Geographic Information Systems & Critical Infrastructure Protection

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CT 8330: Critical Infrastructure Protection (CIP)
Technological Leadership Institute, University of Minnesota

Session on Geographic Information Systems & CIP

Supplementary Material: http://www.cs.umn.edu/~shekhar/tli/

Tu. June 27th, 2017, Alumni Center Rm. 235
Tu. June 28th, 2016, Alumni Center Rm. 235
Tu. June 23rd, 2015, Alumni Center Rm.235
Tu. June 17th, 2014, Alumni Center Rm. 235
Tu. June 18th, 2013
Tu. June 19th, 2012
Fr. June 17th, 2011
Th. July 22nd, 2010
Introductions

- Round-table Introductions
  - Name, Affiliation
  - Background in GIS, GIS for CIP
  - Objective for session on GIS and CIP
Learning Objectives

We should be able to answer the following questions after this session:

1. What is a Geographic Information System (GIS)?
   - What are GIS Data-layers?
   - What are common GIS Operations? What are their inputs and outputs?
   - What are Geo-referencing systems? Data transfer standards?

2. How may GIS help?
   - Critical Infrastructure Protection (CIP)?
   - Emergency Management (EM)?
<table>
<thead>
<tr>
<th>Hour</th>
<th>Topics</th>
<th>Lecture</th>
<th>Exercise</th>
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<tr>
<td>0:00-0:30</td>
<td>Introductions</td>
<td>30 minutes</td>
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<td>0:30 -1:00</td>
<td>Motivation</td>
<td>7 slides, 15 minutes</td>
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<tr>
<td>1:00-1:30</td>
<td>GIS: Data, Standards</td>
<td>14 slides, 15 minutes</td>
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<td>1:30-2:00</td>
<td>GIS: Analytic Tools</td>
<td>14 slides, 15 minutes</td>
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<td>2:00-2:15</td>
<td>Break</td>
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<td>2:15-2:45</td>
<td>GIS for CIP - I</td>
<td>8 slides, 15 minutes</td>
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<td>2:45-3:15</td>
<td>GIS for CIP - II</td>
<td>9 slides, 15 minutes</td>
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<td>3:15-3:30</td>
<td>Case Study</td>
<td>6 slides, 10 minutes, Video (5-minutes)</td>
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<tr>
<td>3:30-3:45</td>
<td>Wrap-up</td>
<td>3 slides (5 minutes)</td>
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Outline

- **Motivation**
  - GIS & London Cholera (1854)
  - GIS & WTC (2001)
  - GIS & DHS/CIP

- Basics of GIS
- How can GIS help CIP?
- Case Study
- Next
GIS & London Cholera

- London Cholera, 1854
- Before germ theory
- John Snow
  - Cluster around a water pump
  - disabling pump helped!
- Modern Use
  - Cancer clusters
  - Crime hotspots
GIS & World Trade Center

- Support firefighters, rescue workers, utility crews
- 50+ GIS professionals for 2+ months

Source: Sean C. Ahern, Hunter College - CUNY
World Trade Center Area
USGS/NASA/JPL

Core Zone: orange/red areas are thermal hot spots
Sept. 16, 2001 mid-day
DHS & GIS

  - 6 Missions: Intelligence/Warning, Protect Key Infrastructure, …
  - 4 Foundations: Information Sharing and Systems, Law, …

  - National Planning Scenarios
  - Universal Task List (UTL), Target Capability List (TCL)
  - National Response Plan

- National Incident Management System (NIMS), 2004
  - Incident Command System
  - Common Operational Picture
NIMS

- Concepts and Principles
  - A Common Operational Picture accessible across agencies

- Interoperability Standards
  - Geospatial Information (item 4)
Example DHS Scenario & GIS

- Preparation of response to a chem-bio attack
- Help public officials to make important decisions
- Guide affected population to safety

PLANNING SCENARIOS
Executive Summaries
Created for Use in National, Federal, State, and Local Homeland Security Preparedness Activities

The Homeland Security Council
David Howe, Senior Director for Response and Planning

July 2004

(Images from www.fortune.com)
A recent use-case

- **Motivation:**
  - Reduce delays
  - Example: Tornado outbreak (2012)

- **Approach:**
  - Monitor Tweets
  - Filter on disaster keywords
  - Color maps

Even before cable news outlets began reporting the tornadoes that ripped through Texas on Tuesday, a map of the state began blinking red on a screen in the Red Cross' new social media monitoring center, alerting weather watchers that something was happening in the hard-hit area. (AP)

A tornado moves through the Dallas-Fort Worth area on Tuesday, April 3, 2012 in this still image taken from video. (Reuters TV/Reuters)
Active Learning Exercise

Learning Objectives: What is a Geographic Information System (GIS)?

Activity: Review the following document:


Answer the following questions using the congressional report:

1. Provide a definition of GIS based on this report.
2. Name two GIS applications used in daily lives of millions of people.
3. The report lists examples of why and how geospatial information is used. Which two examples are relevant to Emergency Management?
4. Name two CIP related federal agencies, which are members of Federal Geographic Data Committee.
Learning Objectives: What is a Geographic Information System (GIS)?


Answer the following questions using the above paper:
1. Name a few transformative spatial computing ideas beyond GIS.
2. List a few recent changes in the field of Spatial Computing.
3. List a short opportunity, which may help in CIP or Emergency Management.
Outline

- Motivation
- **GIS: An Overview**
  - Basics of GIS
  - Transfer Standards
  - Analytical Tools
- How can GIS help CIP?
- Case Study
- Next
**Defining GIS**

- Sample definitions
  - “… a computer data system capable of capturing, storing, analyzing, and displaying geographically referenced information—information attached to a location, such as latitude and longitude, or street location” (USGS.gov)
  - “… It allows you to analyze data visually and see patterns, trends, and relationships that might not be visible in tabular or written form.” (EPA.gov)

- Key: Spatial data are unique because they are linked to maps (location matters!)

- A GIS at least consists of
  - a database
  - map information
  - a link between them

Source: www.epa.gov/region5fields/gis.html
What’s special about spatial?

- Everything happens in geographic space
- Primitive = f(x, y, z, t)
- Tobler’s law
- Geographical relations
- Hagerstrand’s time-space geography
- Makes search and query powerful
Q? What is wrong with circular ranges of missiles (left bottom map)?
Correction: North Korea’s missiles (www.economist.com/node/1788311)
Basics I: Coordinate Systems

- Coordinate system
  - a standardized method for assigning codes to locations
  - so that locations can be found using the codes alone.

- Two directions
  - East-ing, e.g., x-direction value
  - North-ing, e.g., y-direction

- Two kinds of locations
  - Relative location, e.g., units of map’s paper sheet
  - Absolute locations
    - Geographic: Latitude, longitude, elevation
    - Projected: Universal Transverse Mercator System (& polar stereographic)
    - military grid
    - state plane

- Caution:
  - To compare maps, use common coordinate system.
  - To compute distance, direction, over large areas
    - Coordinate systems matter
    - Earth as flat (locally), spherical, ellipsoidal, etc.
Alternative georeferencing

- Symbolic Geo-referencing
  - Place names (e.g., Dinkytown, Eyjafjallajökull,)
  - Street address (200 Union St. SE, MN 55455)
  - Internet URLs

- Geo-code symbolic to numerical geo-reference
  - Ex.: street address to latitude-longitude on map
  - Reverse Geo-code: GPS reading to place-name

- A GIS package should be able to move between
  - map projections
  - coordinate systems
  - datums, and Ellipsoids
  - And do geocoding
Basics II: Spatial Data-Genres

- **Raster**: geo-images e.g., Google Earth
- **Vector**: point, line, polygons
- **Graph**, e.g., roadmap: node, edge, path
Raster Representation as fields

- Space divided into regular grid
  - Pixel = Cell of the grid
  - Each pixel assigned a gray value to represent local intensity
  - Resolution = pixel size

- Issues:
  - Approximation
  - Mixed pixels
  - Drop out
  - Interpolation
  - Multi-resolution
Vector Representation: Arc/node data structure

- **Primitives:** Node, Arc, Area
- **Constraints:** Topology Matters
  - Some GIS operations may be performed without accessing the point files.
  - Example: Is USA a neighbor of Canada?
3D Terrain Models, e.g., Elevation

- **Raster Representation**
  - Regularly Spaced Grid, e.g., 50m to 500m
  - Pixel value represents local elevation

- **Vector Representations**
  - Triangulated Irregular Networks (TIN)
    - Use optimal Delaunay triangulation of a set of irregularly distributed points.
  - Contours

Source for 5 pictures: SpatialSys.com
4D: Adding Time to GIS

- The missing $t$ in $(x, y, z, t)$
- Much interest in spatio-temporal dynamics, models
  - GPS trajectories
  - Seasonal variation
- Only a few methods as yet, still research
- Spatial modeling tools in few GIS, e.g. CA in IDRISI
- Transaction-based problem solved in 2D e.g. Oracle Spatial

Source:
http://upload.wikimedia.org/wikipedia/commons/1/12/2004_Indonesia_Tsunami_100px.gif
Outline

- Motivation
- GIS: An Overview
  - Basics of GIS
  - Transfer Standards
  - Analytical Tools
- How can GIS help CIP?
- Case Study
- Next
Data resources and Formats

Data Sources

- NSDI clearinghouses
- Geospatial One Stop
- National Map
- GDT, ESRI etc.
- Geography network
- Alexandria [www.alexandria.ucsb.edu](http://www.alexandria.ucsb.edu)

Data Formats

- SHP, E00
- DXF
- GeoTIFF
- Img
- VPF
- DRG, DEM, DOQQ
- TIGER/SDTS

Ex. Review MetroGIS datafinder to identify 3 data layers for estimating CIP.

- What kinds of critical infrastructure are covered by these datasets?

Caution: Data exchange by translation can lead to errors in attributes and in geometry.

- Example: Digitization errors
Approach: Interoperability via Standards

• SDTS
  • terminology, set of references, list of features, transfer mechanism, accuracy standard.
  • Includes DLG and TIGER data formats
  • FGDC – standards for metadata and selected feature (e.g., raster profile)
  • Other standards efforts are DIGEST, DX-90, the Tri-Service Spatial Data Standards, ...

• OGC
  • Open GIS Consortium, Inc. (www.opengis.org) with 256 members worldwide
  • Develops standards, Test Compliance
  • Simple feature model, WCS, WML, Sensor ML...

• ISO TC 211
  • 19129 : GIS - Imagery, Gridded and Coverage Data
  • 19130 : GIS-Sensor data model

• Agreement between OGC and ISO
OGC Initiatives

**Recent**
- Critical Infrastructure Protection Initiative, Phase 1.2 (CIPI 1.2) In Progress
- Emergency Mapping Symbology, Phase 1 (EMS 1) In Progress
- Land Information Initiative, Phase 1 (LII-1) Initiated
- OGC Web Services, Phase 2 (OWS-2) Initiated

**Past**
- Conformance & Interoperability Test & Evaluation, Phase 1 (CITE 1)
- Geospatial Fusion Testbed (GFST)
- Geographic Objects (GO-1)
- Geospatial One-Stop - Portal Initiative (GOS-PI)
- Multihazard Mapping Initiative, Phase 1 (MMI 1)
- Object Domain Modeling Support (ODMS) Initiative (ODMS)
- Open Location Services Testbed (OpenLS 1)
- Web Mapping Testbed, Phase 1 (WMT 1)
Active Learning Exercise

- **Learning Objectives:** What are Geo-referencing systems? Data transfer standards?

- **Activity 1:** Review MetroGIS (www.metrogis.org, www.datafinder.org/catalog)
  - Identify 3 data layers (and their data formats) for estimating CIP.
  - What kinds of critical infrastructure are covered by these datasets?
  - How up-to-date and complete are these datasets?
  - Which data transfer standards are supported?


  OMB Circular A-16 was issued to ensure that federal surveying and mapping activities met the needs of federal and state agencies and the general public and to avoid duplication of effort.

  Name a federal GIS initiatives relevant to CIP and its contribution for data transfer standards.
Outline

- Motivation
- GIS: An Overview
  - Basics of GIS
  - Transfer Standards
  - Analytical Tools
- How can GIS help CIP?
- Case Studies
Spatial Data Analysis

Recorded View

1. Data Bases, Queries
   - CUAHSI
   - USGS
   Captures observations and information needs

2. Situational Awareness
   - Where are the hot-spots? When are Hot-moments?
   - How does situation this year compares with historic data?

Predictive View

3. Predictive Analysis
   - From known classes (e.g. terrorist attack, hazmat spills, …), which class of event does this represent?
   - Predict impact of an event given other environmental and socio-economic variables.

4. Knowledge Discovery
   - What other events could occur with this pattern?
     e.g. bar closing or evacuation => crime events nearby a little later
Analytic Tools and GIS

- **Functionality:**
  - Searches based on spatial relationships, e.g. distance
  - Spatial Statistics
  - Spatial Models, e.g. plume simulation
  - Spatio-temporal

- **Example Tools**
  - ESRI ArcGIS, ArcView
  - AutoCAD Map
  - GRASS
  - IDRISI (Clark University, Worcester, MA)
Analytic Tools and GIS

- Measurements, e.g., Distance, perimeter, adjacency, direction
  - Ex.: Open Google Maps (not in Lite mode)
  - Right-click on starting point. Choose Measure distance.
  - Click anywhere on map to create a path to measure.

- Search
- Location analysis
- Terrain analysis
- Flow analysis
- Spatial Patterns
- Create new maps
Search

- Search: Thematic search; Search by region, proximity, nearest neighbor, ...
- CIP Example: What is near a planned electric power transmission line (red)?
  - A gas pipeline (yellow)
  - Mitigation: Protect gas line during construction Or relocate to avoid spatial interdependency
- Source: (Abdalla 2010)
Location Analysis

- Location analysis: Buffer, corridor, overlay, ...
- CIP Example: Defective (yellow) electric power station => outage area (circle)
  - Affects backup (red) communication line between data centers
  - Mitigation: Establish alternative communication
- Source: (Abdalla 2010)
Location Analysis - 2

- Location analysis: Buffer, corridor, overlay, ...
  - Distance or Travel time

- CIP Example: Hospital Drive Time

- Another example: Ecology

Source: Nevada’s approach to CIP (publicintelligence.info/nevadasilvershield.pdf)
Terrain Analysis

- Terrain analysis: Slope/aspect, catchment, drainage, Floods
- CIP Example: Flood prediction using Terrain contours and predicted precipitation
  - Includes a transmission line powering a air traffic radio beacon
  - Mitigation: protect beacon by sandbags, backup generator at beacon
- Source: (Abdalla 2010)
Terrain Analysis-2

- Terrain analysis: Slope/aspect, catchment, drainage, Floods

[Images of DEM, Flow path, Flow direction, 8 directions, and Flow accumulation tables]
Flow Analysis

- Flow analysis: Connectivity, shortest path, travel-time map
- CIP Example: A flood shuts down a power substation (!)
  - serving an air traffic control (tower) and a chemical plant (triangle)
- Source: (Abdalla 2010)
Flow Analysis - 2

- Flow analysis
  - Connectivity
  - Shortest path
  - Travel-time map

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<th>Static</th>
<th>Time-Variant</th>
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<td>Which is the shortest travel time path from downtown Minneapolis to airport?</td>
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<td>Which is the shortest travel time path from downtown Minneapolis to airport?</td>
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</table>
Spatial Patterns

- Spatial Patterns
  - Spatial autocorrelation, Distribution Change detection, …
  - Hotspot, Colocation, …

- CIP Example:

Contaminated Cooling Towers

Five buildings have been identified as the potential source of the Legionnaires' disease outbreak in the South Bronx.

- Possible sources of Legionnaires' outbreak
- Additional sites found with legionella bacteria
- Locations of people with Legionnaires'

Hotel That Enlivened the Bronx Is Now a ‘Hot Spot’ for Legionnaires’

By WINNIE HU and NOAH REMNICK  AUG. 10, 2015

The Opera House Hotel is at the center of the outbreak. Edwin J. Torres for The New York Times
Spatial Patterns

(a) Legionnaire’s in New York (2015)

(b) Output of SaTScan

(c) Output of RHD

Log LR = 34.55
p-value = 0.001

RHD Source: Ring-Shaped Hotspot Detection: A Summary of Results, IEEE Intl. Conf. on Data Mining, 2014 (w/ E. Eftelioglu et al.)
Create new Maps

- Create new maps: map overlay, re-classification, ...
- CIP Example: No fly zones for UAVs
  - overlays airports, military bases, national parks, temporary restrictions (e.g., events)
Simulation to Project Scenarios

- Simulation for Scenario based planning
  - Specify incident location
  - Project impact footprint using a physical model
    - Plume simulation using gas/particle dispersion
    - Flood simulation using water flow
Create new Maps

- Create new maps: map overlay, re-classification,
- CIP Example: South Portland's City Council on Monday approved a buffer between important public facilities and liquefied natural gas distribution plants. The buffers are shown on the map as light blue shaded circles around important public facilities. Courtesy city of South Portland
Active Learning Exercise

Learning Objectives
- What are GIS Data-layers?
- What are common GIS Operations? What are their inputs and outputs?

Learning Objectives: Why and how GIS is use in CIP?

Activity: Use Google Maps to measure (straight line as well as driving) distance between the MSP airport and University of Minnesota.


1. What are critical transportation infrastructures (CTI)? Provide two examples.
2. Review sample CTI disaster information needs (pp. 4). Which of these are geo-spatial?
3. What is remote sensing? How may it help assess infrastructure damage?
4. Match GIS benefits in disaster management (pp. 6) with GIS Analytic Tools, e.g., measurements, search, location analysis, terrain analysis, flow analysis, spatial patterns, ...
Active Learning Exercise (Extra)

Learning Objectives

- What are GIS Data-layers?
- What are common GIS Operations? What are their inputs and outputs?


(a) The attributes of different types of geospatial data - such as roads and bridges, buildings, lakes and rivers, counties - can each constitute a layer or theme in GIS. List three layers of geospatial information relevant to CIP.

(b) The power of GIS is the ability to combine geospatial information in unique ways - by layers or themes - and extract something new. List two possible use of such power in context of emergency management using specific GIS operations discussed in last slide.
Outline

- Motivation
- Basics of GIS
- How can GIS help CIP?
  - Critical Infrastructure
  - Role of GIS in CIP
- Next
**Critical Infrastructure (CI)**

“systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters” (Patriot Act. 2001)

Q? Which CIs are geo-spatial?

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<th>Critical Infrastructure Sectors</th>
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<tr>
<td>Food and Agriculture</td>
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<td>Banking and Finance</td>
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<td>Chemical</td>
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<td>Commercial Facilities</td>
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<td>Communications</td>
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<tr>
<td>Critical Manufacturing</td>
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<tr>
<td>Dams</td>
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<tr>
<td>Defense Industrial Base</td>
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<td>Emergency Services</td>
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<tr>
<td>Energy</td>
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<tr>
<td>Government Facilities</td>
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<tr>
<td>Healthcare and Public Health</td>
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<tr>
<td>Information Technology</td>
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<tr>
<td>National Monuments and Icons</td>
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<tr>
<td>Nuclear Reactors, Materials and Waste</td>
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<tr>
<td>Postal and Shipping</td>
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<tr>
<td>Transportation Systems</td>
</tr>
<tr>
<td>Water</td>
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</tbody>
</table>
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Why are CIs critical?

- Provide **basic support** for life, livelihood, and communities
- Disruption **affects all sectors**: businesses, households, other CIs
- CIs are vulnerable to physical damage in **disasters**
  - 1993 Midwest Floods, 1994 Northridge Earthquake, 2003 Northeast Blackout,
Economic impacts

- **1993 Midwest floods**: Des Moines (IA) suffered more loss from infrastructure outage than from physical flooding.

- **1994 Northridge EQ**: highway damage accounted for 27% (US$1.5 billion) of regional business loss.

- **1995 Kobe EQ**: massive failures of virtually all major infrastructures essentially lead to cessation of urban economic functions.

- **2003 Northeast blackout**: estimated to have cost US$4.5~$10.0 billion in economic loss.

Highway bridge damage in Northridge earthquake (photo: EERI)
Household impacts

- Infrastructure outages can affect households in complex ways
  - Public safety dangers from utility loss and traffic delays for first responders
  - Infrastructure outage could force households to seek emergency shelter
  - Infrastructure loss may compound or even cause health problems and injuries
  - Business disruption may cause job loss or financial hardship; etc.

- Some socio-economic groups (e.g., elderly) are especially vulnerable

- One survey found that households gave highest priority in disaster policy to
  - Electric power
  - Water
  - Hospitals
Mapping Critical Facilities & Infrastructure

- Critical Facilities
  - Cultural Significance, Public Assembly, Technological Hazards, Economic, Critical to City Operation

- Critical Infrastructure
  - Power, Telecom, Water, Transportation, …

Source: Nevada’s approach to CIP (publicintelligence.info/nevadasilvershield.pdf)
Infrastructure Interdependencies

“bidirectional relationship between two infrastructures through which the state of each infrastructure influences or is correlated to the state of the other” (Rinaldi et al., 2001)

Power outage in Kobe led to:

- Loss of water filtration plants & pump stations
- Fire ignitions from natural gas leaks and electricity sparks
- Malfunction of traffic signals
- Loss of satellite emergency communications
- Hospital shutdowns
- Loss of water and elevators in high-rises
- Lack of heating at emergency shelters

Urban fires in 1995 Kobe Earthquake
(Source: Nojima and Kameda, 1996)
Geospatial Interdependencies

- Geographic proximity of infrastructure components
  - Common corridor
  - Transmission lines, water pipelines, gas pipelines, telecommunications
- Geographic catastrophe impacts multiple infrastructures
  - Electric fire may ignite gas pipelines

Physical Interdependencies

**Exercise:** Fill out interaction of various CI with Hospital and Public Health.

<table>
<thead>
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<th></th>
<th>Transport for</th>
<th>Electricity for</th>
<th>Water for</th>
<th>Telecom for</th>
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<td>Communications</td>
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<td>SCADA</td>
<td>Generator fuel</td>
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<td>Cleaning supplies</td>
<td>Pumping, control</td>
<td>SCADA</td>
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<td>Telecom</td>
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<td>Cooling</td>
<td>Heat building</td>
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<td>Oil, Gas</td>
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<td>Compressor, storage control</td>
<td>Cooling, production</td>
<td>SCADA</td>
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<td>Hospital</td>
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</table>
Interdependencies
Active Learning Exercise

- **Learning Objectives:** Why and how GIS is used in CIP?


1. What is a geospatial interdependency? Provide an example to illustrate your definition.
2. How is geospatial interdependency different from physical interdependency?
3. Report states that “*mutual dependence and interconnectedness made possible by the information and communications infrastructure lead to the possibility that our infrastructures may be vulnerable in ways they never have been before.*”

Which GIS operations may be used to identify geospatial interdependencies among critical infrastructure components such as transportation, energy, water, communications, etc.?
Learning Objectives: Why and how GIS is used in CIP?


1. What is a geographic or spatial interdependency? (Section 3.2, pp. 5 & sc. 5.3.1, p. 13).
2. What is location-based Critical Infrastructure Interdependency (LBCII)? List 6 steps of LBCII. List 3 components of LBCII. (Section 4, pp. 8-11).
3. List a few GIS analytical tools used in the Vancouver case study in Section 5.3. Recall GIS Analytic tools include measurements, search, location analysis, terrain analysis, flow analysis, spatial patterns, etc.
Outline

- Motivation
- Basics of GIS
- How can GIS help CIP?
  - Critical Infrastructure
  - Role of GIS in CIP
- Next
Disasters

- Natural
  - Flood, Tsunami, Winter Storm, Thunderstorm, Tornado, Hurricane
  - Earthquake, Volcano, Landslide, Fire or Wildfire, Heat
- Man-made, Technological
  - Terrorism, Nuclear Power Plant Emergency
  - Dam Failure, Chemical Emergencies, Hazardous Material
Disaster Resilience

• Resilience
  – Survival through natural & man-made disasters
  – Needs never exceed resources & ability to respond
  – Physical, Emotional, Relationship and Spiritual

• Disaster life-cycle phases
  – Risk Assessment
  – Risk Reduction & Mitigation
  – Prevention & Preparedness
  – Response
  – Recovery

• Disaster Resilience for critical infrastructure
• Critical infrastructure for Disaster Resilience
Risk Assessment: Risk Maps

Minnesota Tick-borne Disease Risk*

Tick-borne disease (TBD) risk is confined to forested areas throughout the state.
Take precautions to prevent TBD when visiting these areas.

USGS: science for a changing world

Minneapolis Department of Health – Infectious Disease Epidemiology, Prevention and Control Division
(612) 201-5418 – TDD/TTY (612) 201-5497 - www.health.state.mn.us
April 2013
Risk Assessment: Mapping Critical Assets

Government Center

Chemical Factory

Government Center

Hospital

Farm Chemicals

Theatre

Telephone Switching
Delay an adversary from gaining access to critical infrastructure is paramount such as *Pumping Stations, Substations, Regulator Stations, Switching Centers*

Equipment or technology to delay entry or access is based on its spatial relationship to the critical facility or infrastructure

GIS uses include:

- *Perimeter Management*
- *Barrier Management*
- *Patrol route planning*
- *Persistence Surveillance*
Prevention: Perimeter Management

Super Bowl 50 Pedestrian Routes
Super Bowl City is a secure perimeter with four checkpoints. Pedestrians may use the checkpoints, walk around the perimeter and use Muni/BART portals to cross Market Street.
Preparedness: Modeling Scenarios

- GIS for Scenario based planning
- Specify incident location
- Map impact footprint using a model, e.g., plume simulation
- Assess vulnerable population using demographic maps
- Plan response, e.g., evacuation routes or shelter in place
- ...
Preparedness: Emergency Management Planning
Detection & Response

- Detection is accomplished using:
  - video motion detectors
  - infrared
  - vibration
  - closed-circuit television
  - proximity sensors
  - and modeling tools.

- GIS uses include:
  - Emergency Management Planning
  - Mapping Critical Asset Locations
  - Infrastructure Inventory
  - Modeling Events
Response & Recovery

- GIS is used to create a common operational view during response.

- GIS uses in Recovery include:
  - Customer Reliability
  - Emergency Vehicle Dispatch and Tracking
  - System Restoration Monitoring
  - Damage Assessment
Response: Situation Awareness

**OBJECTIVES**

- Provide a real-time situation awareness
- Where are affected people?
- Which roads and sites are usable?
- Structural health and performance, …

**GIS Technologies**

- Field deployable in an ad-hoc environment
  - Flood
  - Partial Infrastructure loss (e.g. electricity, cell towers, Internet, …)
- Remote sensing: air, satellite, …
- VGI, e.g. OpenStreetMap
- Citizens as sensors, e.g. Tweets
- In-situ sensing
  - Reestablish within 12-24 hours
  - Despite poor infrastructure
Active Learning Exercise

Learning Objectives
- Why and how GIS is used in Critical Infrastructure Protection (CIP)?

Activity: Review: M. Kulawiak et al, “Geographical Information System for Analysis of Critical Infrastructures and their Hazards due to Terrorism, Man-Originated Catastrophes and Natural Disasters for the City of Gdansk”, in Information Fusion and Geographic Information Systems (Ed. V.V. Popovich et al.).

1. Name two GIS layers used in this case study.
2. Name two kinds of GIS analysis used in this case study.
3. Did the case study address the issue of interoperability across data sources?
4. Did it address the issue of data accuracy?
5. Is their system capable of addressing multiple incident?
Outline

- Motivation
- Basics of GIS
- How can GIS help CIP?
- Case Study
- Next
Scenario- Nuclear Power Plant Accident

Nuclear Power Plants in Minnesota

Monticello

Twin Cities

Prairie Island
Buffer Zone (10-miles) Around a Nuclear Power Plant

Monticello Power Plant
Affected Cities
Evacuation Destination
U of M
A Scenario: Monticello Emergency Planning Zone and Population

Emergency Planning Zone (EPZ) is a 10-mile radius around the plant divided into sub areas.

<table>
<thead>
<tr>
<th>Monticello EPZ</th>
<th>Subarea</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>4,675</td>
</tr>
<tr>
<td></td>
<td>5N</td>
<td>3,994</td>
</tr>
<tr>
<td></td>
<td>5E</td>
<td>9,645</td>
</tr>
<tr>
<td></td>
<td>5S</td>
<td>6,749</td>
</tr>
<tr>
<td></td>
<td>5W</td>
<td>2,236</td>
</tr>
<tr>
<td></td>
<td>10N</td>
<td>391</td>
</tr>
<tr>
<td></td>
<td>10E</td>
<td>1,785</td>
</tr>
<tr>
<td></td>
<td>10SE</td>
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<td></td>
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<td>3,408</td>
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<td>2,354</td>
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<tr>
<td></td>
<td>10NW</td>
<td>707</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>41,950</strong></td>
</tr>
</tbody>
</table>

Data source: Minnesota DPS & DHS
Web site: http://www.dps.state.mn.us
http://www.dhs.state.mn.us
Estimate EPZ evacuation time:
Summer/Winter (good weather):
3 hours, 30 minutes
Winter (adverse weather):
5 hours, 40 minutes
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Evacuation Zone</th>
<th>Possible Event Locations</th>
<th>Evacuation Population</th>
<th>Evacuation Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear Detonation – 10-Kiloton Improvised Nuclear Device</td>
<td>Large (50 m.)</td>
<td>Entire Metro</td>
<td>Over 2 million.</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Chemical Attack – Blister Agent</td>
<td>Medium (2-5 m.)</td>
<td>CBD (Mpls, St. Paul)</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Chemical Attack – Toxic Industrial Chemicals</td>
<td>Medium (2-5 m.)</td>
<td>Refinery (Newport)</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Chemical Attack – Nerve Agent</td>
<td>Medium (2-5 m.)</td>
<td>CBD (Mpls, St. Paul)</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Chemical Attack – Chlorine Tank Explosion</td>
<td>Medium (2-5 m.)</td>
<td>Rail yards</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Radiological Attack – Radiological Dispersal Devices</td>
<td>Medium (2-5 m.)</td>
<td>CBD (Mpls, St. Paul)</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
<tr>
<td>Explosives Attack – Improvised Explosive Device</td>
<td>Small (1-2 m.)</td>
<td>Mall of America, U of M sports event</td>
<td>TBD</td>
<td>Out of Evac. Zone</td>
</tr>
</tbody>
</table>
Outline

- Motivation
- Basics of GIS
- How can GIS help CIP?
- Case Study
- Next
  - geospatial.umn.edu
  - Csci 5715: Spatial Computing (Fall 2014)
Looking Ahead

- **Csci 5715: From GPS and Google Earth to Spatial Computing**
  - Fall 2016: Mondays 630pm-9pm, 3-115 Keller Hall (9/12-12/12)

- **Topics:** Positioning, Remote Sensing, Spatial Statistics and Data Mining, Spatial Databases (SQL3/OGIS), data-structures (e.g., R-tree, Vornoi diagram), algorithms (e.g., routing), Geo-visualization (e.g., cartography).

- Recent Syllabus: [http://www.spatial.cs.umn.edu/Courses/Fall15/5715/](http://www.spatial.cs.umn.edu/Courses/Fall15/5715/)
Spatial Resources at UMN

- Provides training on spatial tools and data-sets

- **Recent Workshops:**
  - Mapping 101: Introduction to Spatial Analysis using ArcGIS Online
  - Desktop GIS 101: Analyzing Data and Creating Maps
  - SQL 101: Spatial Data Revealed
  - Imagery 101: Discovering Commercial Satellite Imagery with DigitalGlobe Basemap
  - LiDAR 101: Basics of Using LiDAR Data
  - Cartography 101: Designing Appealing Maps
  - Esri Virtual Campus

- Details: [https://uspatial.umn.edu/](https://uspatial.umn.edu/)
Other Resources on GIS & CIP

- 2016 book