ESREL 2018

European Safety
and Reliability Conference
Trondheim, Norway, 17-21 June 2018

Common Cause Failures and Cascading Failures

Lin Xie
Mary Ann Lundteigen
Yiliu Liu

Background

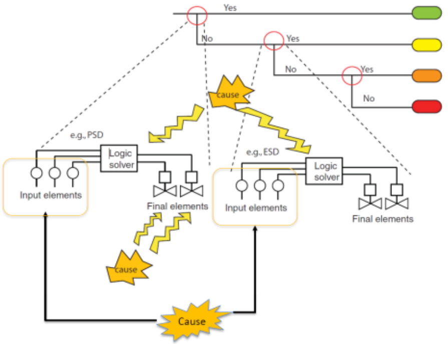
- Complex systems
  - Advanced and digitalized functions
  - Interactions and dependency
- Dependent failures
  - Common cause failure (CCF)
  - Cascading failures
- Objectives:
  - Similarities
  - Differences
  - Barriers

Why is it important

- To understand phenomena and mechanisms of the failures:
  - CCF: Main contributors of the failures in safety critical systems(oil & gas)
  - Cascading failures: fires (chemical), blackouts (power), conflicts(railway)
- To help making decisions on barrier strategies:
  - Barriers against CCFs V.S. Barriers against cascading failures

CCFs

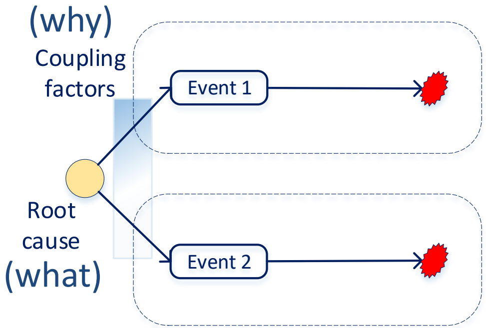
Ref: TPK5170 course note



Definitions

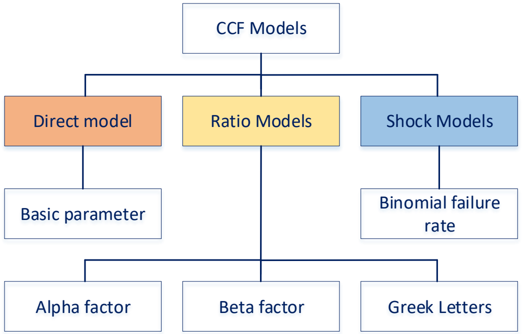
- Two or more component faults
- Exist simultaneously or in a short time interval
- A shared cause

Ref: PDS Report



Explanation

- Root causes: most basic reason for the component failure
- Coupling factors: characteristic of components with same causal mechanisms



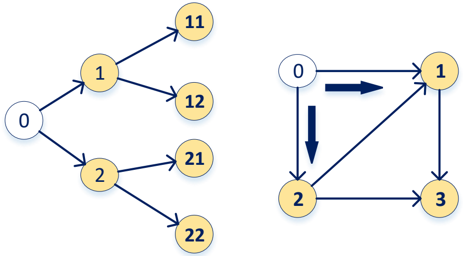
Models

- Direct estimate models
- Ratio models
- Shock models

At least two failures are due to a shared or common cause

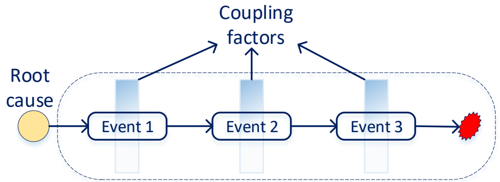
NTNU

Cascading failures



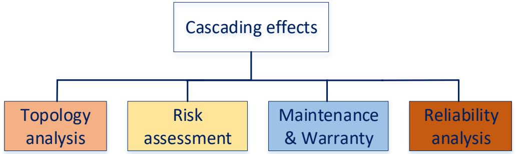
Definitions

- Multiple failures initiated by the failure of one component
- Result in a chain reaction
- Affect remaining components



Explanation

- Root causes
- Coupling factors
- Coupling paths



Models

- Topology analysis
- Probabilistic risk assessment
- Optimization of maintenance
- Reliability analysis

Multiple failures may have sequential effects

Similarities

- Multiplicity
- Timeliness
- Root causes

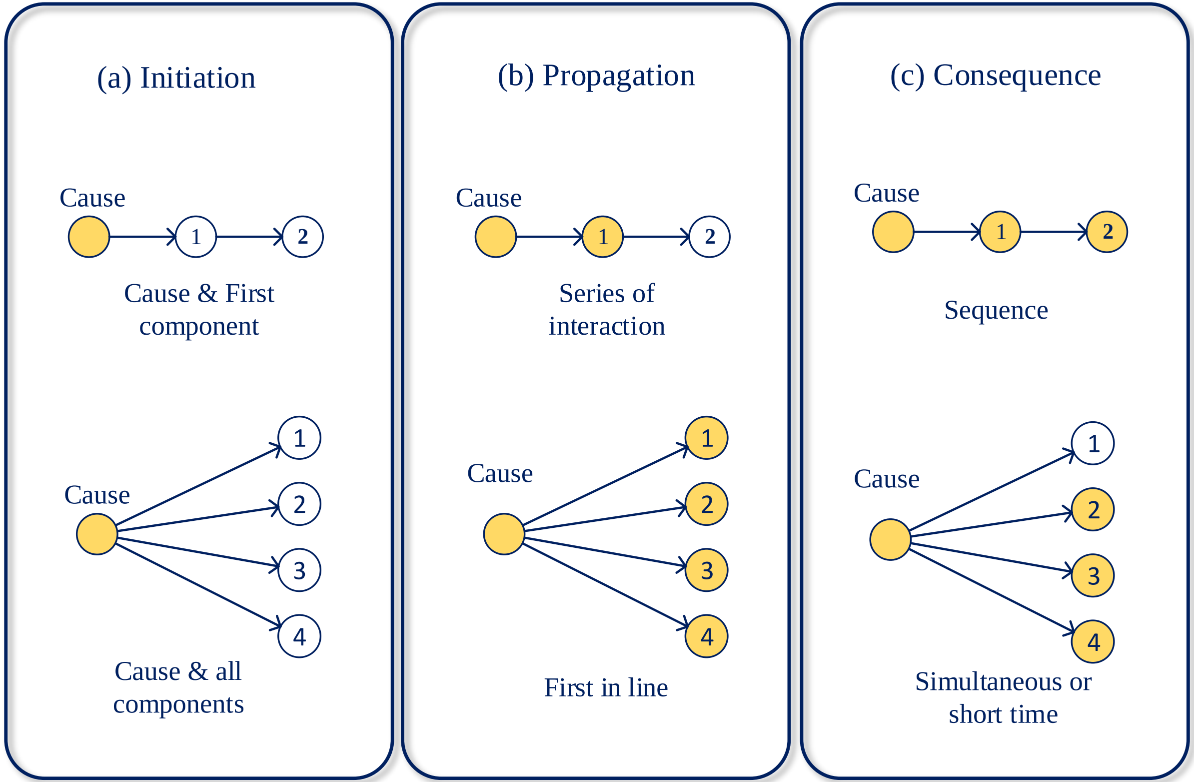


Fig. 1. Comparison of CCFs and cascading failures

Differences

- Initiation
- Propagation
- Consequence

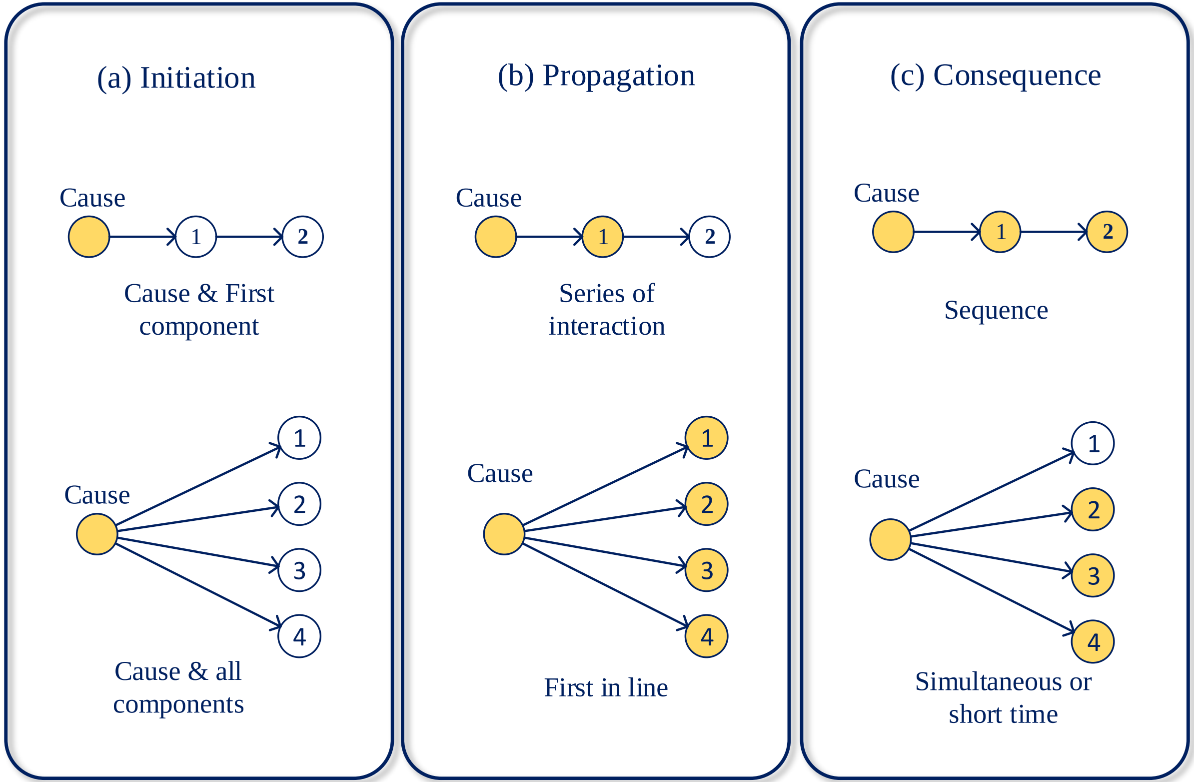


Fig. 1. Comparison of CCFs and cascading failures

Barriers

- Barriers for both failures
- Barriers for CCFs
- Barriers for cascading failures

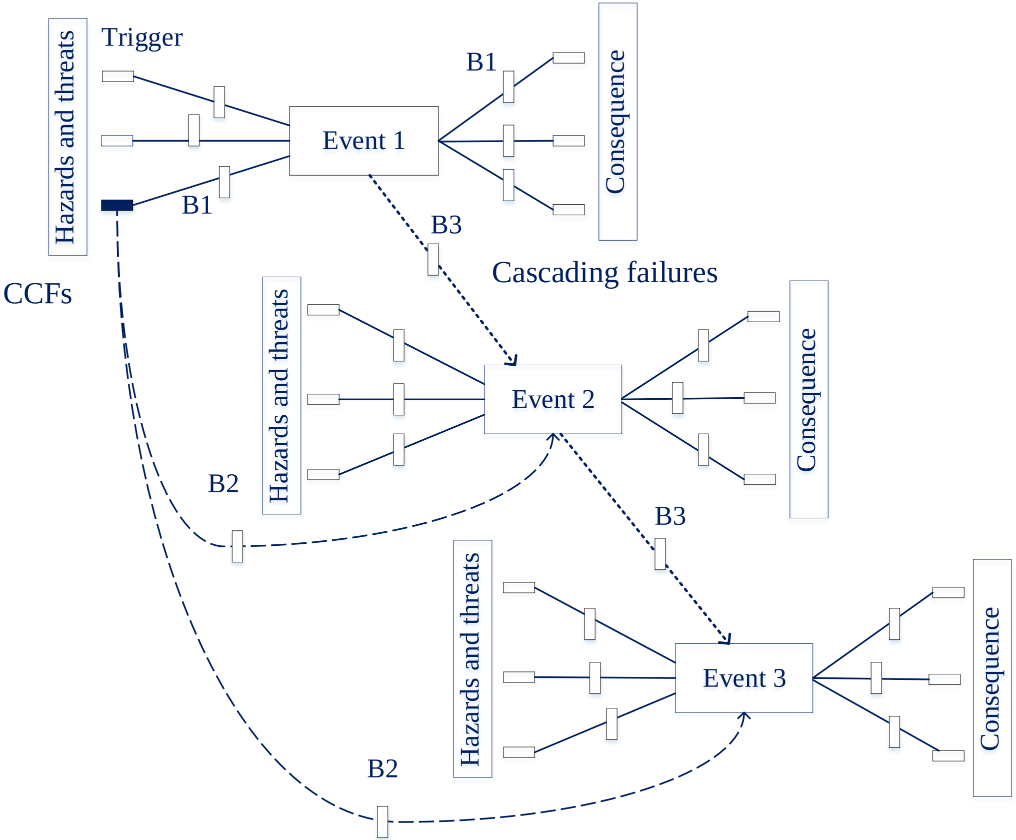


Fig. 2. Safety barriers against DFs based on bow-tie models

λ=0.001/hour

Case study 1

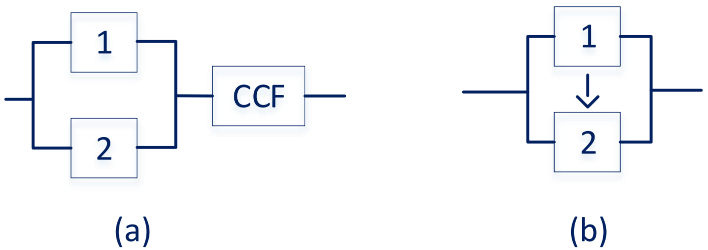


Fig. 3 Two-component system with CCFs and cascading failures

Assumptions:
- CCF:
  - β=0.1
- Cascading failures:
  - P_{12}=0.1

Method:
- Analytical formulas

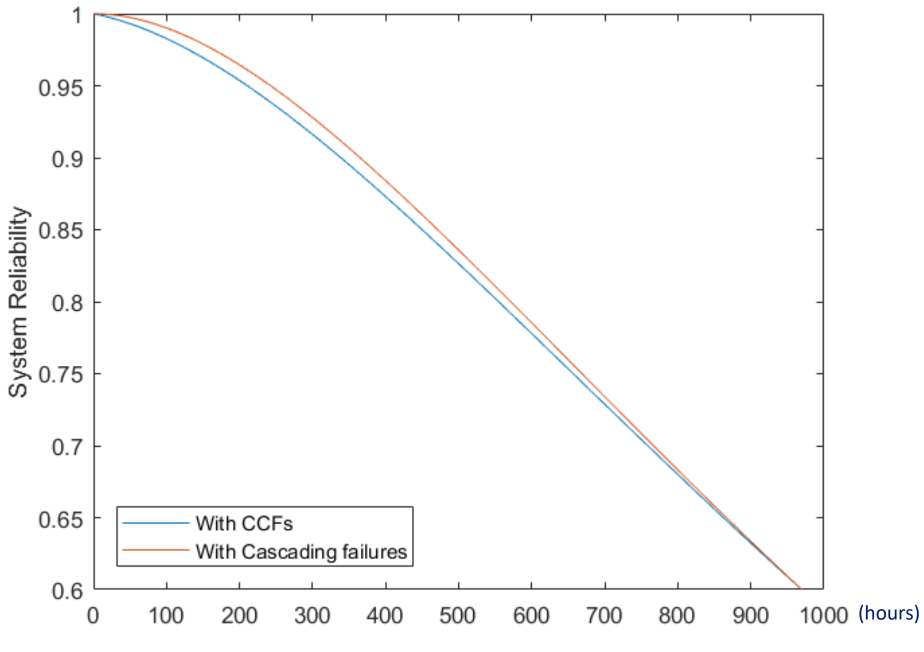


Fig. 4 Effects of CCFs and cascading failures on system reliability

Case study 2

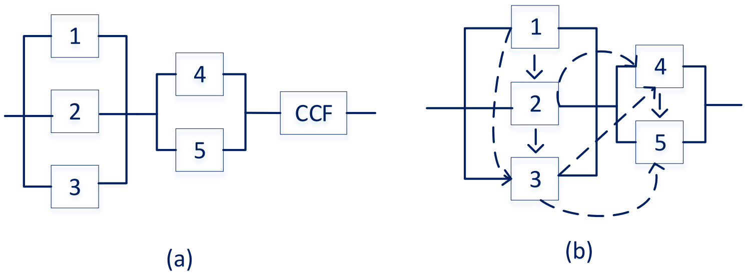


Fig. 5 Five-component system with CCFs and cascading failures

Assumptions

- CCF: β=0.1->0
- Cascading failures:
  - B1: P_{12}=0.3->0
  - B2: λ_2=0.001->0
  - B3: P=0.3->0

Method:

- Monte Carlo Simulation

λ=0.001/hour

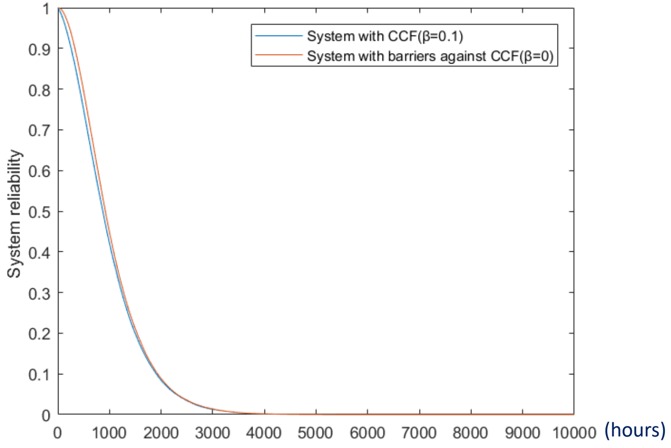


Fig. 6 Effects of barrier against CCFs

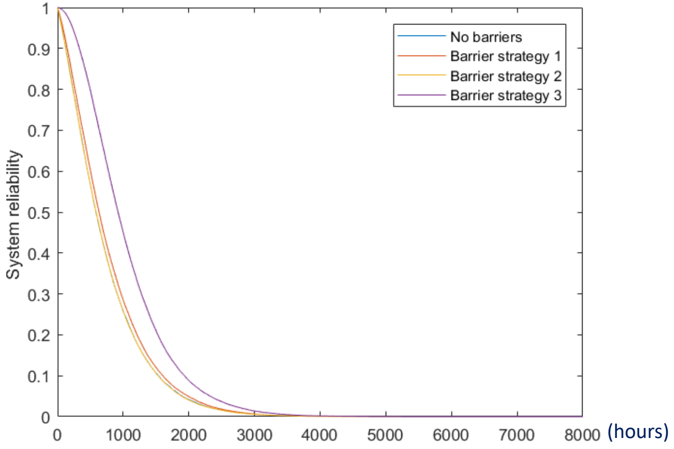


Fig. 7 Effects of barriers against cascading failures

Conclusion and further work

- Answer the questions:
  - Why such dependent failures initiate
  - How dependent failures contribute to disruptions of systems
  - What kinds of barriers are needed and implemented

- Further works:
  - More advanced quantitative analyses are required in a larger and more complex system
  - To perform further barrier analysis for dependent failures

Thanks!