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Bayesian Networks:
Exercise Session

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Getting Started

The exercises that follow will be solved in **GeNIe Modeler**, a specific tool for Bayesian Network inference

You can download it from the GeNIe download page:

1. Make sure it is the **Academic version** (https://download.bayesfusion.com/files.html?category=Academia)

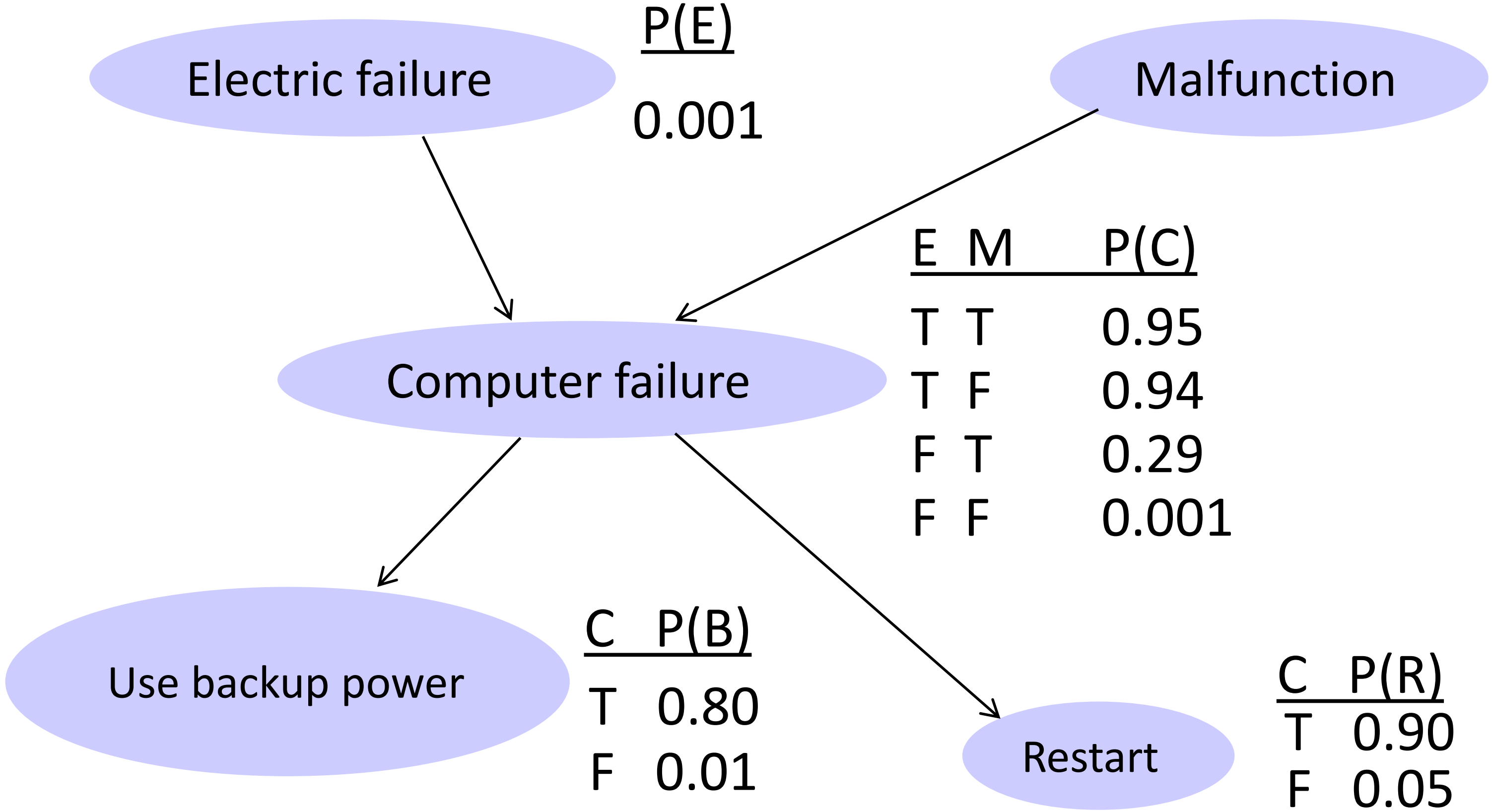
2. Download **genie_academic_setup.exe** (you might need to log in) and run it)

3. Follow the installing instructions (when requested to log in you can fill in with your name, company name and personal email. Make sure that you select the first option “student version…)

4. Enjoy the exercises!

GeNIe user guide https://support.bayesfusion.com/docs/GeNIe.pdf

Exercise 1: BN model for the computer example



P(E)
0.001

P(M)
0.02

E	M	P(C)
T	T	0.95
T	F	0.94
F	T	0.29
F	F	0.001

C	P(B)
T	0.80
F	0.01

C	P(R)
T	0.90
F	0.05

Exercise 1: BN model for the computer example

Analytically calculate the following:

1. What is the probability that the backup power is working given an electrical failure?

2. What is the probability that the electricity is not working given a backup power event (you RELY on backup power)?

3. What is the probability that the electricity is not working given a backup power event (you do NOT rely on backup power)?

Exercise 1: BN model for the computer example

Verify the analytical results of the following using GeNIe Modeler:

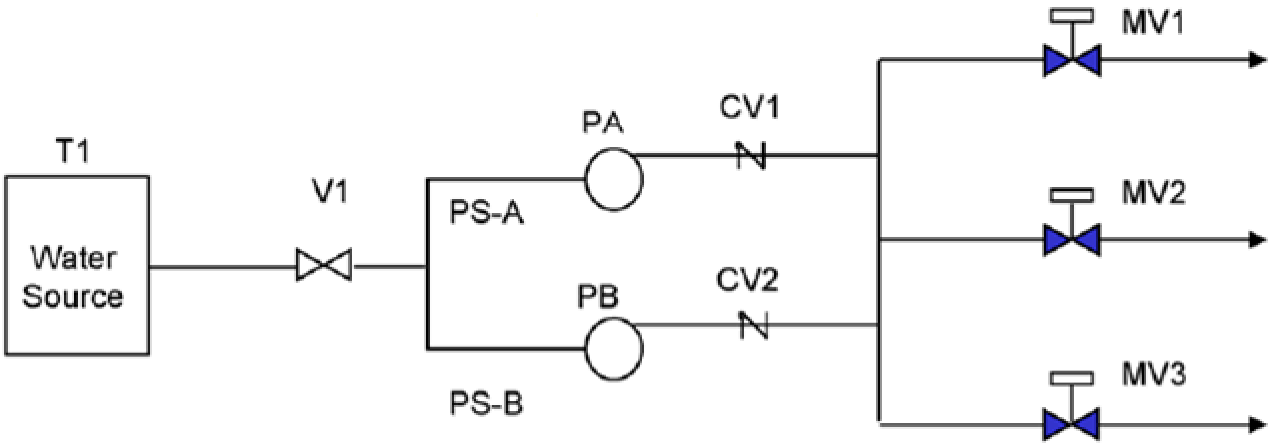
1. What is the probability that the backup power is working given an electrical failure?

2. What is the probability that the electricity is not working given a backup power event (you RELY on backup power)?

3. What is the probability that the electricity is not working given a backup power event (you do NOT rely on backup power)?

Exercise 2: Emergency Cooling Injection System

Consider the emergency cooling injection system in the Figure below. The following system is designed to deliver emergency cooling to a nuclear reactor (William E. Burchill, MNE, 2010)



Flow from any one pump through any one MV is success
T_ tank
V_ manual valve, normally open
PS-_ pipe segment
P_ pump
CV_ check valve
MV_ motor-operated valve, normally closed

Continue ...

Exercise 2: Emergency Cooling Injection System

Use the following failure data:

- Tank rupture probability = E-6
- Valve V1 HEP for failure to reopen following maintenance = 2E-1
- Pump PA unavailability = 5E-2
- Pump PB unavailability = 5E-2
- Check valve CV1 demand failure probability = 3E-2
- Check valve CV2 demand failure probability = 3E-2
- Motor-operated value MV1 demand failure probability = 2E-1
- Motor-operated value MV2 demand failure probability = 2E-1
- Motor-operated value MV2 demand failure probability = 2E-1

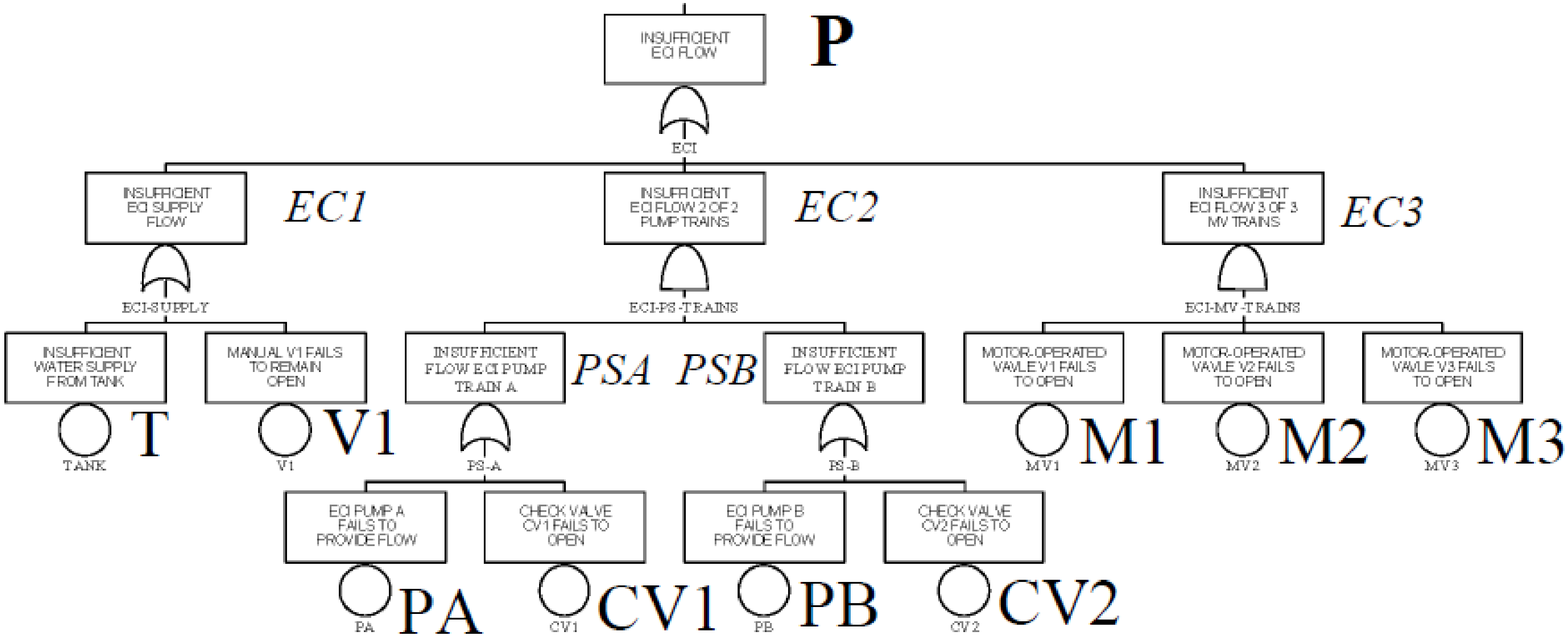
1) **Determine the system failure probability.**

2) **If there is insufficient flow, what is the probability that the Check Valve CV1 fails to open?**

3) **If Valve V1 fails to reopen, what is the probability of insufficient flow?**

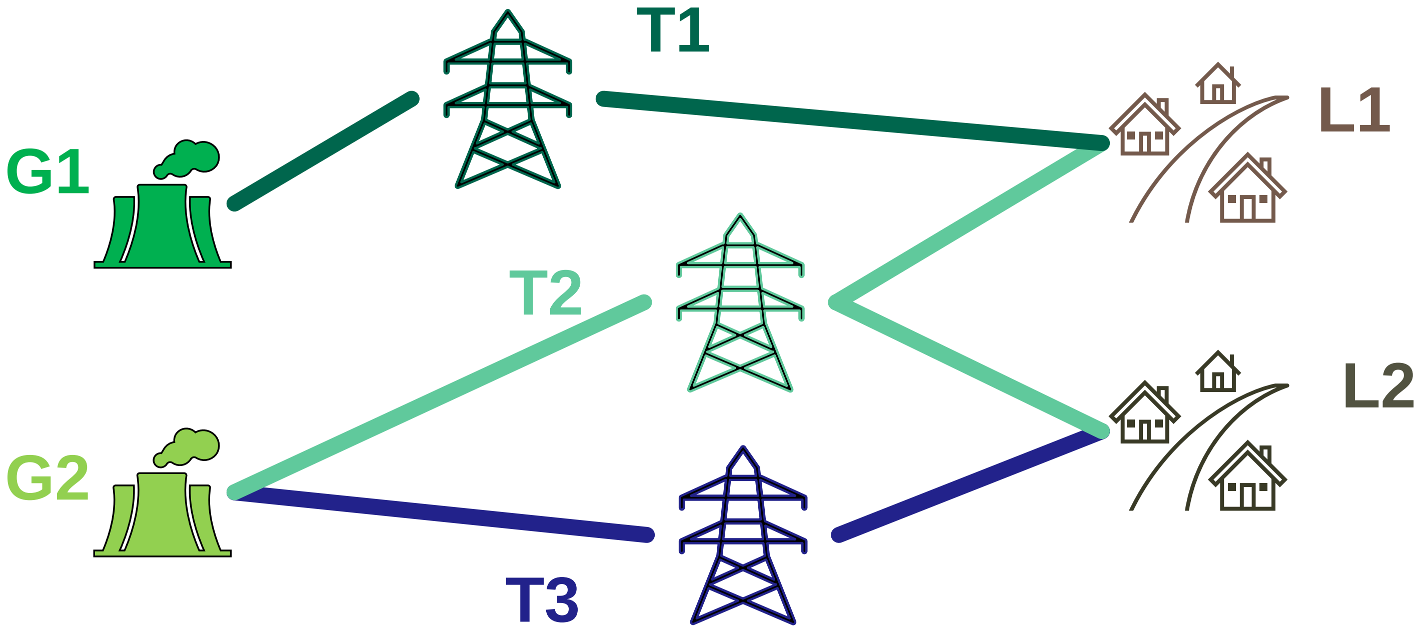
Exercise 2: Emergency Cooling Injection System

Fault tree of the system:



Exercise 3: Design retrofit for resilience improvement

Consider the electric power network system in the Figure. The following system dispatches the electric power coming from the power plants G1 and G2 to two communities characterized by the loads L1 and L2, through three different transmission lines T1, T2 and T3.



Exercise 3: Design retrofit for resilience improvement

The system works if both loads are satisfied, which happens if each community is connected to at least one working generator. Suppose that there is a seismic risk for the power plants and the transmission lines and when an earthquake occurs, there is a probability that the generators and the transmission lines are disconnected. Assuming that:

- the generators and the transmission lines are independent, each can only be in two different states “UP” and “DOWN”, and in normal condition they are in the state “UP” with probability equal to 1;
- An earthquake can happen with probability 1e-4 and when it happens, there is a probability of 0.5 for each generator and transmission line to go “DOWN”.

1) Model the system reliability with a Bayesian Network
2) Is the system reliable if an earthquake occurs?

Exercise 3: Design retrofit for resilience improvement

The system managers have decided to improve the resilience of the system by retrofitting its design with anti-seismic countermeasures. Suppose that two different design actions can be implemented on each unit of the system to reduce their probability of failure in case of an earthquake, and their effect is summarized in the following table:

ACTIONS	Generators		Transmission lines	
	Probability of failure	Cost (M€)	Probability of failure	Cost (M€)
A1	0.3	100	0.3	50
A2	0.1	250	0.1	150

Assume that a total budget of 250M€ is available.

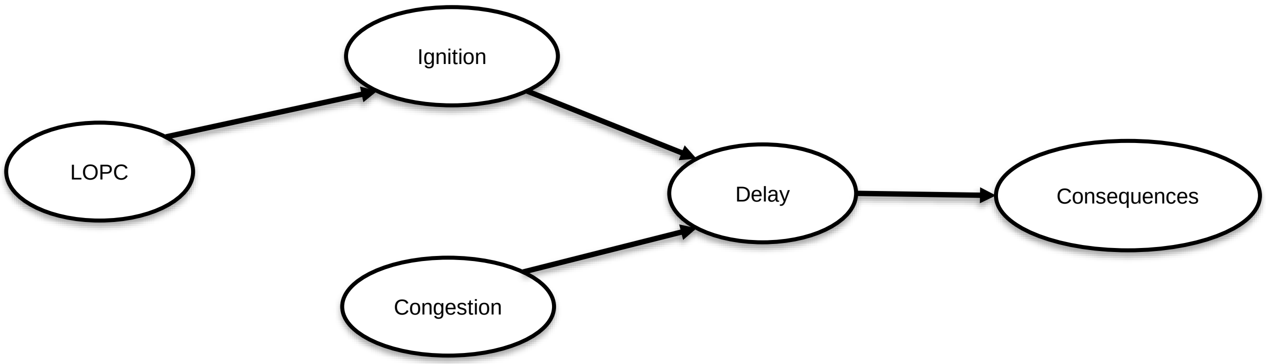
3) What is the set of actions that guarantees the maximum resilience of the system (the largest probabilities to satisfy the community loads in case of an earthquake)?

Exercise 4: Slug catcher of an oil & gas onshore plant

Hands-on (Practice at home using GeNIe modeler): Send in your solution by email

Multistate BN

Consider the BN of a slug catcher Loss Of Primary Containment (LOPC) shown in figure.



Consequences:

- JF – Jet Fire
- PF – Pool fire
- FF – Flash Fire
- EX – Explosion

It is known that:

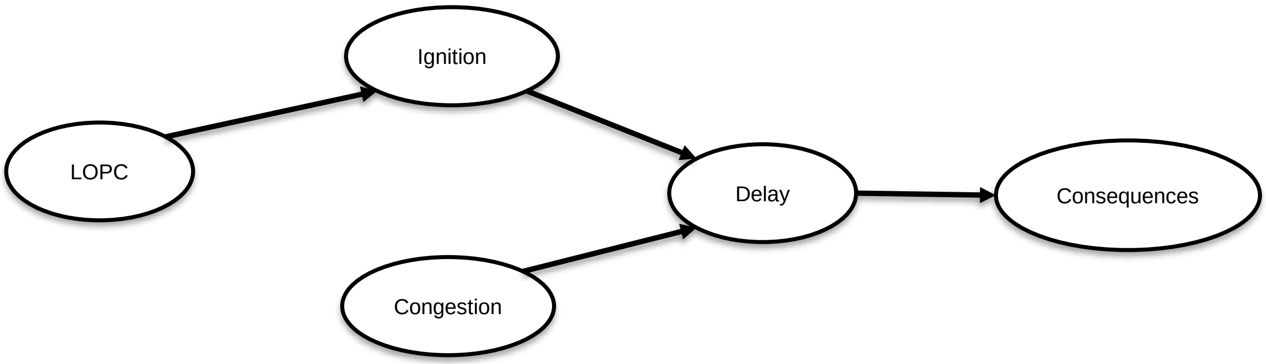
- The probability of a LOPC is $P_{LOPC} = 0{,}024$
- In case of LOPC, the probability of ignition of the released fluid is $P_{Ign} = 0{,}08$
- FF and EX only manifest in case of delayed ignition (50% of ignition events) and PF and JF only manifest in case of immediate ignition;
- In case of delayed ignition, a congested area ($P_{Cong} = 0{,}1$) would lead to EX, while a not congested area would lead to FF;
- An immediate ignition would lead to JF 5 times out of 6, to PF 1 time out of 6.

Exercise 4: Slug catcher of an oil & gas onshore plant

Hands-on (Practice at home using GeNIe modeler): Send in your solution by email

Multistate BN

Consider the BN of a slug catcher Loss Of Primary Containment (LOPC) shown in figure.



Consequences:

- JF – Jet Fire
- PF – Pool fire
- FF – Flash Fire
- EX – Explosion

Evaluate:

1. The probability of each consequence FF, EX, JF and PF
2. The impact of the implementation (both individually and combined) of the following safety barriers on the consequence probability. **If any of the safety barriers are working, the LOPC does not happen**.

Barrier 1: Task Management

HS	P(HS)	FP(HS)
H	0,62	0,42
M	0,37	0,47
L	0,01	1

Barrier 2: Pressure Protection System

HS	P(HS)	FP(HS)
H	0,25	0,04
M	0,41	0,15
L	0,34	1