Reducing Service Interruptions in Linear Infrastructure Systems (Transportation and Water/Sewer) by Synchronizing Schedules for Selected Maintenance Activities

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Introduction

Interdependency of lifeline systems:

- Electric and potable water transmission and distribution, wastewater collection and treatment, highways, railroads, seaports and inland waterway ports.

Interdependent linear infrastructure systems (ILIS)

- In ILIS events are linked by time and dynamics of the interactions between the systems.

Introduction

Interdependent linear infrastructure systems (ILIS)

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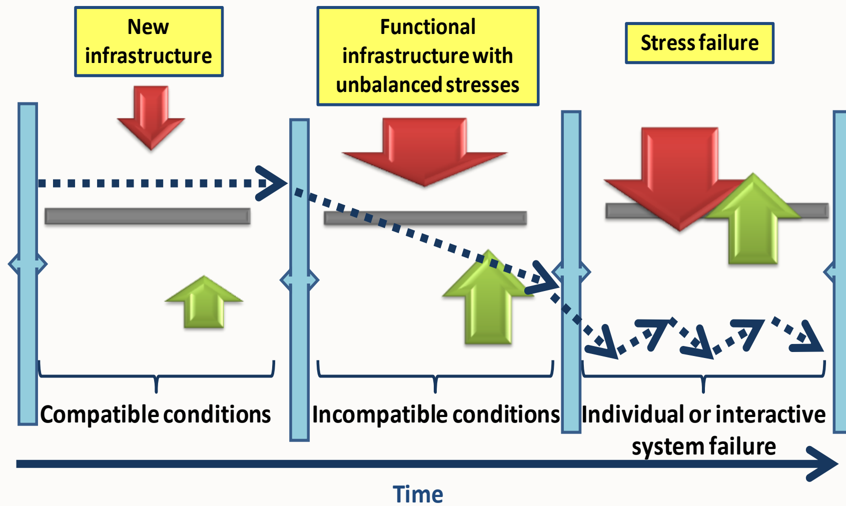

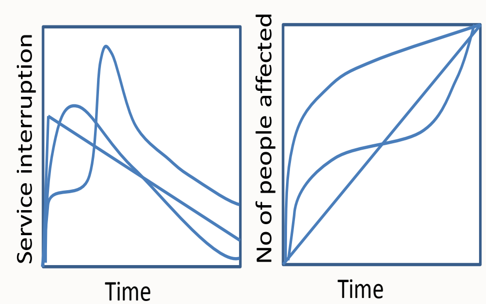

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Project objectives

Objectives of this research are to:

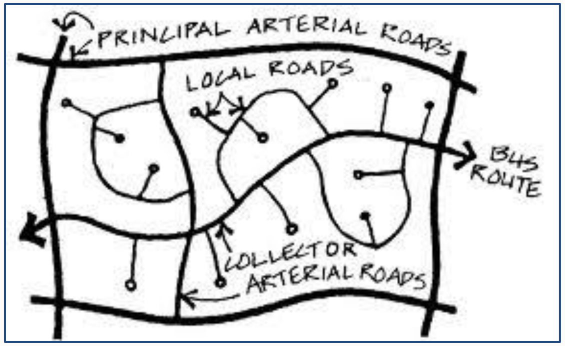
- Characterize service interruption profiles in interdependent linear infrastructure systems (ILIS);
- Identify interactively the major events which cause service interruptions;
- Develop a tool to establish checkpoints for service quality.



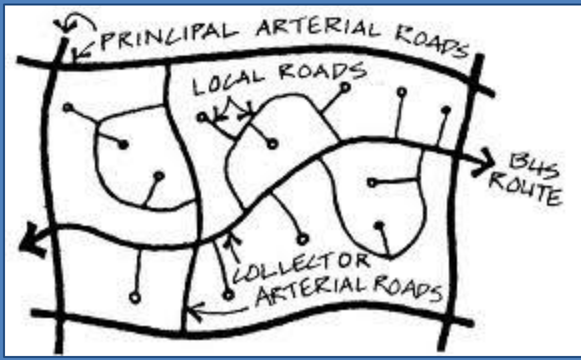


Problem Statement

1. What are the similarities in service interruption profiles in ILIS (transportation, water/sewer)?
2. How do the service failure events relate to one another in ILIS?
3. How can we establish check points?
4. How can we develop coordinated maintenance schedules to reduce service interruptions and increase maintenance cost effectiveness?

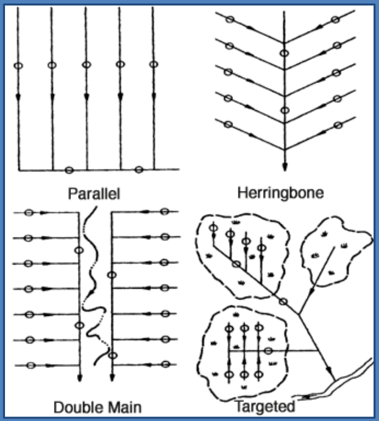


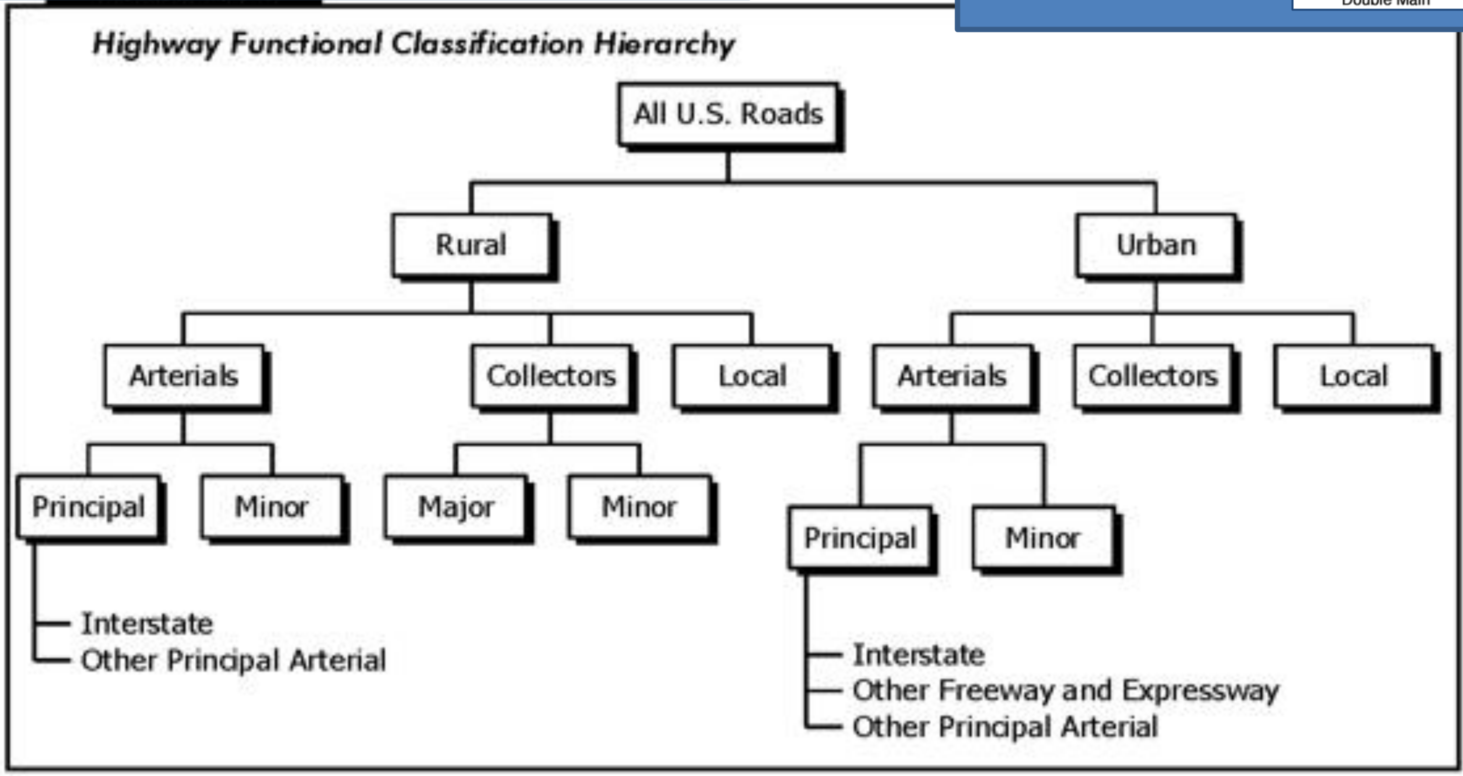
Classification hierarchy



Roads

Pipelines





Methodology

A. Identification of service interruption hazard modes in linear infrastructure systems (transportation, water & sewer, power)

1. ***Causes of service quality decline and interruptions (service specific maintenance factors)***

   (*i.e.,* design and operational elements such as stresses during operation, aging and wear out, a software coding error, human errors, or operator-and-maintenance-induced factors).

2. ***Service quality and system redundancy***

   (Identification of mechanisms to detect service interruptions with ease and in a timely manner).

3. ***Service quality metrics***

   (Potential consequences due to quality decline and interruptions).

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Methodology

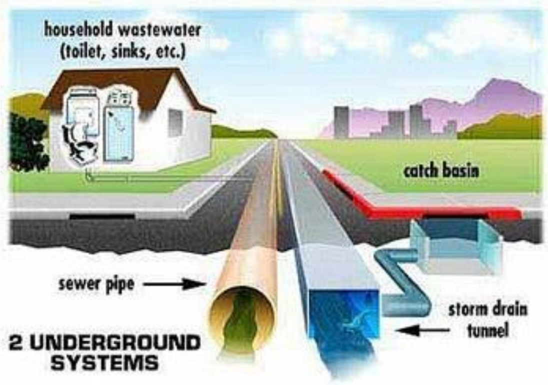
B. Service quality and priority assessment

- Interactive analysis to quantify the possible service interruptions due to system specific failure mechanisms.
- ILIS consequence number (ILIS-CN): Being developed using criteria based on frequency and severity of consequences.

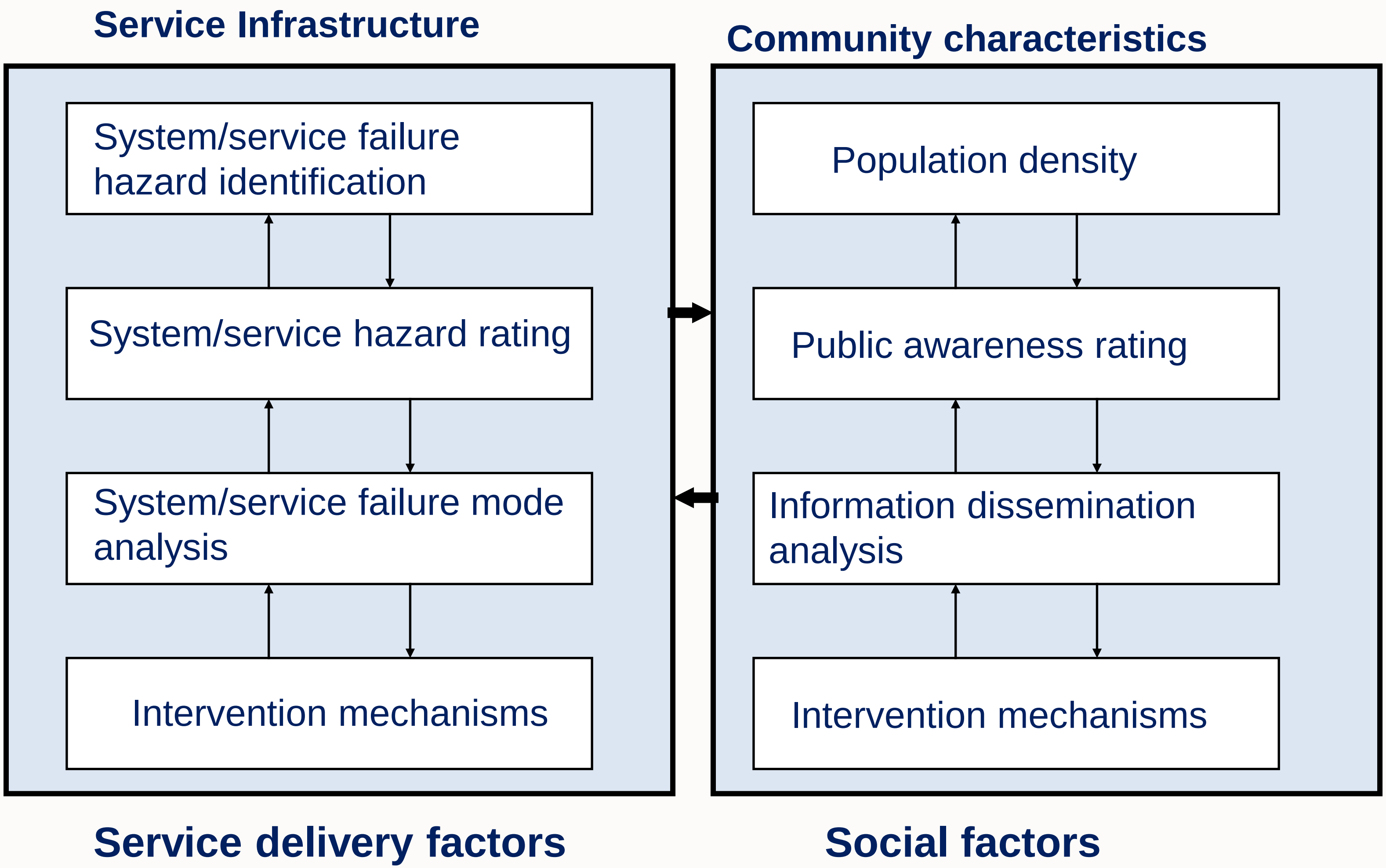
Methodology

C. Profiling, classification and rating of hazard modes

- A rating system (metrics) for different service interruption hazard modes based on:
  - *Failure frequency*
  - *System redundancy for failure*
  - *Consequence rating*
  - *Potential impacts on functioning of other co-located linear infrastructures*



Methodology
Risk management in lifeline systems



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Methodology
Risk management in lifeline systems

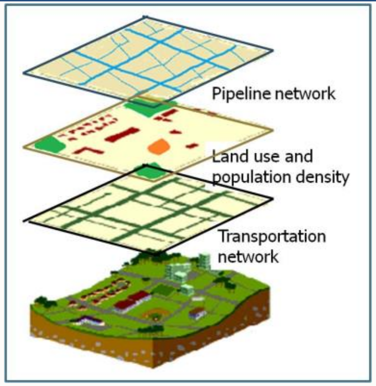
Hazard driven measures

Technology driven measures

Regulatory driven measures

What is desired

Service Quality



Economic limitations

Demographic limitations

Environmental limitations

What can be achieved

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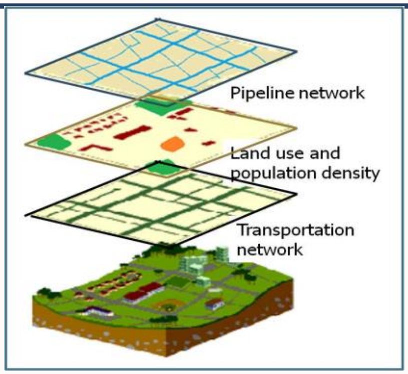
Methodology- Design factors

Origin	Pipeline Service Failure Risk Factors	Transportation Service Failure Risk Factors
Design	Age (D2) Pipe Material (D3) Pipe Length (D4) Pipe Capacity (D5) System Redundancy (D6) Pipe Pressure (D8) Material being piped (D9)	Age (D2) Road Material (D3) Travel Distance (D4) Road Capacity (D5) System Redundancy (D6) Traffic Load (D8) Transport needs (people, goods) (D9)

Methodology- Design factors

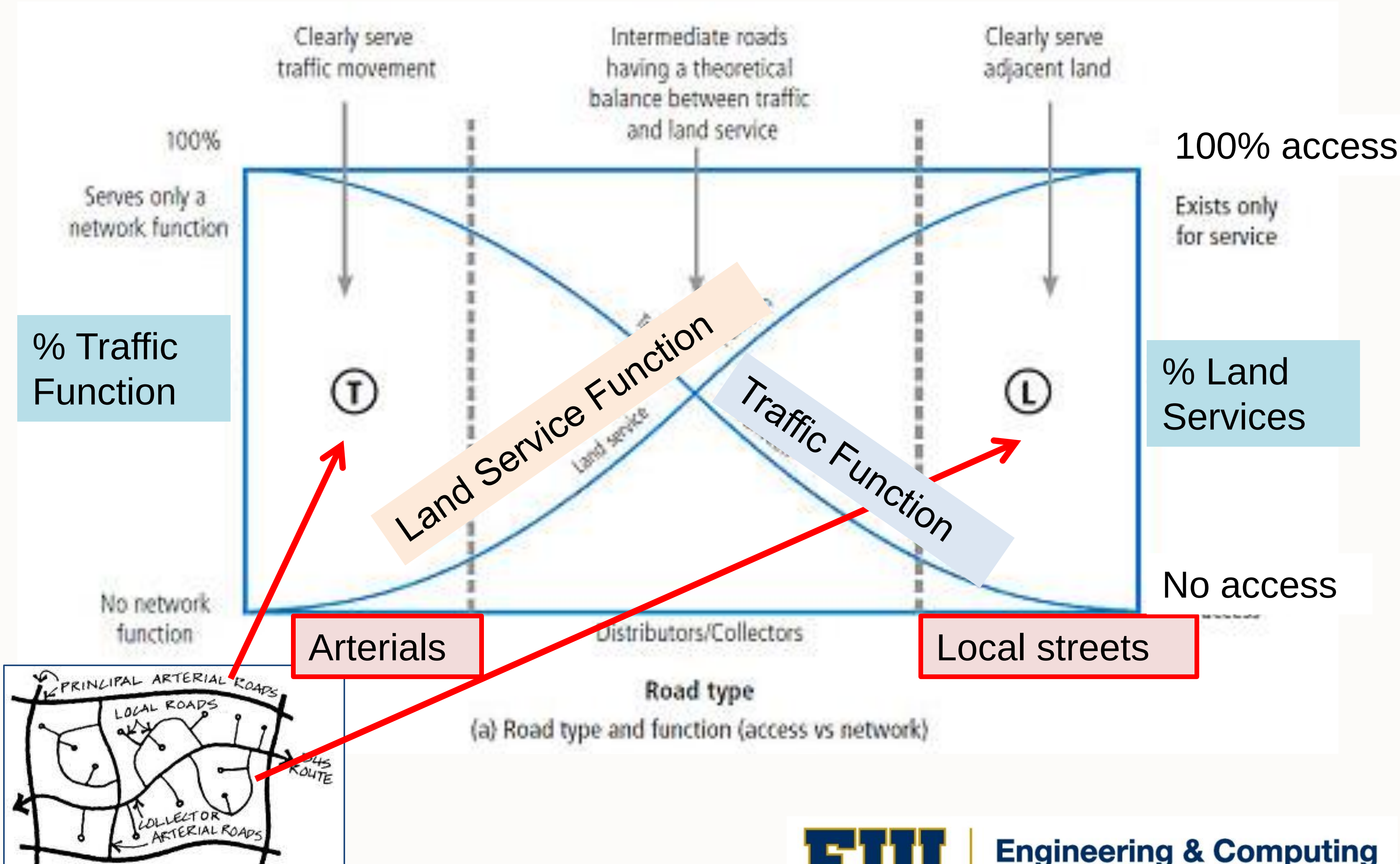
Origin	Pipeline Service Failure Risk Factors	Transportation Service Failure Risk Factors
Design	Age (D2)	Age (D2)
	Pipe Material (D3)	Road Material (D3)
	Pipe Length (D4)	Distance (D4)
	Pipe Capacity (D5)	Capacity (D5)
	System Redundancy (D6)	System Redundancy (D6)
	Degree of Automation (D7)	Degree of Automation (D7)
	Pipe Pressure (D8)	Traffic load (D8)
	Material being piped (D9)	Transport needs (people, goods) (D9)
Operational	No. of People Employed (O1)	No. of drivers (O1)
	Periodic Training Program (O2)	
	Frequency of Inspection (O3)	
	Work Hours (O4)	Work Hours (O5)
	Morale (O5)	Morale (O6)
	Work Ethics (O6)	Driving Habits (O7)
Environmental	Geology (E1)	Geology (E1)
	Geography (E2)	Geography (E2)
	Weather (E3)	Weather (E3)
	Vibration (E4)	Vibration (E4)
	Nearby Activities (E5)	Nearby Activities (E5)
Acts of God	Earthquake (G1)	Earthquake (G1)
	Arson (G2)	Arson (G2)
	Flood (G3)	Flood (G3)
	Hurricane (G4)	Hurricane (G4)



Urban Factors

1. Population density
2. Land use
3. Transportation network structure
4. Pipeline netwrok structure

Numerical Analyses



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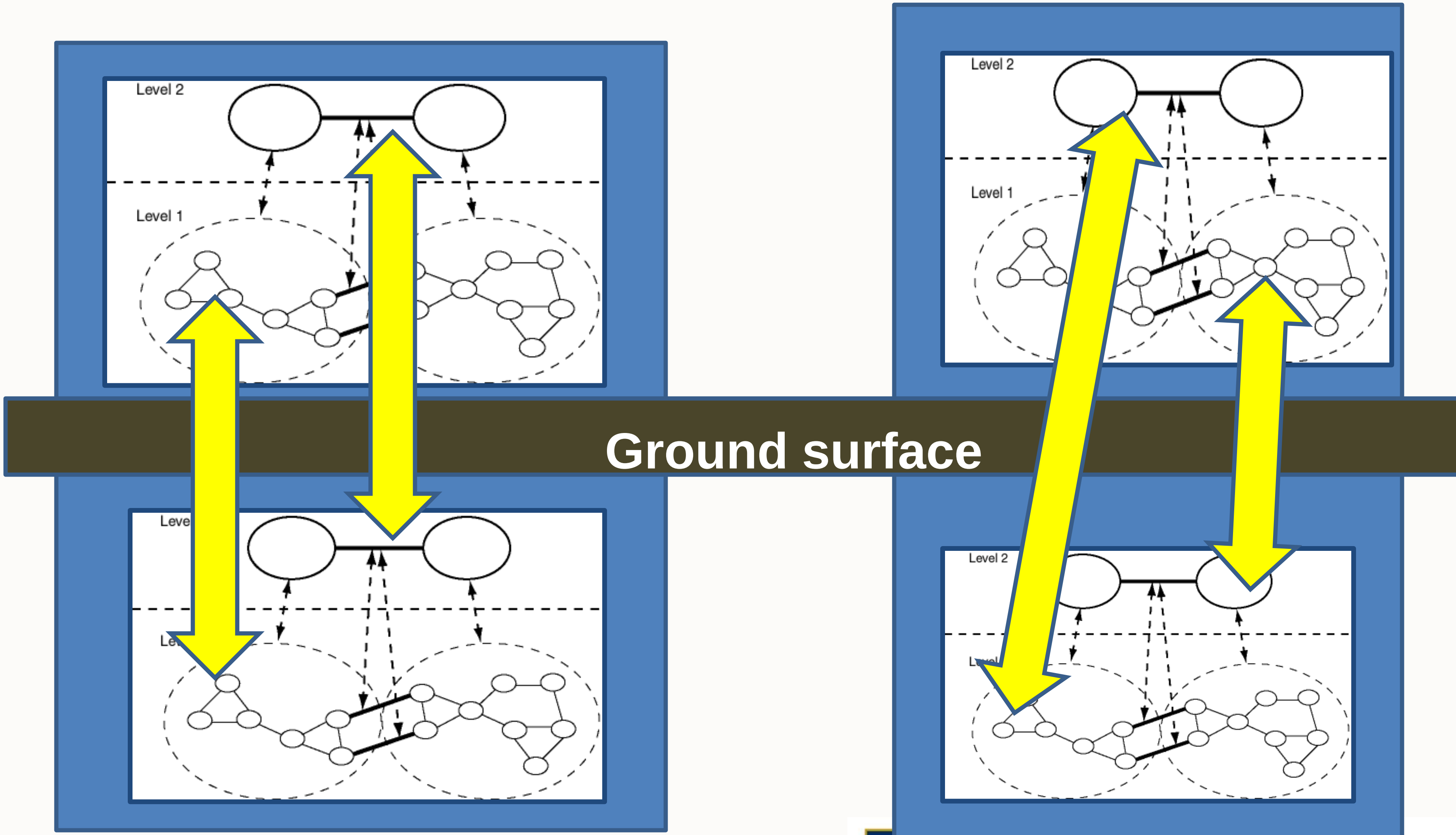
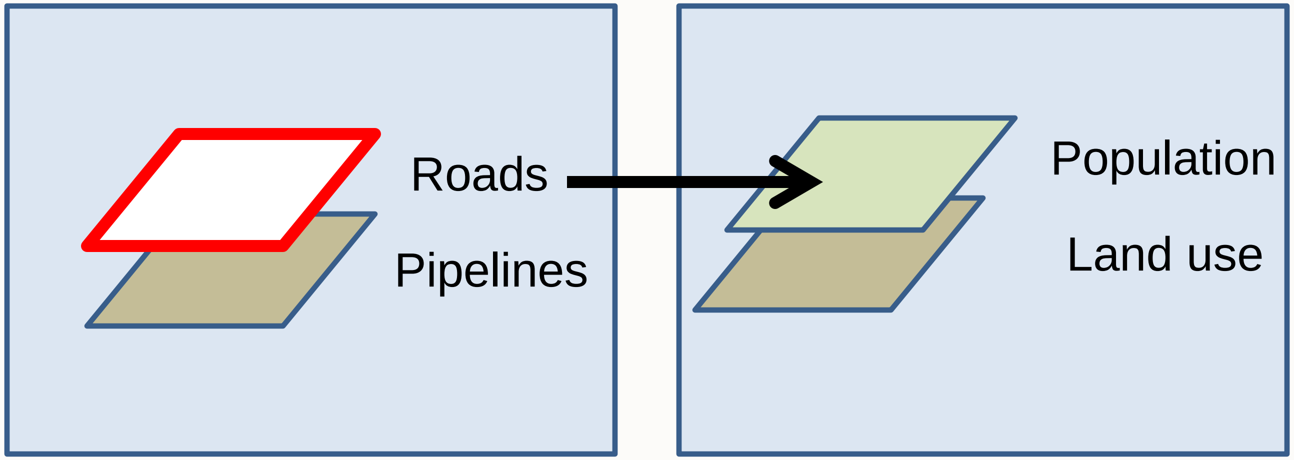
Pipeline classification hierachy



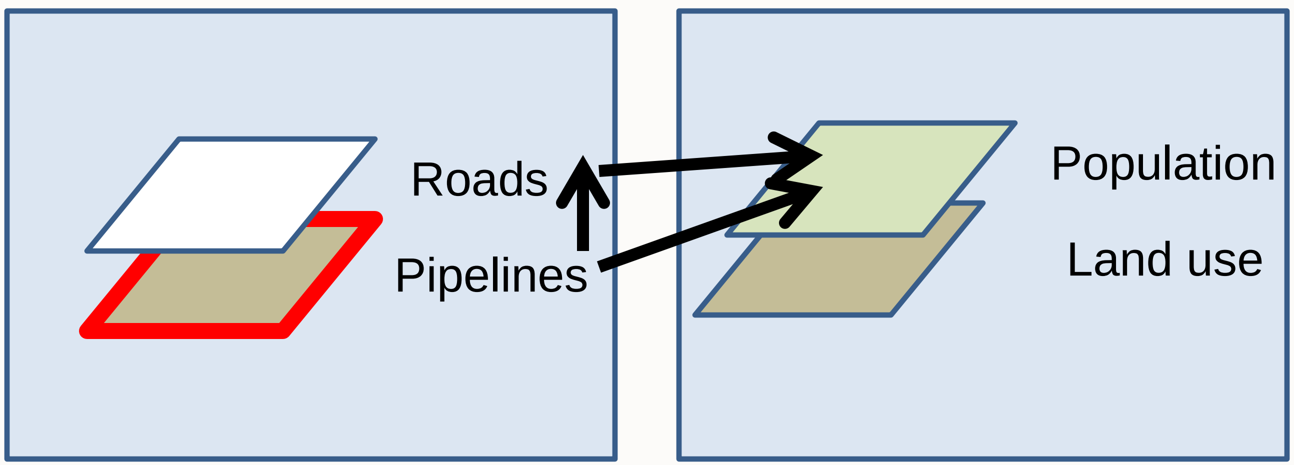
Numerical Analyses (Roads)

Origin	Failure Risk Factor	Risk Factor Score	Detectability Score	Consequence Score	VPN
Design	Age	10	4	5	200
	Road Material	4	1	6	24
	Road Distance	10	6	5	300
	Road Capacity	2	2	6	24
	Road Redundancy	2	2	6	24
	Traffic Load	4	2	5	40
	Transport Need	4	2	4	32



Numerical Analyses (Pipeline)

Origin	Failure Risk Factor	Risk Factor Score	Detectability Score	Consequence Score	VPN	Overall VPN
Design	Age	10	4	5	200	40000
	Pipe Material	4	1	6	24	576
	Pipe Length	10	6	5	300	90000
	Pipe Capacity	2	2	6	24	576
	System Redundancy	2	2	6	24	576
	Degree of Automation	4	2	5	40	1600
	Pipe Pressure	4	2	4	32	1024



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Numerical Analyses

- Vr = vulnerability due to road closure

Road closure = Population impact due to road closure

Road only



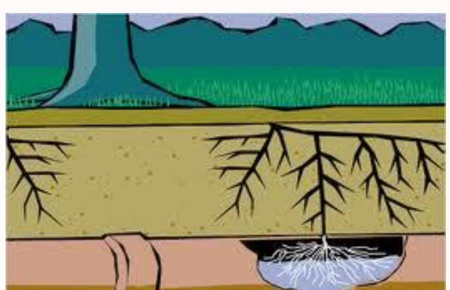

- Vp = vulnerability due to pipeline breakage

Pipeline breakage =

Population impact due to road closure **X**

Population impact due to pipeline service failure

Road + Pipeline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Benefits for end users

- Developing strategies to minimize service interruptions

  (i.e., identifying areas where agencies can coordinate maintenance schedules to maximize maintenance efficiencies to improve service quality and reduce cost);

- Improving service quality (technical, environmental, social, economic) factors;
- Improving service quality by smart maintenance planning for transportation and water/sewer infrastructure.

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Thank you

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