a combination of elements providing valuable services for its users.

The design of any system must take into account its criticality. Will the system be expected to function during a natural disaster? Systems that might once have been considered non-essential (like a social-networking website or broadcast radio system) can end up providing extremely useful services during a crisis (helping to find missing persons or proving crucial advice to the population).

Understanding the criticality of the system will lead the designer to consider not just the specification of its components and network links, but design techniques like redundancy and diverse routing can be employed.

Examples - DIT systems include –

- a mobile cellular system (billing and invoicing software; network links, masts, antennas and base-stations; interfaces to other telephone networks, call-routing equipment; handsets);
- an early warning system (climate and weather monitoring sensors, network links, computing resources; command and control interfaces and several communications methods to alert the authorities and the public).

2.4 Operational Facilities

Operational facilities are where users interact with DIT systems. Operational facilities often sit at the hub of communications systems, and provide controlled environments for sensitive components, or hardened, resilient infrastructure support, like multiple power supply sources.

In a smart city context, the main operational facility could be a control room based in a civic centre. For a mobile cellular network provider, the main operational facility might be their network operations centre.

Within a disaster risk mitigation context, operational facilities can be crucial to the coordination of disaster response. For that reason, the procurement and design of operational facilities should be arranged so that they are physically situated away from foreseeable climate hazards – for example out of flood plains or away from coastal zones.

Examples - DIT Operational Facilities include –

- An emergency services despatch centre
- The emergency telephone call centre (112 / 999)
- A power station control room
- A smart city control-room

Figure 6.
Operational Facility – the Perth Airport Coordination Centre

Since operational facilities are 'hub' locations, their specification should include consideration of features and functions that will keep them operational under extreme conditions. Operational facilities are often specified to include multiple power sources, including on-site generation; multiple, separate network links and access to multiple communication systems; and easy access from multiple primary roads.

2.5 Software

Software is the set of pre-defined and pre-configured instructions a computer-controlled DIT follows. Many DIT components and systems now rely on software elements for their features and functions.

Within operating facilities concerned with disaster management, special-purpose software is often used to support decision-making, to display geographic information, manage task lists and provide access to pre-written contingency plans and operating procedures. The records kept by such software systems can be valuable in learning lessons from any incident or disaster.

At a lower-level, many components' actions are determined by in-built software, which might govern reporting processes, actions to take when network links are disrupted, and how to react when overloaded by high demand.

When developing software specifications for disaster management, considerations include – automatic fall-back when other components and network links fail; ease-of-use; degree of automation; reliability and correctness; efficiency; ability to seamlessly support backups and operation from multiple locations.

Examples - DIT Software include –

- Control-room applications, sometimes called Public Safety Information Management software; which present dynamic information to support decision-making
- GIS, geographic information systems, used for the display and maintenance of geospatial information
- Component firmware, which governs the behaviour of the component.

3. Procurement Context

Agencies procuring and specifying DIT must determine a procurement strategy. One key trade-off is the amount of control and responsibility they will retain, and how much they will pass on to the supplier.

In some cases, the procurer takes little or no interest in the practicalities of the DIT, but instead attempts to define and procure a service. The supplier will then have to design and operate some DIT resources to meet required service levels.

At the other extreme, the procuring agency may employ designers and analysts, and seek to procure components, network links and installation services from the market.

There are best practice international standards which can be used to ensure that the DIT's resilience and effectiveness is not undermined, these include:

- ISO 10845-1:2010 which describes processes for developing a procurement system, and provides rules and guidelines relating to standard procurement methods and procedures. It also gives a framework for developing a procurement policy and establishes the manner in which procurement is to be managed and controlled. Whilst this standard is aimed at a built environment, the system of procurement is a useful framework.
- ISO 37001 – Anti-bribery management systems
- EU guidance: Guide for the procurement of standards-based ICT — Elements of Good Practice

3.1 Services Procurement

When procuring DIT services, the agency must have very clear definitions and specifications in place for acceptable service levels. The service contracts should include measurable criteria like:

- Availability – the proportion of time the service is available and operating correctly - often stated as a percentage.
- Notification of down-time – to allow the supplier to carry out planned maintenance, and whether to subtract it from the availability criteria.
- Acceptable reductions in availability due to failures in supporting infrastructure. For example, the supplier may excused some failures if the route cause was not foreseeable and not in their control. A power failure or a natural disaster might qualify.
- Business Continuity arrangements – depending on the service being offered, the supplier might be able to provide secondary, alternative services in the event that their primary DIT is unavailable. If part of their service offering is an email alert; an acceptable business continuity arrangement might be a scheduled telephone call or faxed report.
- Disaster Recovery – the service contract may seek to place limits on how long any particular DIT disruption may impact the service. Properly-specified Disaster Recovery clauses will lead the supplier to deploy redundant, diverse, resilient systems, though this is likely to impact their price offering.
- Emergency Scenarios – the service contract may seek to impose special arrangements for emergency scenarios. For example, where the supplier's DIT systems are used to deliver multiple services, the procuring agency require priority access during an emergency.

It is not sufficient to contract on the basis that the criteria will be met - the procurement agency should also impose design features and other DIT System-level considerations on the supplier. For example, a requirement to completely avoid single points of failure; to always provide multiple network links, or to have multiple power sources available. The procurement process should involve a review of the supplier's DIT designs to ensure their compliance. Note that these are indicative criterions and others may be applicable based on the location of the procurement.

	Procuring Agency	Tier 1 Supplier
Service	Defines and Specifies Procures	Provides
System	Reviews and assures system design	Designs; Procures; Commissions; Operates
Operating Facilities		Designs; Procures; Commissions; Operates
Network Links		Procures; Commissions; Operates
Components		Procures; Configures; Installs
Software		Procures; Configures; Operates; Supports

Table 5.
Supplier and Procurer Responsibilities – Services Procurement

3.2 System Procurement

When procuring a system, the agency will specify design criteria including:

- Minimum levels of redundancy and resilience
- Dual network links, on diverse routes
- Duplicated components where necessary to ensure continuous operation.
- Alternative power supplies.
- Automatic failovers and fall-back so that system performance is maintained when individual components, network links or power supplies fail.

Candidate suppliers can be required to submit high-level designs before their appointment, so that their level of compliance can be taken into account in the selection process.

In addition to the system design criteria, the procuring agencies should seek to ensure components being procured by the supplier are suitable for purpose.

Finally, the supplier must be required to provide detailed "as-built" information, asset registers, operations and maintenance manuals, and all design documentation. The quality and completeness of this material are important criteria for the successful close of the procurement process. The agency may then take full ownership of the system, and understand its performance during natural disasters.

	Procuring Agency	Tier 1 Supplier
Service	Self-provides	Provides
System	Defines and Specifies; Operates Procures	Designs; Procures; Commissions; Documents;
Operating Facilities	Tests and assures; Operates	Designs; Procures; Commissions;
Network Links	Tests and assures; Operates	Procures; Commissions;
Components	Tests and assures; Operates	Procures; Configures; Installs
Software	Tests and assures; Operates	Procures; Configures; Supports

Table 6.
Supplier and Procurer Responsibilities – System Procurement

3.3 Component Procurement

In a component-level procurement the agency is taking responsibility for the development of the service and the system, and is going to the market to procure the necessary components only.

In this scenario, the characteristics of the components are the focus of the specification efforts. Factors are likely to include:

Environmental

- Water proofing
- Operating humidity and condensation ranges
- Operating temperature ranges
- Wind loading and impact loading
- Lightning strike resilience
- Moisture proofing
- Dust ingress prevention

Features and Functions for resilience

- Degree of unattended operation
- Remote monitoring and maintenance
- Dual power supply
- Automatic failover between network links

	Procuring Agency	Tier 1 Supplier
Service	Self-provides	
System	Defines and Specifies; Operates; Designs; Procures; Commissions; Documents; Procures	
Operating Facilities	Tests and assures; Operates; Designs; Procures; Commissions;	
Network Links	Tests and assures; Operates; Designs; Procures; Commissions;	Supplies
Components	Tests and assures; Operates; Designs; Procures; Commissions;	Supplies
Software	Tests and assures; Operates; Designs; Procures; Commissions;	Supplies

Table 7.
Supplier and Procurer Responsibilities – Component Procurement

4. Suggested Performance Specifications for DIT

By analysing the outline approaches of several Indian projects, and similar DIT elsewhere, we have determined the elements which are important to any performance specification.

However, because we have no formal role in any of the current Indian DIT procurements, therefore we have no detailed insight into their specifications and no formal means to influence them.

For the purpose of this specifications report we have assumed in each case that the procurement is being carried out for the sole benefit of the DIT purchasing authority and will be owned and operated by them; i.e. we have set aside procurement of DIT-enabled services. The intent of the clauses could still apply in the case of DIT-enabled services, but each would be expressed differently.

The current procurements are being considered with different purposes in mind:

- NCRMP* will be vital, so its specification should include measures to boost resilience. (At regional as well as communital level)
- Some Smart City DIT may not be intended for use during a natural disaster, and so its specification need only address day-to-day resilience.
- Much Smart City DIT will be general-purpose, and may prove useful in unexpected ways during contingency situations.

Note only the NCRMP has disaster mitigation as a stated intention. The Smart Cities procurements have a wide range of purposes – including improved efficiencies, and better management of resources. Whatever the purpose of a DIT procurement, some assessment should be carried out in advance to determine the level of importance the DIT will have before, during and after a natural disaster situation.

We have created specification clauses catering to DIT that is either intended for use during a disaster, or which is intended to have a high degree of usefulness during a natural disaster. Other functional and non-functional requirements can only be specified by the procuring agencies.

*National Cyclone Risk Mitigation Project

4.1 Systems Specification

- The system shall be capable of continuous operation during planned maintenance tasks.
- The system shall have sufficient capacity to process anticipatable demands during a natural disaster.
- The system design shall not rely on single points of failure, including;
  - All system storage elements shall be duplicated in real time, and configured to allow hot swapping of any storage elements without shutting down the entire system.
  - All critical system elements shall be duplicated to provide redundancy. The system shall be configured to allow seamless fallback from damaged or inoperative elements to other redundant elements. The system shall be configured so that detectable failures or damage is reported or alerted to the operators, whether or not a failover has been successful.
  - All critical system elements shall be supported by multiple power sources, which may include –
    - Dual mains power supplies made available over diverse routes.
    - Alternative power supply sources such as UPS systems or generators.
  - All communications network links between critical systems elements shall be over diverse routes, and should be via alternative bearers (e.g. via both wired and wireless network links). In the event of the failure of one network link, the system shall be configured so that operations can automatically continue on the alternative link. The system shall be configured so that detectable failures of any network link is reported or alerted to the operators, whether or not a failover has been successful.
    - The system design shall allow compliance with the International Standard on Business Continuity (ISO 22301:2012) to ensure that the system has the capability to deliver service at an acceptable predefined level following a disruptive incident.
- All system storage elements shall be routinely and automatically backed-up to a secondary location.
- The system shall be capable of unattended operation.
- The system shall be comprised of components, network links and software that is suitable for deployment in the designed locations, including meeting the environmental characteristics likely to pertain throughout the design life of the system.

4.2 Components Specification

4.2.1 Physical Characteristics [Mandatory]

- All components to be deployed away from controlled environments shall be inherently:
  - Water proof, including rainfall and driven rain proof, bearing in mind:
    - [Kakinada: Average rainfall levels could be as high as 219mm/month during summer by the 2050s]
    - [Kakinada: Wet season extreme rainfall levels currently can exceed 600mm/month and this is likely to increase]
    - [Indore: Average rainfall levels could be as high as 190mm/month during summer by the 2050s]
    - [Indore: Wet season extreme rainfall levels currently can exceed 600mm/month and this is likely to increase]
  - Situated away from flood prone regions, given extreme climate scenarios which may include average sea level rises of [0.26m in Kakinada]
  - Humidity proof, including condensation proof.
    - [Kakinada: Average humidity is 72%; and average maximum humidity is 95%]
    - [Indore: Average humidity is 52%; and average maximum humidity is 88%]
  - Have an operating ambient temperature range -10 to 60°C and be installed such that ambient temperatures and heat dissipation do not cause the operating temperature ranges to be exceeded.
    - [Kakinada: Mean ambient temperature in March-August may rise to 32.8°C by the 2050s].
    - [Kakinada: annual average maximum daily temperature may be as high as 57°C by 2050]
    - [Indore: Mean ambient temperature in March-May may rise to 33.4°C by the 2050s].
    - [Indore: annual average maximum daily temperature may be as high as 47°C by 2050]
  - Temperature shock proof
  - Where installed above ground, be capable of operating in high levels of sunlight and solar radiation.
  - Where installed above ground, able to withstand average wind-loads and gusts in the 2050s climate scenario.
    - [Kakinada: Gusts could currently reach 48 m/s; average winds of 1.8m/s]
    - [Indore: Gusts could currently reach 57 m/s; average winds of 4.6 m/s]
  - Electro Magnetic Compliance (EMC) . Assure that it doesn't create electromagnetic interference and that it can resist electromagnetic interference produced by other components.
  - Dust proof
  - Vibration and physical shock proof

- The containment or housings shall not worsen the environmental parameters the components are exposed to. For example, it shall not induce a build-up of humidity or trap heat.
- Given the expected lifetime of several decades for network links, the physical characteristics should be specified to allow for the climate scenarios in Table 2 and Table 3. The housing, mountings, cabinetry or other containment shall not worsen the environmental parameters the components are exposed to. For example, it shall not induce a build-up of humidity or trap heat.
- DIT components might have an expected design life of a decade; therefore their physical characteristics should be specified to allow for the climate scenarios in Table 2 and Table 3 of at least the 2020s.

4.2.2 Installation Requirements [Mandatory]

- All field-deployed component assets shall be installed so as to:
  - Maintain their environmental characteristics.
  - All field cabinets shall utilise ventilation, shading, pedestals and other means necessary to enhance and maintain environmental resilience.
- Unless operational requirements dictate otherwise, all field-deployed components shall be installed to avoid natural disasters including fluvial flooding, cyclones, storm surges and tidal flooding, and other natural hazards likely to be faced during the design life of the system.

4.2.3 Operational Requirements [Mandatory]

- Networked components shall be capable of remote monitoring, alerting, and reporting.
- Components shall have dual power supplies or be installed to make use of dual power supplies.
- All components shall be fully documented, including equipment lists and part numbers, firmware version numbers, physical routes taken and installation methods used, and the precise geographical location of all elements.

4.2.4 Systems Integration Requirements [Mandatory]

- All networked components shall be addressable and controllable using non-proprietary, industry-standard protocols and network access technology.

4.3 Network Links Specification

4.3.1 Physical Characteristics [Mandatory]

- All network links and network link equipment to be installed outside controlled environments shall be inherently:
  - Water proof, including rainfall and driven rain.
    - [Kakinada: Average rainfall levels could be as high as 219mm/month during summer by the 2050s]
    - [Kakinada: Wet season extreme rainfall levels currently can exceed 600mm/month and this is likely to increase]
    - [Indore: Average rainfall levels could be as high as 190mm/month during summer by the 2050s]
    - [Indore: Wet season extreme rainfall levels currently can exceed 600mm/month and this is likely to increase]
  - Situated away from flood prone regions, given extreme climate scenarios which may include average sea level rises of [0.26m in Kakinada]
  - Humidity proof, including condensation proof.
    - [Kakinada: Average humidity is 72%; and average maximum humidity is 95%]
    - [Indore: Average humidity is 52%; and average maximum humidity is 88%]
  - Have an operating ambient temperature range -10 to 60°C and be installed such that ambient temperatures and heat dissipation do not cause the operating temperature ranges to be exceeded.
    - [Kakinada: Mean ambient temperature in March-August may rise to 32.8°C by the 2050s].
    - [Kakinada: annual average maximum daily temperature may be as high as 57°C by 2050]
    - [Indore: Mean ambient temperature in March-May may rise to 33.4°C by the 2050s].
    - [Indore: annual average maximum daily temperature may be as high as 47°C by 2050]
  - Temperature shock proof
  - Where installed above ground, be capable of operating in high levels of sunlight and solar radiation.
  - Where installed above ground, able to withstand average wind-loads and gusts in the 2050s climate scenario.
    - [Kakinada: Gusts could currently reach 48 m/s; average winds of 1.8m/s]
    - [Indore: Gusts could currently reach 57 m/s; average winds of 4.6 m/s]
  - Electro Magnetic Compliance (EMC) . Assure that it doesn't create electromagnetic interference and that it can resist electromagnetic interference produced by other components.
  - Dust proof

- Vibration and physical shock. The containment or housings shall not worsen the environmental parameters the components are exposed to. For example, it shall not induce a build-up of humidity or trap heat.
- Given the expected lifetime of several decades for network links, the physical characteristics should be specified to allow for the climate scenarios in Table 2 and Table 3 of at least the 2050s.

4.3.2 Installation Requirements [Mandatory]

- All cabling shall be terminated in accordance with the termination procedures compliant to the manufacturer's standards and requirements for performance and application assurance warranty.
- No communications cables be tied to power cables or run along the same conduits or ducts or run through the same connection box.
- All cabling and cabling components should be appropriately rated for the correct application in the environment e.g. Temperature rating for harsh environments.
- All cables should be Low Smoke and Zero Halogen (LSOH) and complying with IEC 60332-1, IEC 61034-2 and IEC 60754-2 standards.
- Design documentation shall include the obligation for the Contractor to test fibre optic cables in accordance ISO/IEC 14763-3 Edition 1.1: Testing of Optical Fibre Cabling.
- Cable management panels shall be provisioned for all terminated cabling permitting the management of patch cords providing full support and permitting routing of cords whilst maintaining cable bend radii and manufacturers requirements.

4.3.3 Operational Requirements [Mandatory]

- All elements of each network link shall be fully documented, including equipment lists and part numbers, firmware version numbers, physical routes taken and installation methods used, and the precise geographical location of all elements.

4.3.4 Systems Integration Requirements [Mandatory]

- Network link equipment shall be designed and installed to facilitate seamless failover from damaged or inoperative network links to other suitable links, to form part of a self-healing network.

4.4 Operational Facilities Specification

4.4.1 Physical Characteristics [Mandatory]

- All operational facilities shall be situated with due consideration to climate hazards and potential triggers of natural disasters, including fluvial flooding, cyclones, storm surges and tidal flooding.
- All operational facilities shall be situated so that their access roads are not subject to disruption by natural hazards, including fluvial flooding, cyclones, storm surges and tidal flooding.
- All operational facilities shall be situated so that their network links can be deployed along diverse routes.
- All operational facilities shall be situated so that power can be supplied along multiple diverse routes.
- All operational facilities shall be constructed to maximise their resilience to natural hazards including fluvial flooding, cyclones, storm surges, tidal flooding, prolonged high temperatures and drought conditions.
- Operational Facilities could have a design life of many decades; therefore their location and physical strength should be specified to take into account the extreme climate scenarios into at least the 2080s; as described at Table 2 and Table 3. Different cities will have varying environmental & climate parameters to account for.

4.4.2 Operational Requirements [Mandatory]

- All operational facilities shall be sized to accommodate all staffing levels required for normal operating conditions, and for foreseeable emergency scenarios, including those documented in all relevant operational procedures.
- Where off-site data centres, hosting or cloud services are used, a local cache and local on-site alternative applications shall be available and maintained up to date in the event that connection to off-site locations are lost.
- All on-site and off-site data centres shall be designed and maintained to comply with appropriate resilience characteristics from ANSI-BICSI-002-2014.

4.4.3 Systems Integration Requirements [Mandatory]

- All operational facilities shall be supported by redundant infrastructure, including:
  - Redundant and resilient wide area network links, installed along wholly separate routes.
  - Redundant and resilient sources of electrical power, including two separate mains feeds; on-site generators and UPS.
  - Multiple travel routes to the facility from population centres, so as to allow operations to be maintained during travel disruption.

4.5 Software Specification

- Software deployed as part of DIT shall not rely on the accessibility of third-party resources to function correctly; for example access to supplier systems to validate licence keys.
- Software deployed as part of DIT shall not place limitation on the number of simultaneous users during a natural disaster.
- Software deployed as part of DIT shall have a user interface available in the local languages:
- Software deployed as part of DIT shall continue to operate as fully as possible if there are failures of supporting infrastructure, network links or components. For example;
    - if a sensor providing input to a software element fails, that software element should continue to operate with the remaining inputs.
    - if the primary data centre becomes unavailable, the software should seamlessly access data from any accessible secondary sources, triggering an alarm that the primary is unavailable, without ceasing to function.
- As far as practicable, software deployed as part of DIT should not rely on proprietary data formats, protocols or methods.
- As far as practicable, software deployed as part of DIT shall offer well-documented, stable application programming interfaces (APIs) for integration, configuration and automation.
- All software deployed as part of DIT shall log and retain a history of configuration changes and other key events.
- All software shall have been tested to comply with ISO/IEC/IEEE 29119-1:2013, "Software and systems engineering - Software testing" or subsequent standard.
- All software shall also be designed to record and log events, changes and activities undertaken, in a form that supports a post-disaster or post-incident review, audit or inquiry. It shall comply with a standard such as ISO 19011:2011, "Guidelines for auditing management systems".
- All software shall be supplied with all operating manuals, software and hardware configuration information, license agreements, and escrow agreements where applicable.
- New software shall be prepared and evaluated under the terms of ISO 25010:2011 or its successor standards.
- Software should take into account the risk of malicious harm (eg: cyberhacking).

5. Checklist

5.1 Procurement

STRATEGY	• What outcome is sought? • What DIT is required? • How will it be maintained and operated?
DISASTER PROOFING	• What use will the new DIT be put to during a natural disaster? • How critical will these uses be to disaster response? • Therefore, what level of resilience is required?
PROCUREMENT	• What use will the new DIT be put to during a natural disaster? • How critical will these uses be to disaster response? • Therefore, what level of resilience is required?

5.2 Services Specification

SERVICE LEVELS	• Establishment of Service Levels. • Establishment of service management framework. • Should services include participation in municipal disaster contingency planning?
BUSINESS CONTINUITY	• What alternative services will be accepted during losses or problems? • How soon will the service provider be expected to restore full service; and what disaster scenarios will excuse underperformance?
DESIGN CRITERIA	• What design criteria will apply? • When and how will the procuring agency assure compliance with design criteria?

5.3 System Specification

SYSTEM PARAMETERS	• What levels of redundancy and resilience are called for? • Level of duplicated components and links. • Automatic failovers and unattended operation. • Dependency on pre-exsting infrastructure?
COMPONENT CRITERIA	• General criteria for all components in the system including environmental parameters. • Measures to assure.
DELIVERABLES AND DOCUMENTS	• Requirement of as-built information, asset registers, O&M manuals, design documents. • Measures to check deliverables for adequacy and correctness; contractual mechanisms to support process.

5.4 Component Specification

ENVIRONMENTAL PARAMETERS	• Operating temperatures; wind loading, humidity, etc. are all set down; and have been established with due consideration to climate change extremes. • Design life of the components has been compared with anticipated climate change impacts.
RESILIENCE CAPABILITIES	• Components offer unattended operation, remote monitoring, dual power supply, and automatic failover features.
ASSURANCE AND TEST	• Contractual mechanisms in place for acceptance tests

Appendix A
Kakinada Climate Profile

Kakinada Climate Profile

A brief summary is provided below for each climate variable in Kakinada, describing both current data as well as future projections. As it is a coastal city, see Figure 2, information on cyclones and sea level rise are considered.

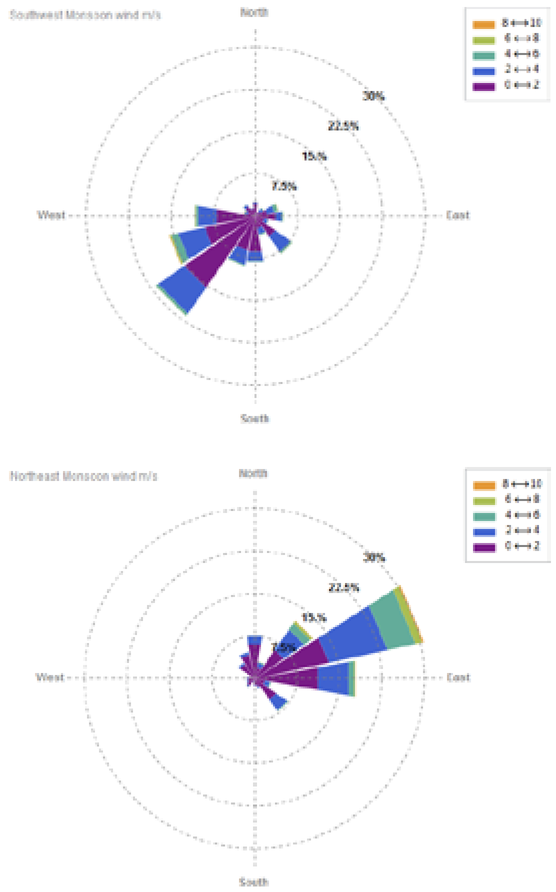


Figure 7.
Wind roses showing the seasonal variation in wind direction and speed.

Wind

Current climate
Figure 7 shows wind roses for the two monsoon seasons in Kakinada. These indicate the prevailing winds are from the southwest for most of the year, except from October to December when they are from the northeast.

A wind rose is a graphic way to show the frequency and speed of winds blowing from particular directions over a period of time. The frequency of occurrence of winds from a specific directions is illustrated by size of the triangles, the colours indicate the wind speed in [m/s]. These were built using data from the last 30 years.

The frequency of occurrence of winds from a specific directions is illustrated by size of the triangles, the colours indicate the wind speed in [m/s]. These were built using data from the last 30 years.

Figure 8 shows the direction and speed of wind during the year which is greater than 10 m/s. It shows that there can be moderate high wind speeds from southwest and extreme high wind speeds from northeast to southeast (most likely linked to cyclones).

Future climate
There is considerable uncertainty in projections for changes in wind speed and direction. A number of studies show that there is not a clear trend on the variations in wind speed. It is possible that there will be changes in monsoon arrival time, with an anticipated increase in the variability in monsoon time.

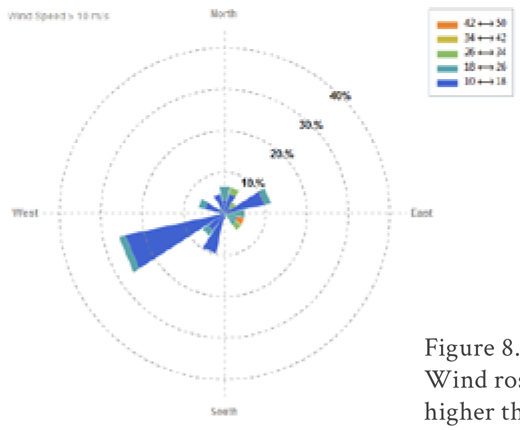
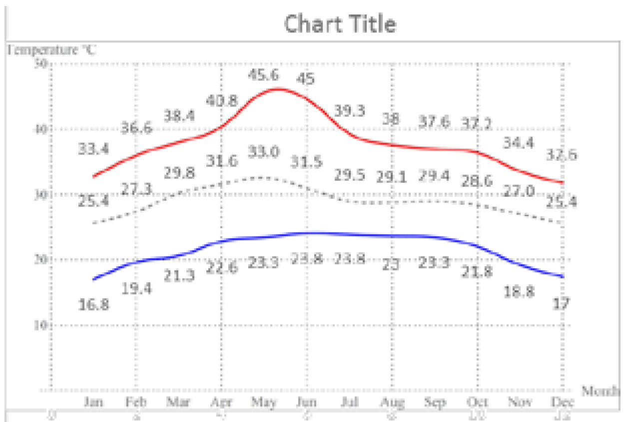


Figure 8.
Wind rose showing the direction and speed of winds higher than 10m/s.

Temperature

Current climate
Figure 9 shows monthly average, minimum and maximum temperatures in Kakinada. Monthly average temperatures are always above 25°C and the warmest time of the year is late May and early June, when maximum temperatures can reach above 45°C. Average temperatures peak during the day at around 2pm at an average temperature of 32°C. The minimum average temperature during the day, generally occurring at around 5am, is 25°C.



Key:

Monthly average maximum temperature

Monthly average temperature

Monthly average minimum temperature

Figure 9.
Annual variation in temperature based on data collected over the past 30 years.

Future climate
In the future, a similar increase in mean temperature is projected for all seasons, with an increase of up to 4°C by the 2080s when considering a high emissions scenario (see Figure 10). There is a projected increase in maximum temperature (Figure 11) of up to 6°C with an average increase of 4°C. An increase in the duration of warm spells is projected.

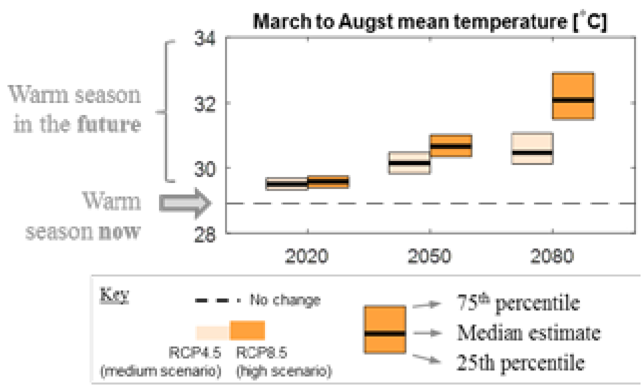


Figure 10.
Projections for future temperatures during the warm season (March-August) in Kakinada

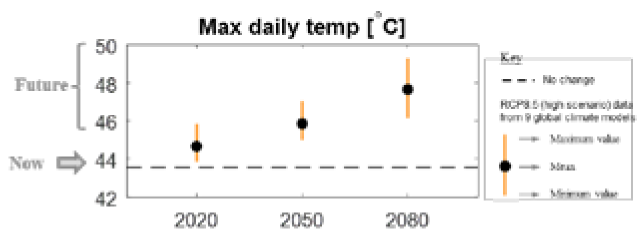


Figure 11.
Projections for extreme maximum temperature compared the current maximum temperature

Blue bars show the with the dashed lines showing

Precipitation

Current climate

The wet season typically starts around June and lasts until November, see Figure 12. The average monthly rainfall during these months is 200mm/month. Rain intensity is highest from around 10am to 1pm. On average there are 16 days with heavy precipitation in a year (>20 mm/day). Heavy precipitation most commonly occurs in October (linked to the cyclone season) but also occurs between May to September. The average duration of dry spells is three months (97 days).

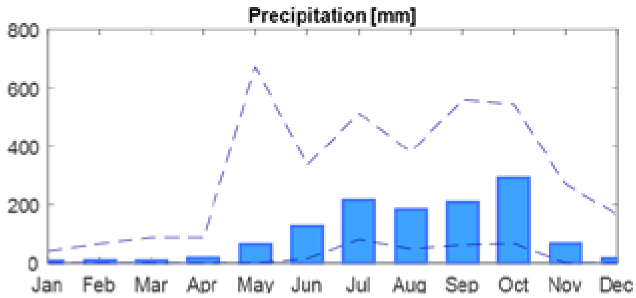


Figure 12.
Seasonal variation in precipitation, data collected during 1982-2013.

Key:

Mean precipitation

minimum and maximum

Future climate

Future rainfall projections contain greater uncertainty than future temperature projections do. Figure 13 shows that by the 2080s, an increase of up to 40% in rainfall is projected.

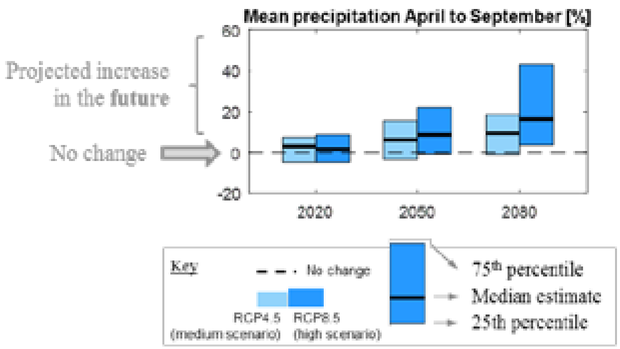


Figure 13.
Future projections in precipitation during April to September in Kakinada.

The number of days with heavy precipitation is also projected to increase in the future. This could potentially be up to 10 days more a year by 2080, with an average projection of a 2 day increase. Dry spells could be up to 30 days longer with an average projected increase of 10 days. Projections indicate an increase in precipitation during cyclones. However, uncertainty exists in projections for changes to the intensity, frequency and duration of cyclones in the region.

11. http://maps.who.int/airpollution/

12. http://appcb.ap.nic.in/ambient-air-quality-monitoring-national-air-quality-monitoring-programme-namp/

13. Horton, D. E., Skinner, C. B., Singh, D. & Diffenbaugh, N. S. Nature Climate Change http://dx.doi.org/10.1038/nclimate2272 (2014).

Humidity

Average monthly humidity in Kakinada does not vary considerably during the year with current average values between 66% and 78%, see Figure 14. August to October are typically the months with the highest humidity, with March to May generally showing the lowest humidity.

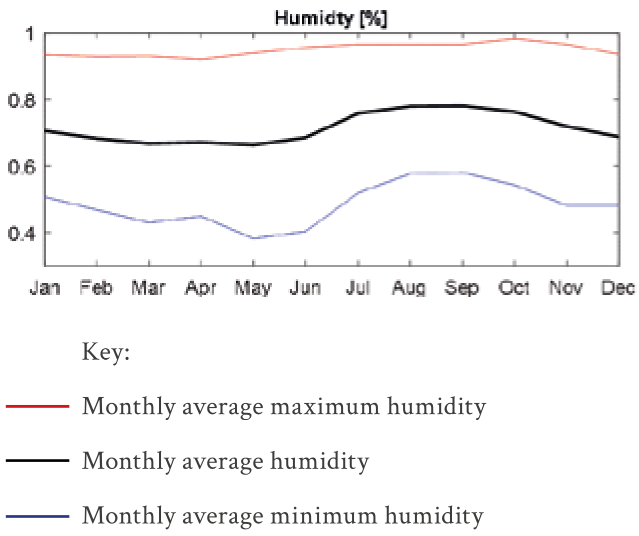


Figure 14.
Annual variation in humidity in Kakinada based on data collected in the past 30 years.

Sea level

High sea levels and storm surges currently affect Kakinada. Projections indicate a rise in sea levels of up to 0.42m by the end of this century. Due to the importance of Kakinada's harbour for the city's economy and employment sea level rise and storm surges will need to be planned for and managed appropriately.

Air quality

Air quality and public health impacts are heavily linked with air stagnation. Air stagnation occurs when there are light winds and a lack of precipitation, leading to air mass remaining over an area for an extended period of time. Higher air stagnation can lead to higher concentrations of particle matters, pollutants and ozone.

Table 8 shows the concentrations of SO2, NO2, PM2.5 and PM10 recorded in Kakinada in 2012 and 2014. The table shows that the current concentrations of PM2.5 and PM10 are above the recommended limits by the WHO.

Table 8: Air pollutant measurements for Kakinada from 2012 and 2014. Values in green are below WHO limits whereas red indicates that the figures are above WHO limits.

Pollutant	2012[11]	2014[12]
SO2 (µg/m3)	-	12.6
NO2 (µg/m3)	-	20
PM2.5 (µg/m3)	31	66.5
PM10 (µg/m3)	58	-

Climate change projections point towards an increase in the number of air stagnation days in the future[13]. This could potentially lead to an increase in the number of days with worse air quality. This is more likely in autumn (September – December) due to an increase in the number of dry days and low wind speeds.

Appendix B
Indore Climate Profile

Indore Climate Profile

A summary is provided below for each climate variable in Indore, describing both current data as well as future projections. As it is an inland city, see Figure 2, cyclones and sea level rise are not considered.

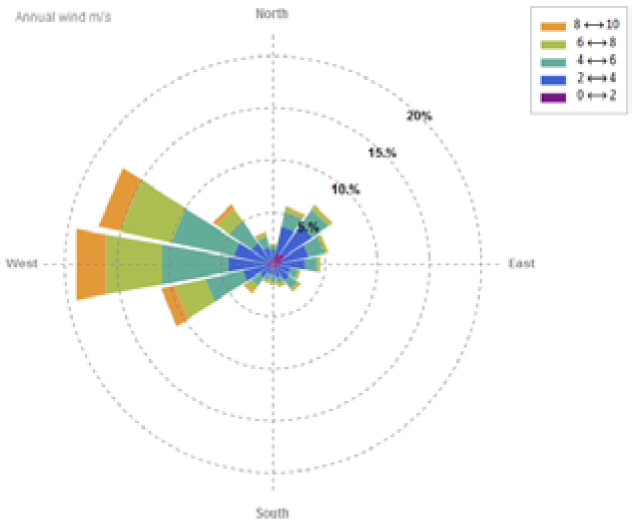


Figure 15.
Wind rose showing annual variation in wind speed and direction.

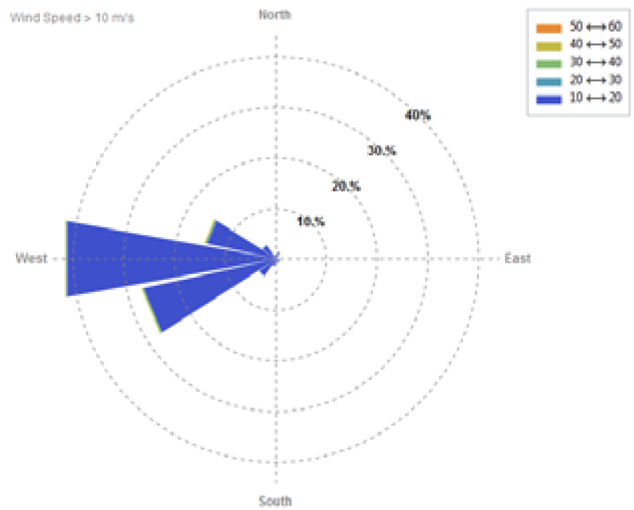


Figure 16.
Wind rose showing the direction and speed of winds higher than 10m/s.

Wind

Current climate
Figure 15 shows a wind rose showing the annual variation in wind direction and speed. The figure shows that prevailing winds are from the west for the majority of the year. No significant diurnal variation is observed, with wind predominantly from the west during the day and occasionally from the northeast in the afternoon and evening

Figure 16 shows the direction and speed of wind during the year which is greater than 10 m/s. This indicates that extreme wind speeds are improbable although there are moderate high wind speeds from the west.

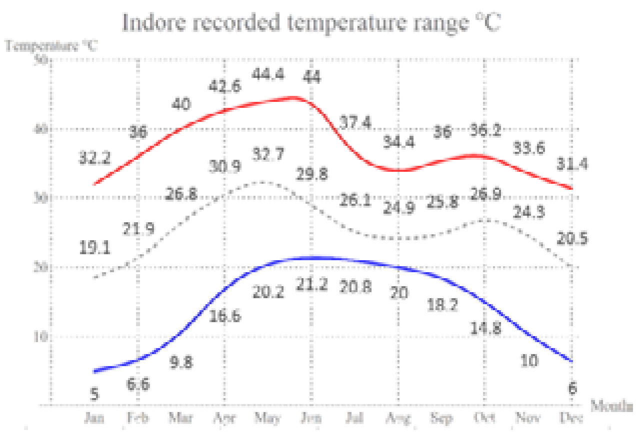
A wind rose is a graphic way to show the frequency and speed of winds blowing from particular directions over a period of time. The frequency of occurrence of winds from a specific directions is illustrated by size of the triangles, the colours indicate the wind speed in [m/s]. These were built using data from the last 30 years.

Future climate
Considerable uncertainty exists in projections for changes in wind speed and direction. A number of studies show that there is not a clear trend on the variations in wind speed.

Temperature

Current climate

Figure 17 shows that monthly average temperatures in Indore are usually above 20°C. The warmest time of the year is during May and June, with maximum temperatures slightly lower than 45°C. Average temperatures during the day peak at around 2pm at an average temperature of 31°C.



Key:

Monthly average maximum temperature

Monthly average temperature

Monthly average minimum temperature

Figure 17.
Seasonal variation in temperature for the historical data collected over the past 30 years.

Future climate

Figure 18 shows the anticipated changes in mean temperature for Indore during the warm season. An increase in mean temperature across all seasons is projected. Indore is already exposed to an Urban Heat Island (UHI) effect. The UHI effect could add 2-4°C to the climate change impact on mean temperature in Indore.

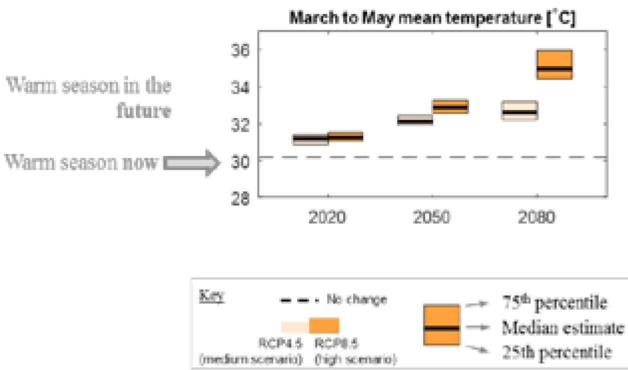
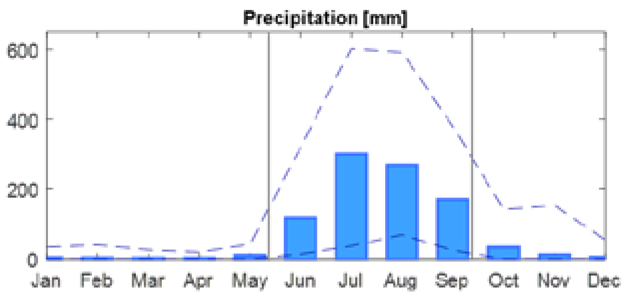


Figure 18.
Projection for future temperatures during the warm season in Indore (March – July)

On average, the maximum daily temperature each year is currently 43°C. By the 2080s, his could reach 49°C when considering a high emissions scenario.

Precipitation

Figure 19 shows monthly mean, maximum and minimum precipitation based on the last 30 years of data available. The wet season typically starts around June and lasts until September. During these months the average monthly precipitation is slightly above 200 mm/month. Figure 20 provides a visual representation of the monsoon arrival and duration. Monsoon months are usually very regular in Indore, however, in some years the arrival of the monsoon is early or delayed. Daily precipitation intensity is generally highest from around 4pm till 10pm.



Key:

Average monthly precipitation

Monthly average maximum precipitation

Monthly average minimum precipitation

Figure 19.
Seasonal variation in monthly precipitation.

The bars represent the mean monthly precipitation and the dashed lines represent the maximum and minimum precipitation.

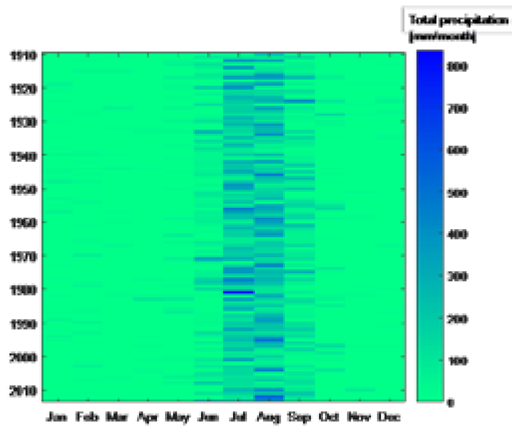


Figure 20.
Total monthly precipitation [mm/month] for each month from 1910 to 2013

Figure 21 shows the projected percentage increase in precipitation for a range of future time periods and emissions scenarios. By the 2080s, mean precipitation is projected to increase up to 50%.

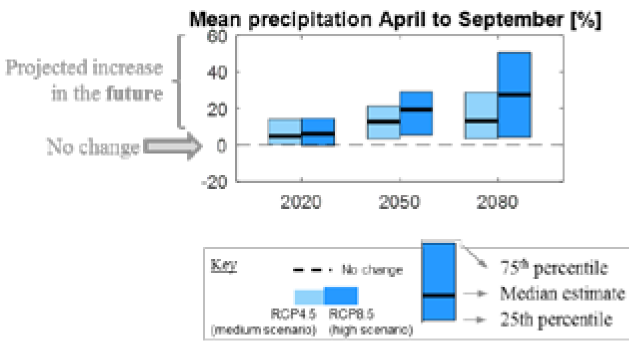
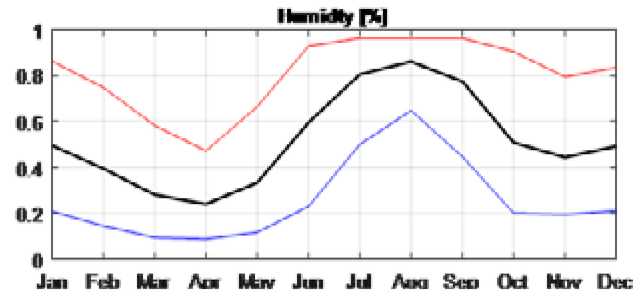


Figure 21.
Future projections in precipitation during the wet season in Indore.

Changes in the arrival time of monsoons can also be expected. In current conditions, the average number of days with heavy precipitation (>20 mm/day) is 15 days per year. The duration of dry spells is approximately 3.5 months (~106 days). Projections indicate an increase in the number of days with heavy precipitation. Large uncertainties exist for changes to duration of dry spells, but it could be up to 50 days longer.

Humidity

Humidity currently varies from 25% to 86%, with June to October the months with the highest humidity, see Figure 22. On average during the day, humidity is lowest around midday and highest at night.



Key:

Monthly average maximum humidity

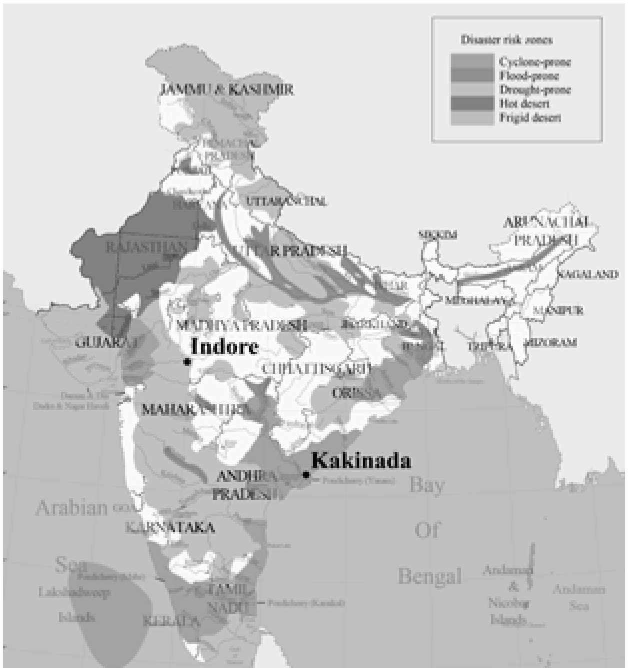
Monthly average humidity

Monthly average minimum humidity

Figure 22.
Annual variation in humidity for data collected in the past 30 years.

Air quality

Air quality is expected to worsen in the future. Air stagnation occurs when there are light winds and a lack of precipitation, leading to air mass remaining over an area for an extended period of time. Climate change projections point towards an increase in the number of air stagnation days.


Disaster risk zones
Cyclone-prone
Flood-prone
Drought-prone
Hot desert
Frigid desert
JAMMU & KASHMIR
UTTARANCHAL
RAJASTHAN
UTTAR PRADESH
SIKKIM
ARUNACHAL PRADESH
NAGALAND
MANIPUR
MIZORAM
MADHYA PRADESH
GUJARAT
Indore
ORISSA
Kakinada
ANDHRA PRADESH
KARNATAKA
TAMIL NADU
KERALA
Arabian Sea
Lakshadweep Islands
Bay Of Bengal
Andaman & Nicobar Islands
Andaman Sea

'The project will improve the ability of Indian emergency services to operate during climate extremes by adopting UK best practice and digital technology in selected cities in India.'

Arup Disaster Proofing Indian Smart Cities, 2016

'Stating that tackling natural calamities will be the big challenge in the future, Chief Minister N Chandrababu Naidu said the government will use best technologies and practices to make capital city Amaravati strong enough to withstand all kinds of calamities in the centuries to come. He said expert architects and planners from UK could join hands with the state government. He said AP's long coastline has been hit by many cyclones and floods recently. and managing the cyclones and adverse monsoon conditions with adoption of technology and designs could be vital for the long existence of Amaravati.'

The Times of India, 12 Nov 2016 reporting on the interactive session with UK specialists organised by British High Commission in Vijaywada.

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