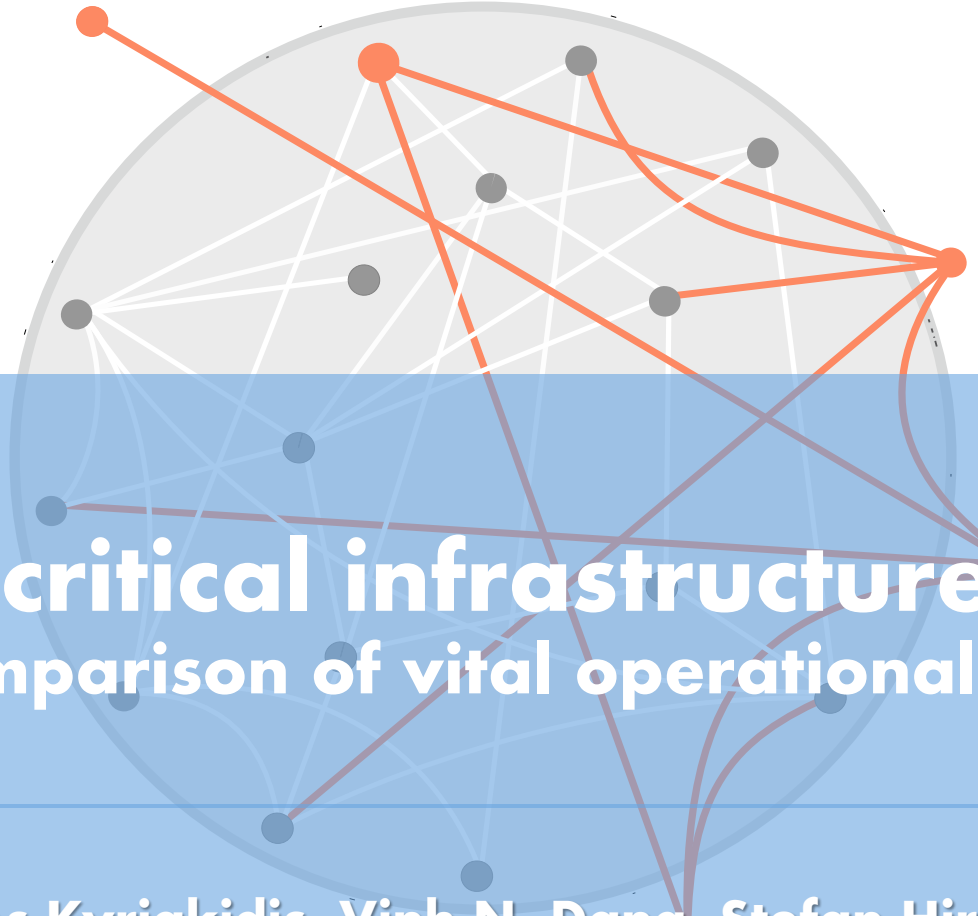

Building critical infrastructure resilience

Cross-sectoral comparison of vital operational tasks and practices

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Outline

- Motivation - Aim
- Methodology
- Data Sources
- Results
- Conclusions and Future work

Motivation

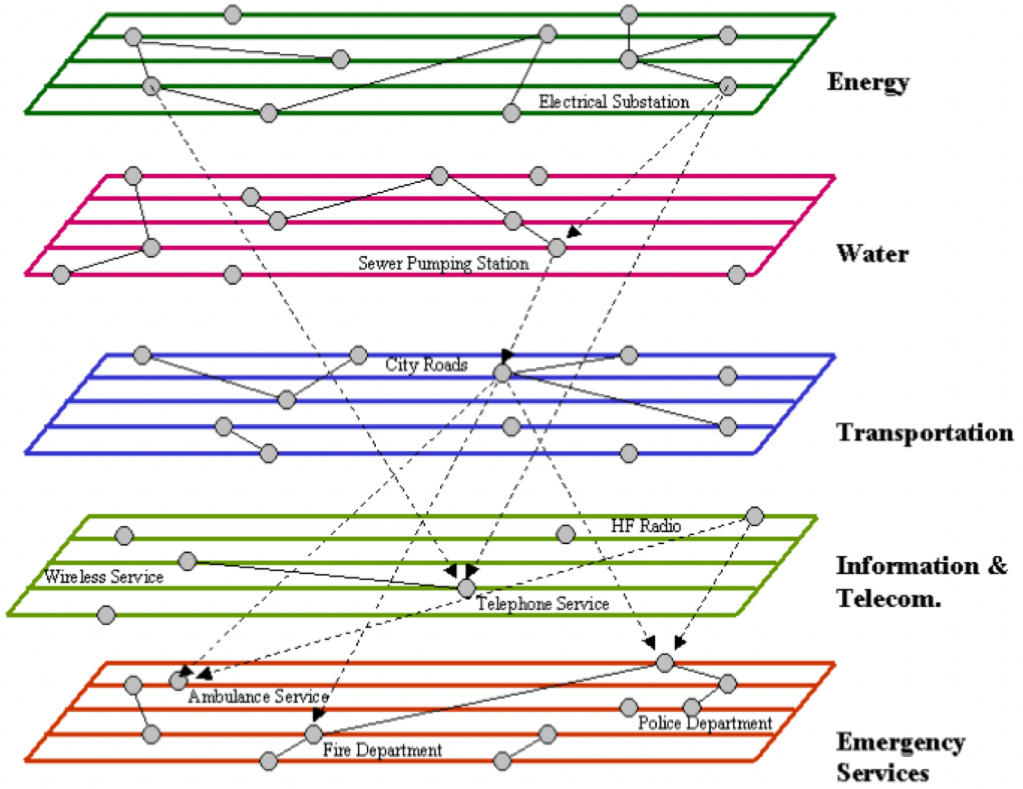
To develop a human-technical system model with the aim to

quantitatively assess the system's resilience

- measuring the effectiveness of "preparedness" in terms of outcomes and their probabilities
- identifying potential weaknesses and the means to counter these

Motivation

- Towards building more resilient systems we shall consider that:
  - CIs are coupled, mutually dependent, and highly interconnected
  - Operators largely contribute with their planning, decisions, and actions to building (or not) resilience

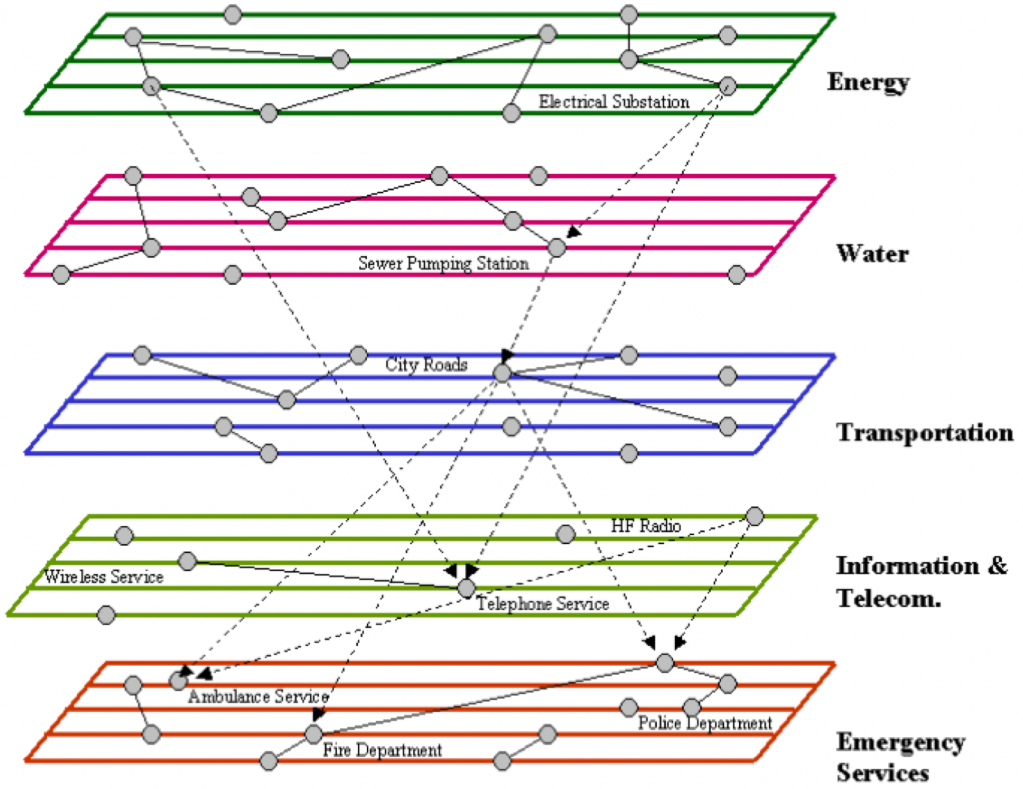


Source: Pederson et al. (2006). *Critical Infrastructure Interdependency Modeling: A Survey of U.S. and International Research*. Idaho National Laboratory.

Aim

- Towards building more resilient systems we shall consider that:
  - CIs are coupled, mutually dependent, and highly interconnected
  - Operators largely contribute with their planning, decisions, and actions to building (or not) resilience

1. Identify, compare, and analyse critical tasks during normal and disrupted operations
2. Define the factors (PSFs) that affect operators' performance
3. Determine correlations between the tasks, PSFs, severity of consequences upon disruption, recovery time, and loss of service



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Methodology

Accident data analysis	• Critical tasks based on their importance to operation
Hierarchical Task Analysis	• Insights on tasks complexity, similarities and differences
Accident data analysis	• The most relevant and important PSFs
Statistical analysis	• Correlations (if any) between tasks, PSFs, severity of consequences, recovery time and loss of service

Data Sources

Electricity Sector

- 6 major worldwide blackout events
- Include a contributing element related to human performance
- Differ in the magnitude of service loss and duration of recovery
- Description of human contribution to the event

Railway Sector

- 8 serious worldwide railway accidents
- Human involvement main cause of accidents
- Similar in magnitude of service loss
- Duration of recovery not clearly indicated
- Description of human contribution to the event

Results – Accident data analysis

Table 1 Analysis of major blackouts

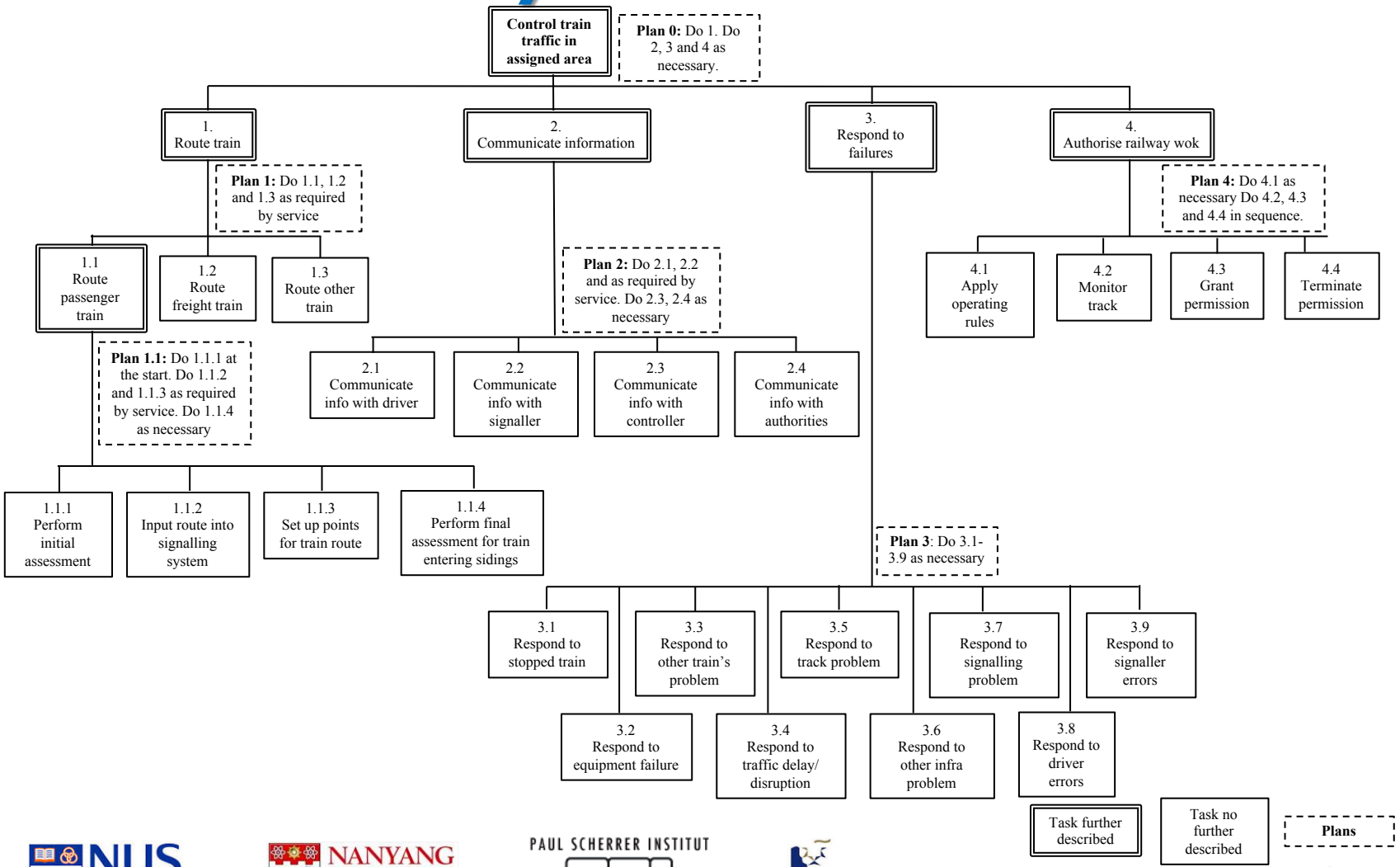
Event	Year	Service loss	Time to recover	Causes related to human involvement
USA – Canada	2003	~ 70 GW	Up to 2 weeks	• System understanding - planning • Dispatchers' situational awareness • Maintenance practices
Italy	2003	~ 27 GW	Up to 19 hours	• System understanding • Dispatchers' situational awareness • Maintenance practices
Continental Europe	2006	~ 16 GW	Up to 2 hours	• Coordination between Transmission System Operators • Training
USA	2011	~ 8 GW	Up to 12 hours	• System understanding - planning • Dispatcher' situational awareness
India	2012	Up to 84 GW in total	Up to 2 days	• Coordination between the State Load and Regional Load Dispatch Centres
Turkey	2015	~ 11 GW	Up to 10 hours	• Awareness of system's operational condition • Maintenance practices

Table 2 Analysis of serious railway accidents

Event	Year	Service loss	Time to recover	Causes related to human involvement
Austria	2006	Suspension of traffic on this line section	Not clearly indicated	• Communication • Procedures • Safety culture • System design
France	2006	Suspension of traffic on this line section	Not clearly indicated	• Supervision - Teamwork • System design - HMI • Training • Procedures • Safety culture
Switzerland	2006	Suspension of traffic on this line section	Not clearly indicated	• Time pressure • Teamwork • Communication
USA	2007	Suspension of traffic on this line section	Not clearly indicated	• Distraction • Safety culture • Procedures
Czech Republic	2008	Suspension of traffic on this line section	Not clearly indicated	• Teamwork • Communication • System design • Workload • Fatigue • Situational awareness
USA	2009	Suspension of traffic on this line section	Not clearly indicated	• Quality of procedures • Safety culture • Situational awareness
United Kingdom	2010	Suspension of traffic on line section and level crossing	Not clearly indicated	• Distraction • Time pressure • Familiarity
Norway	2010	Suspension of traffic on this part of the station	Not clearly indicated	• Training • Communication • Teamwork • Safety culture • System design • Procedures

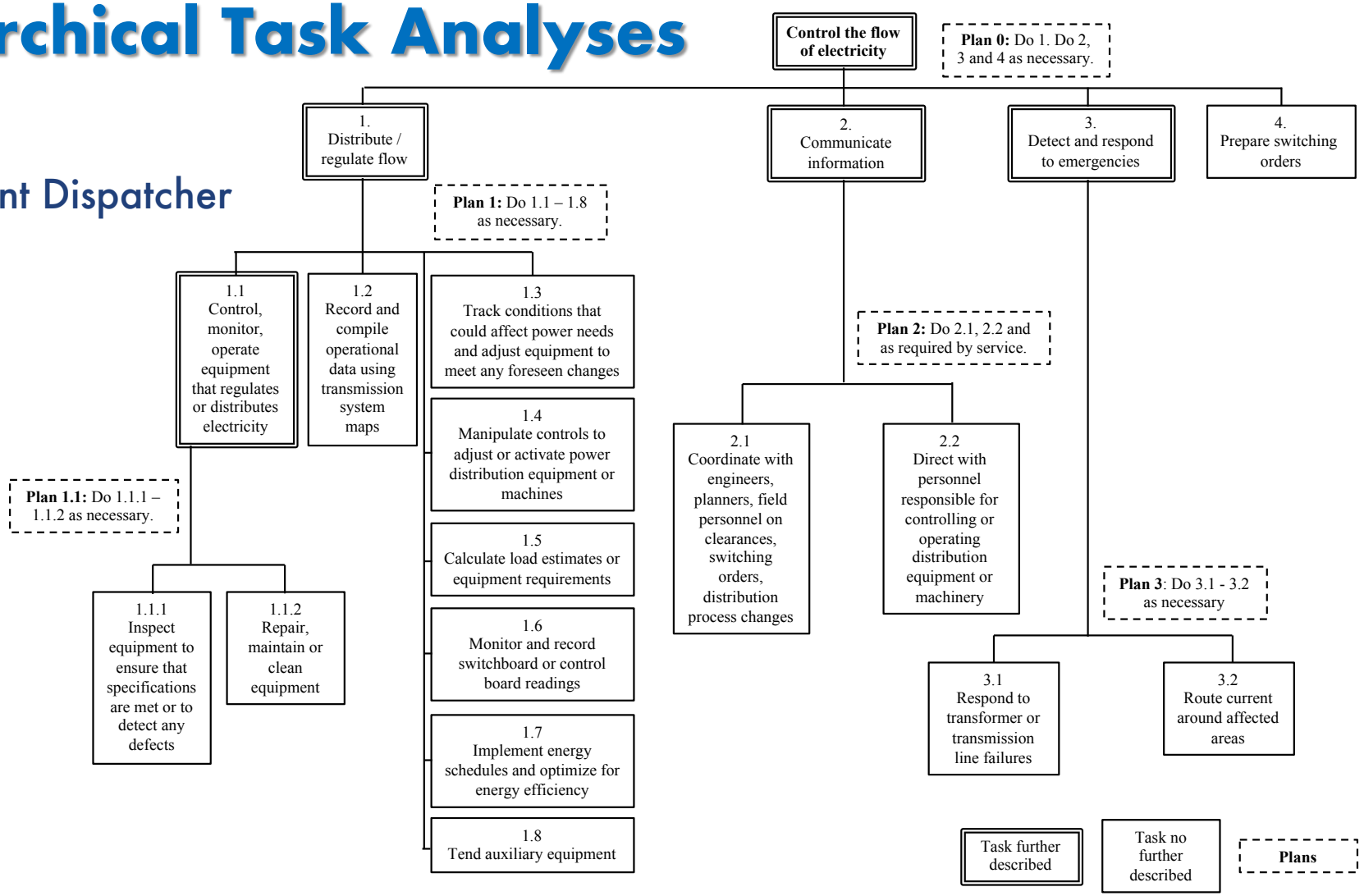
Results – Hierarchical Task Analyses

HTA for Railway Dispatcher



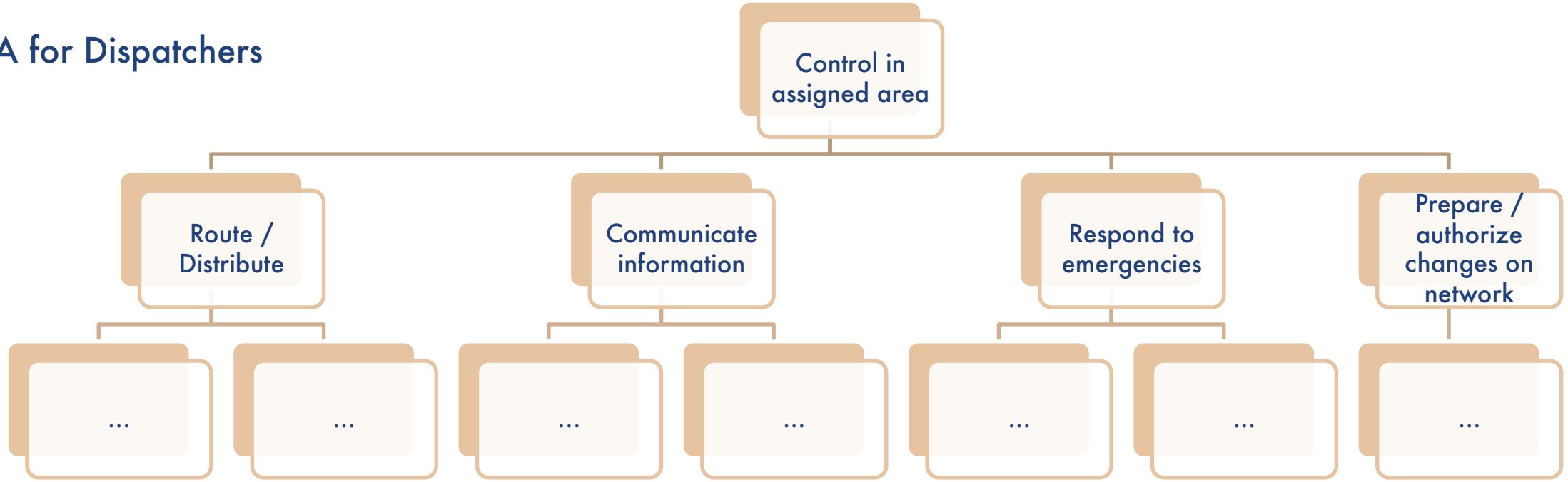
Results – Hierarchical Task Analyses

HTA for Electricity Power Plant Dispatcher



Results – Hierarchical Task Analyses

HTA for Dispatchers



Results – Dominant PSFs per Type of Operator

Railway Traffic Controllers / Dispatchers	Electricity Power Plants Dispatchers
Quality of procedures	Quality of procedures
Situational awareness	Situational awareness
*Distraction**	*Task complexity**
Teamwork / Crew dynamics	Teamwork / Crew dynamics
System design	*Ergonomics / HMI*
Workload, time pressure, stress	Workload, time pressure, stress
Experience / Training	Experience / Training
Adequacy of organization (safety culture)	*Adequacy of organization (staffing and resources)*
Communication	Communication

** indicates factors that differ across sectors*

Results – Statistical analysis

Relationships in the electricity sector

Specific PSFs appear to be **more dependent** on some of their counterparts, e.g., **teamwork** with **training, and situational awareness** with **system understanding**

No significant correlations between the type of PSFs with either the magnitude of the service loss, and/or the recovery time

Relationships in the railway sector

1. **Safety culture** associated with all events
2. **Procedures**, **teamwork**, **communication**, **training**, and **workload** associated with disrupted operations

Data **do not** support any analysis on recovery time

Results – Statistical analysis

Relationships between electricity and railway sectors

No significant correlation between the identified **PSFs** and type of **infrastructure**

Any generalization requires attention as the results were derived, to a large extent, from the analysis of events with service loss of the same magnitude

Conclusions

- Tasks with similar attributes across sectors may result in different resilient performances with regard to recovery time and service loss
- The identified PSFs have no significant influence on disruption in the two sectors in terms of loss magnitude and recovery time
- The relevant actors / stakeholders shall account for the differences between
  - the operational systems and the system's surroundings,
  - available and alternative resources for recovery

Future work

- Analysis of events of different magnitudes in the railway and electricity sectors to explore whether the severity of consequences is affected by the existence/contribution of specific PSFs
- Review of tasks in other sectors, e.g., emergency, communication and healthcare, to derive a more comprehensive list of critical tasks and best practices towards building more resilient CIs

Future work

- Analysis of events of different magnitudes in the railway and electricity sectors to explore whether the severity of consequences is affected by the existence/contribution of specific PSFs
- Review of tasks in other sectors, e.g., emergency, communication and healthcare, to derive a more comprehensive list of critical tasks and best practices towards building more resilient CIs
- A quantitative method to represent human performance in the modelling of the emergency response in critical infrastructure scenarios