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Dynamic bayesian updating approach for predicting bridge condition based on Indonesia-Bridge Management System (I-BMS)

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Background
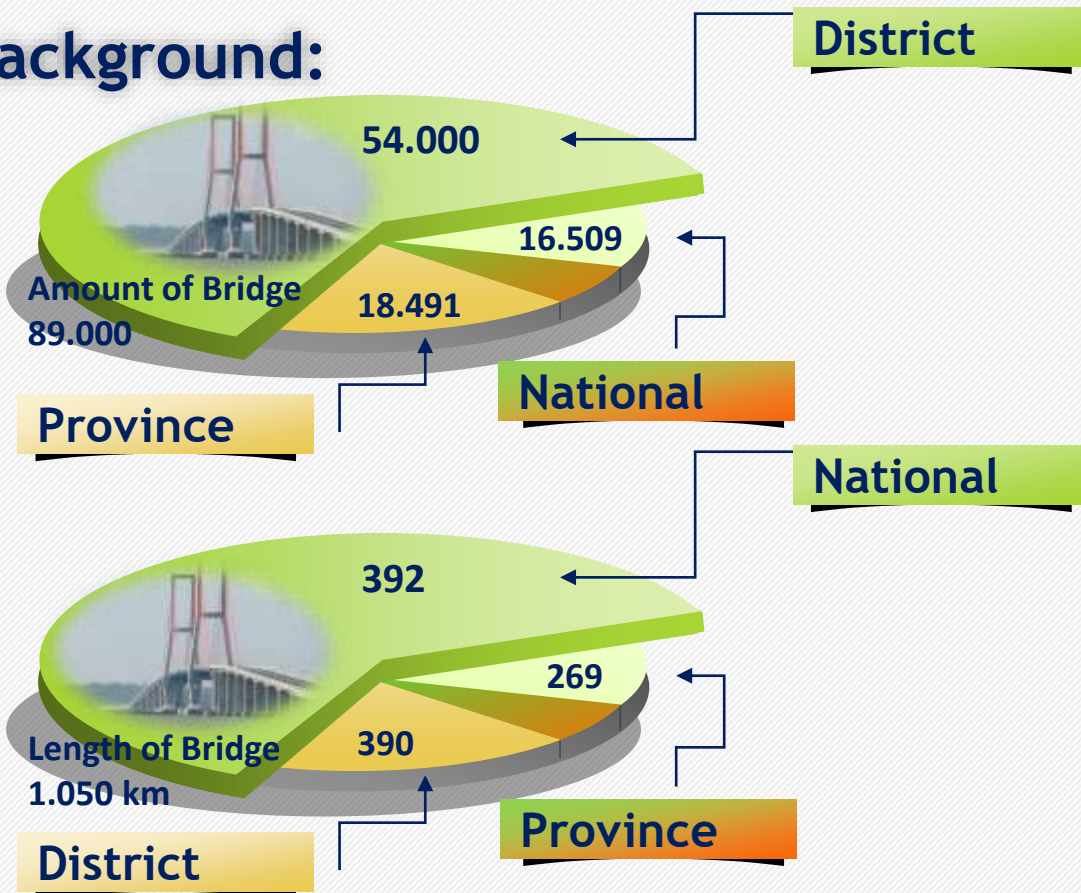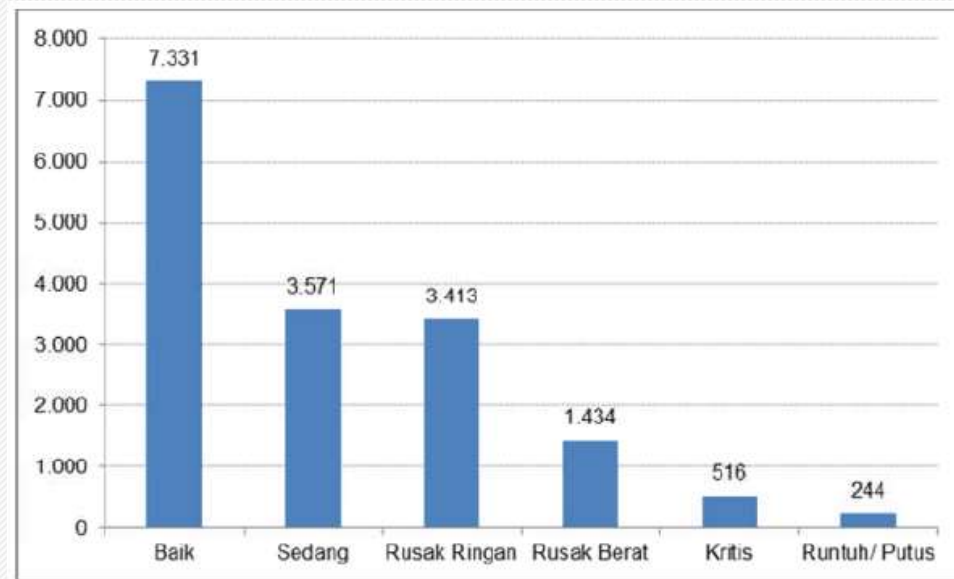
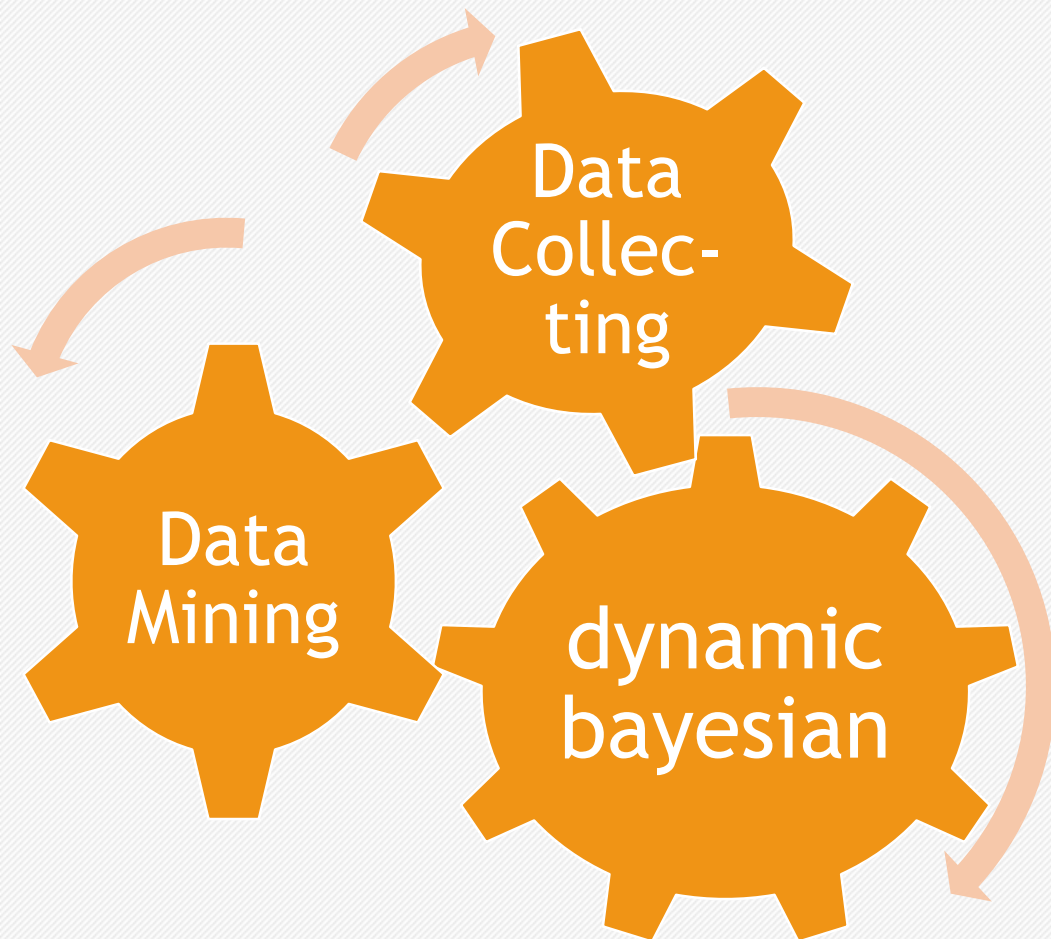Do you think they have no inspection for maintenance????

Background

Background:

Amount of Bridge 89.000
- District: 54.000
- Province: 18.491
- National: 16.509

Length of Bridge 1.050 km
- National: 392
- Province: 390
- District: 269

National bridge condition at 2012

Baik	Sedang	Rusak Ringan	Rusak Berat	Kritis	Runtuh/Putus
7.331	3.571	3.413	1.434	516	244

Damage: 32.5%
Collapse: 1.5%

Model Construction

Data Collec-ting

Data Mining

dynamic bayesian

1. **Data collecting: BMS from Directorate of Bridge, Directorate General of Bina Marga, the Ministry of Public Works and Housing.**

2. **Data mining: to find the pattern of data**

3. **Model DB: to predict the probability of an event based on previous event**

Collecting Data and Data Mining

1. Use 3.166 bridges (reinforced-concrete girder bridge) from 2013-2015: 80% (for modeling) and 20% (for calibration)

2. The assessment BMS consists of: structure, damage, volume, function, and influence → Bridge has range value 0-5

3. For further analysis, this scale must change to state condition (G: Good, M: Moderate, F: Fail)

Failure Condition

5	0%	
4	20%	Fail
3	40%	
2	60%	Moderate
1	80%	
0	100%	Good

Good Condition
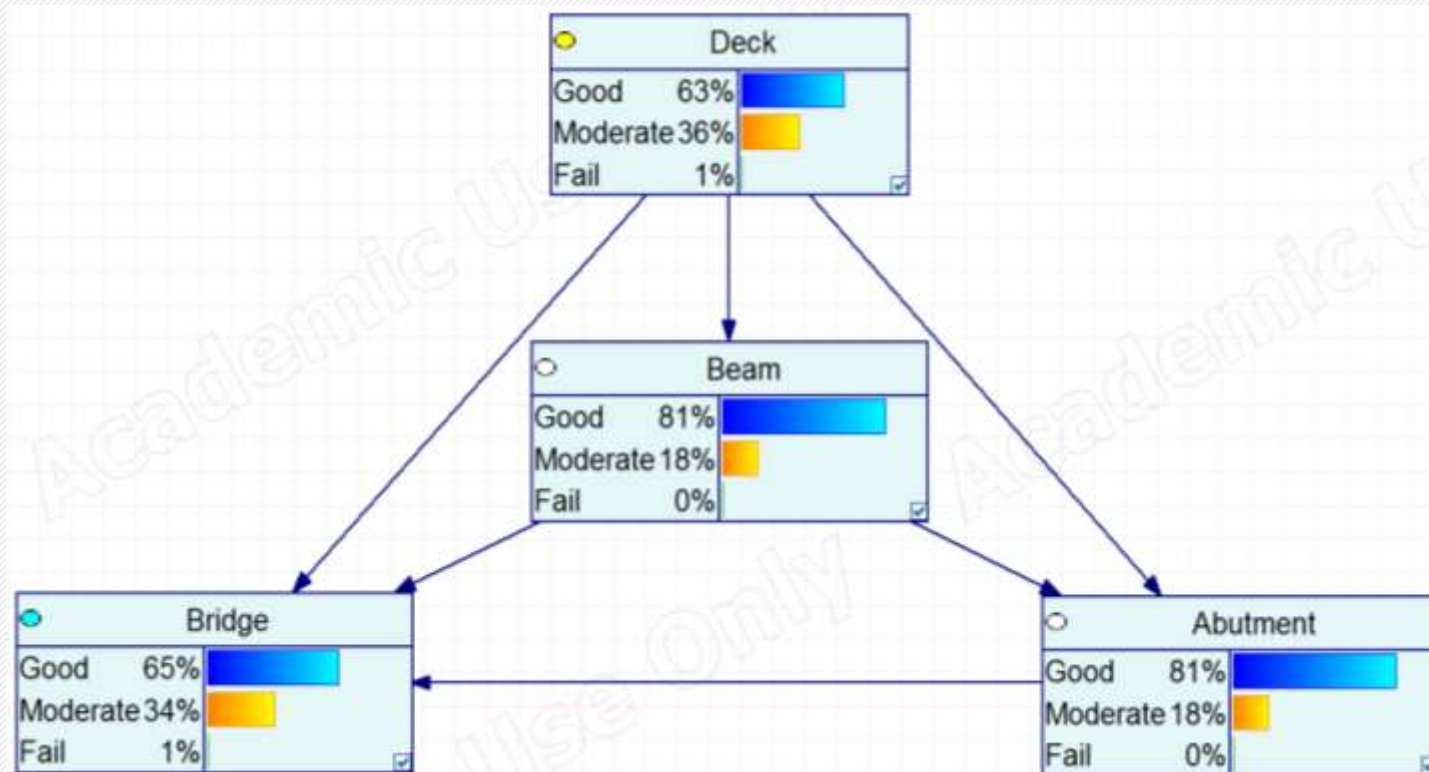
BMS scale
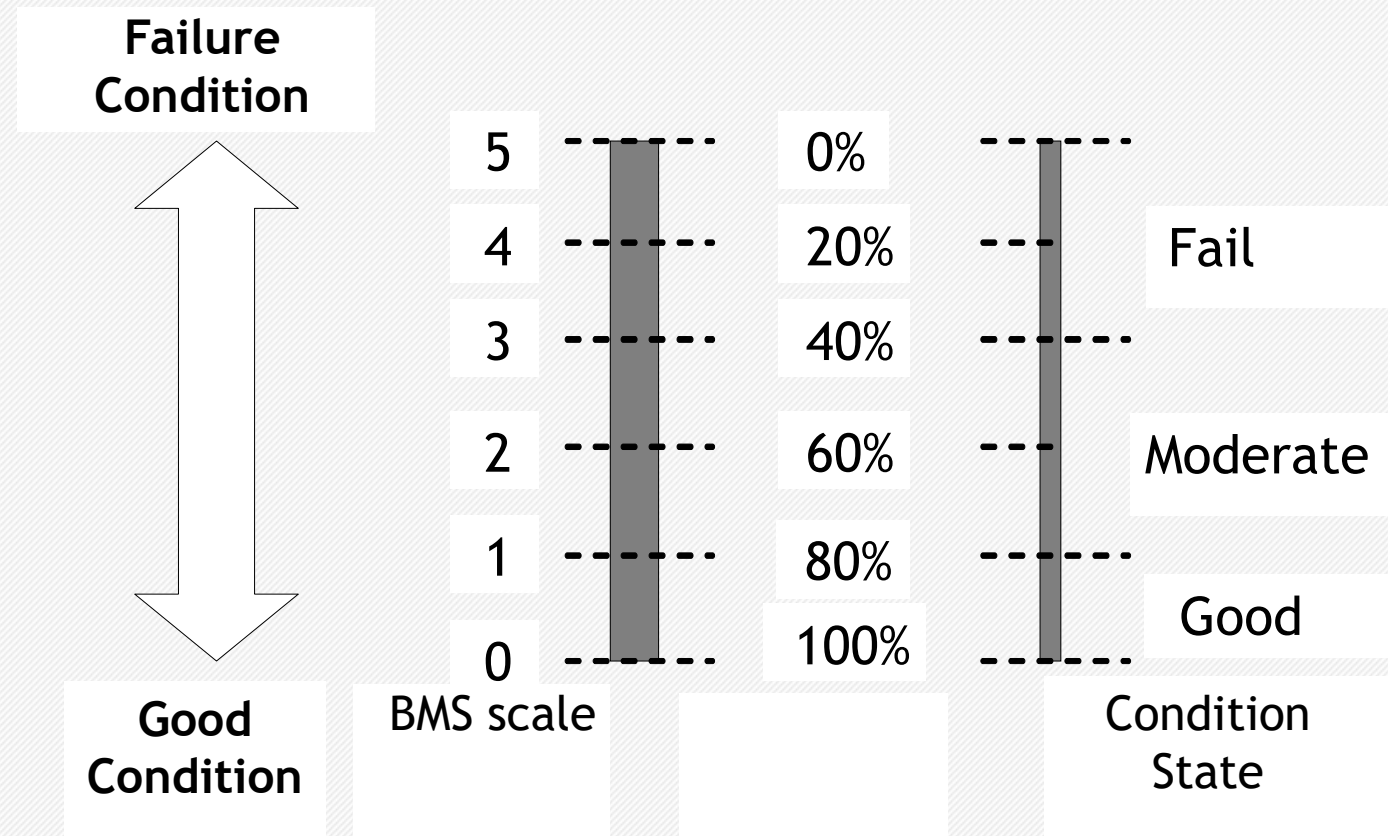
Condition State

Bayesian

1. $p(y) = \int p(\theta)p(y|\theta)d\theta$
2. Make the DAG (Direct Acyclic Graph)
3. Estimate CPT (Conditional Probability Table)
4. Dynamic Bayesian Network (DBN)
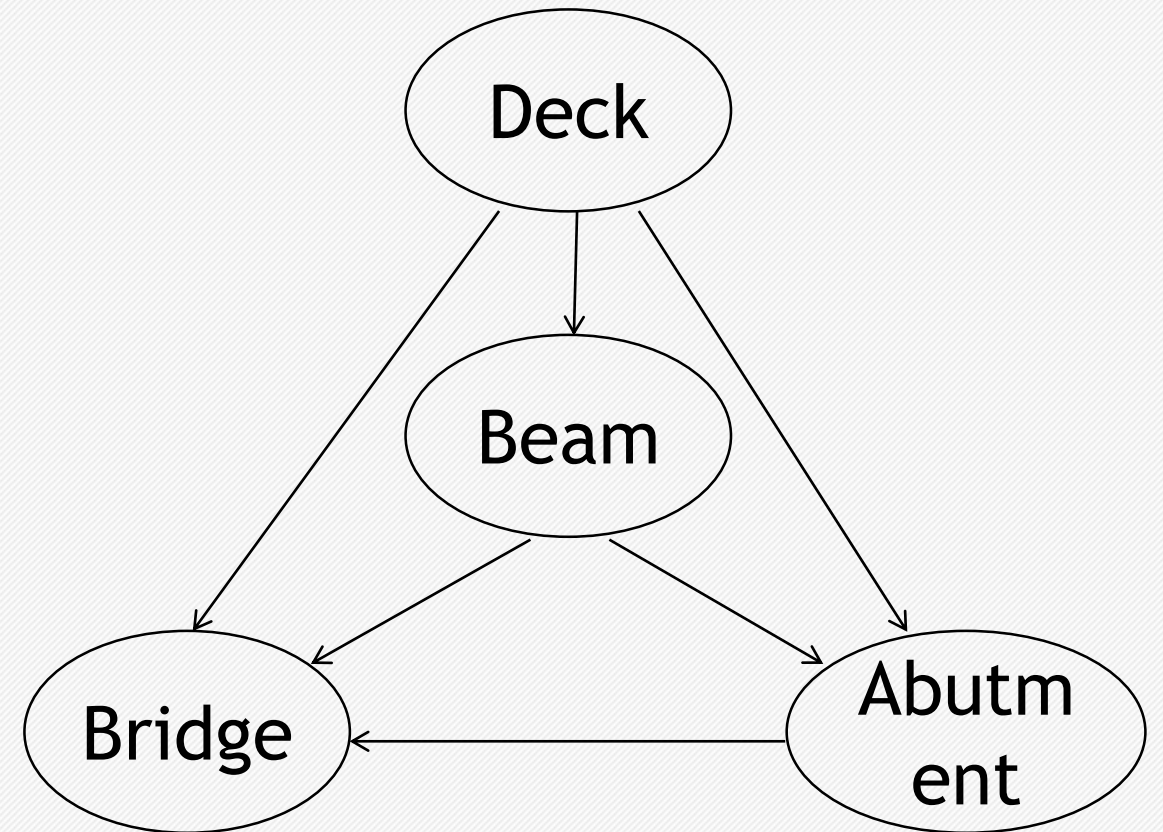
DAG (Direct Acyclic Graph)

A graphical model makes a probabilistic relationship among variables

CPT (Conditional Probability Table)

Deck	Probability
G	0.632
M	0.357
F	0.011

|	Deck	G	M	F
Beam	G	0.873	0.707	0.753
	M	0.123	0.289	0.141
	F	0.003	0.004	0.106

the CPT is arranged in several stages:

Step1: Verifying the I-BMS data especially Reinforced-Concrete Bridge with spans of 10 to 25 metres

Step 2: Giving random numbers on each bridge data and then sorting its data to divide into 2 groups, i.e. 80% data for the model and 20% for data testing.

Step 3: CPT is calculated based on the 80% data model using the formulas (1) and (2)
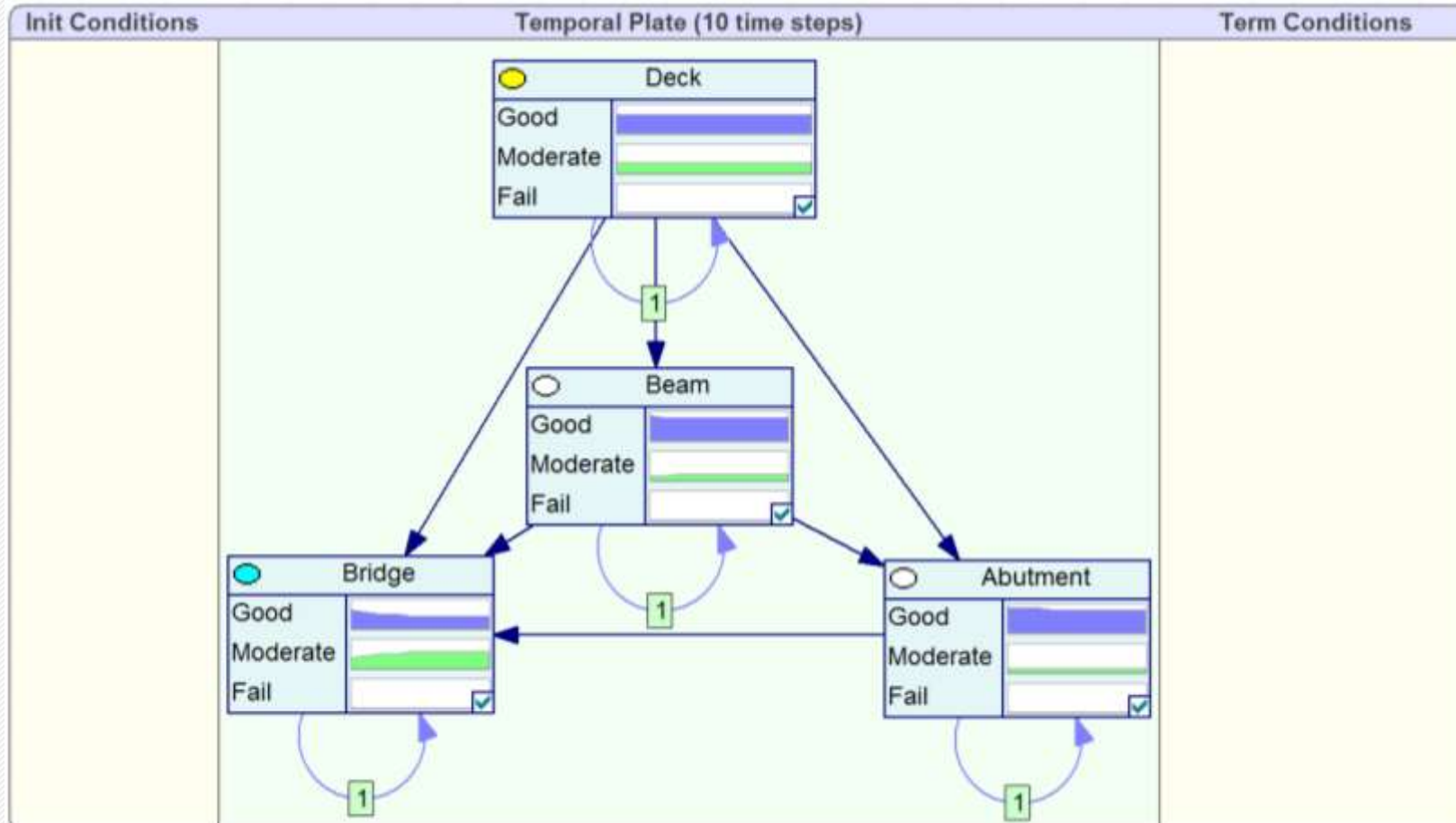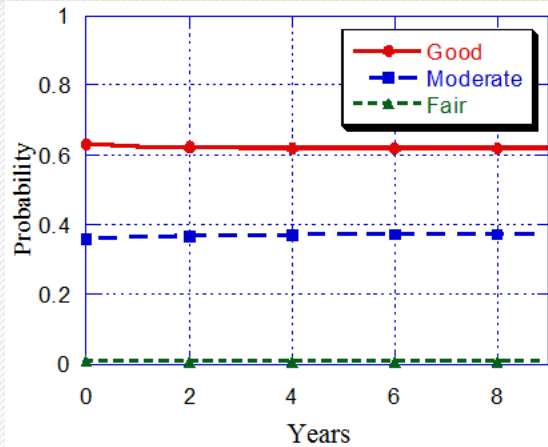
Dynamic Bayesian Network (DBN)
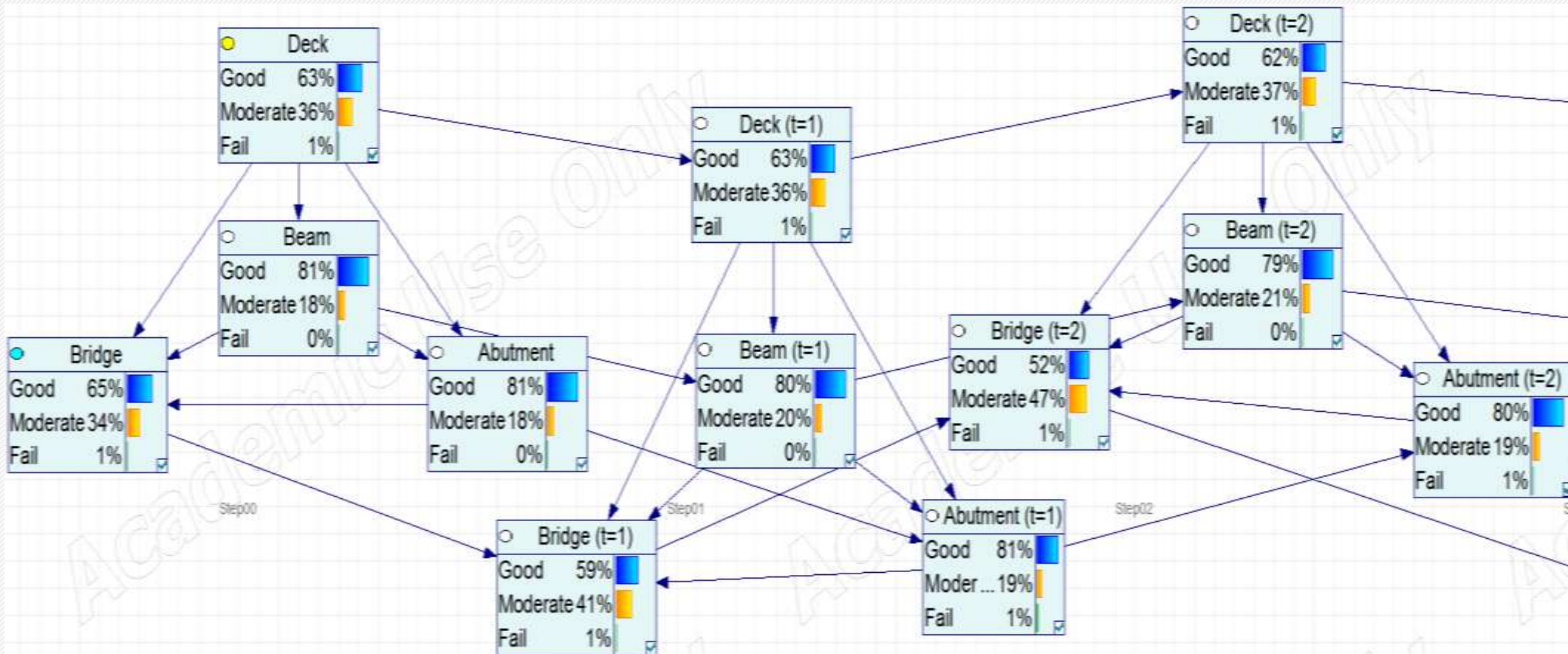
The DBN consists of several parts of the BNs, each of it representing a system in a slice of time
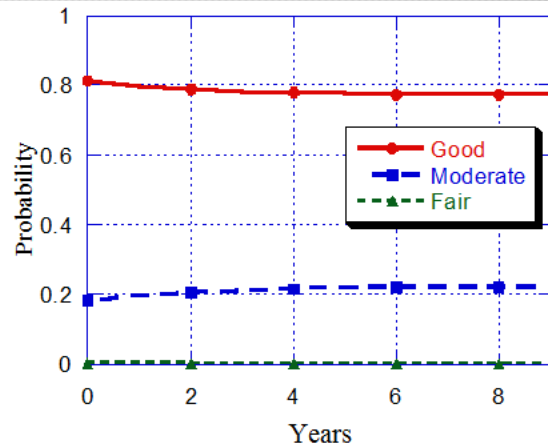
Result and Discussions

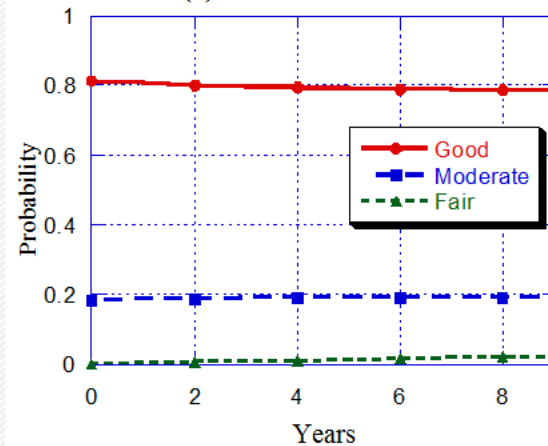**DBN model is simulated using GeNle 2.1 software**
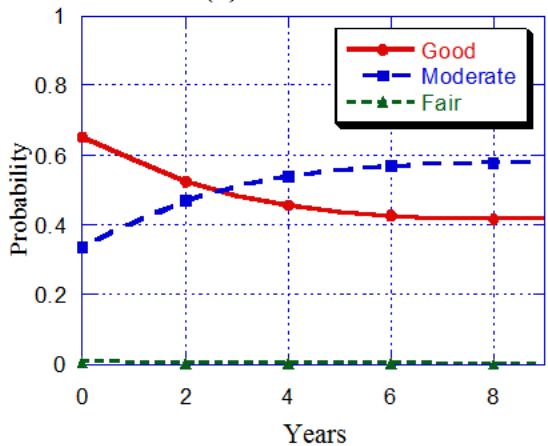
DBN Model Simulation

(a) DBN Deck

(b) DBN Beam

(c) DBN Abutment

(d) DBN Bridge

- **The graph of condition probability of bridge and its component based on I-BMS**

- **The result of the simulation are:**

1. **Probability of Bridge is strongly influenced by the probability of Beam and Abutment**

2. **Probability of Deck has a very small effect on the probability of Bridge**

DBN Model Validation

Bridge	Deck			Beam			Abutment			Bridge (data)			Bridge (model)		
Year	0	1st	2nd	0	1st	2nd	0	1st	2nd	0	1st	2nd	0	1st	2nd
1	G	G	G	G	G	G	G	M	M	G	M	M	G	G	G
2	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
3	G	G	G	M	M	M	G	G	G	M	M	M	M	M	M
4	M	M	M	G	M	M	G	G	G	G	M	M	G	G	G
5	G	M	M	G	M	M	G	G	G	G	M	M	G	G	G
6	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
7	M	G	F	G	G	G	M	G	G	M	G	M	M	M	M
8	G	G	G	G	M	M	F	F	F	F	F	F	F	F	F
9	M	M	M	M	M	M	G	G	G	M	M	M	M	M	M
10	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
11	M	G	M	G	G	G	G	G	G	G	G	G	G	G	G

To validate the model and calculate the model accuracy is used a "match/ no match" approach.

	No Match

DBN Model Validation

	Deck			Beam			Abutment			Bridge (data)			Bridge (model)		
Year	0	1st	2nd	0	1st	2nd	0	1st	2nd	0	1st	2nd	0	1st	2nd
Bridge															
12	G	G	M	G	G	G	G	G	G	G	G	G	G	G	G
13	G	G	G	M	G	G	G	G	G	M	G	G	M	M	M
14	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
15	M	G	M	G	G	M	G	G	M	G	G	M	G	G	M
16	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
17	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
18	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
19	G	M	M	G	G	G	G	G	G	G	G	G	G	G	G
20	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	Percentage of Accuracy (%)												100%	80%	80%

Scenario Model DBN

Scenario	Deck	Beam	Abutment
1	G	G	G
	M	G	G
	F	G	G
2	G	G	G
	G	M	G
	G	F	G
3	G	G	G
	G	G	M
	G	G	F

Scenario intended to study the effect of behavior changes of bridge component conditions.
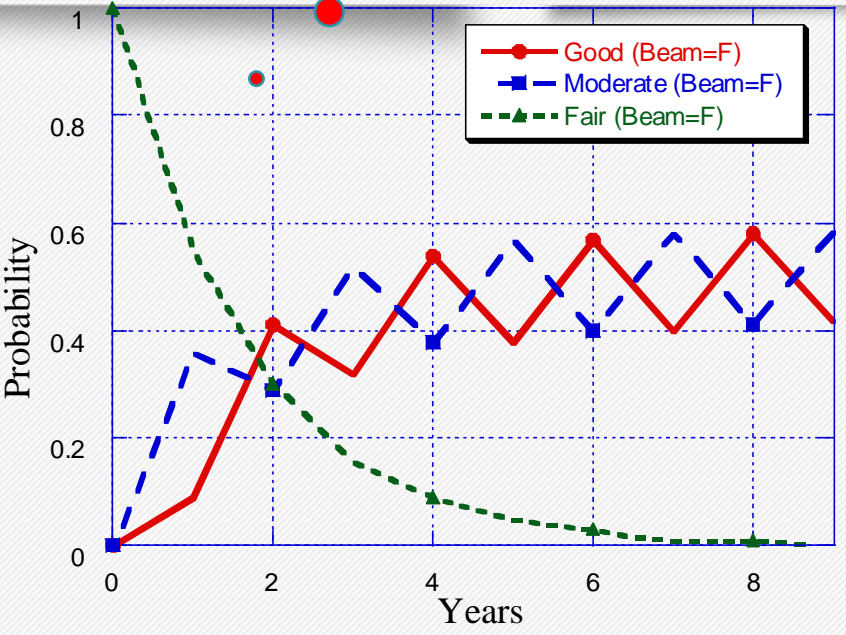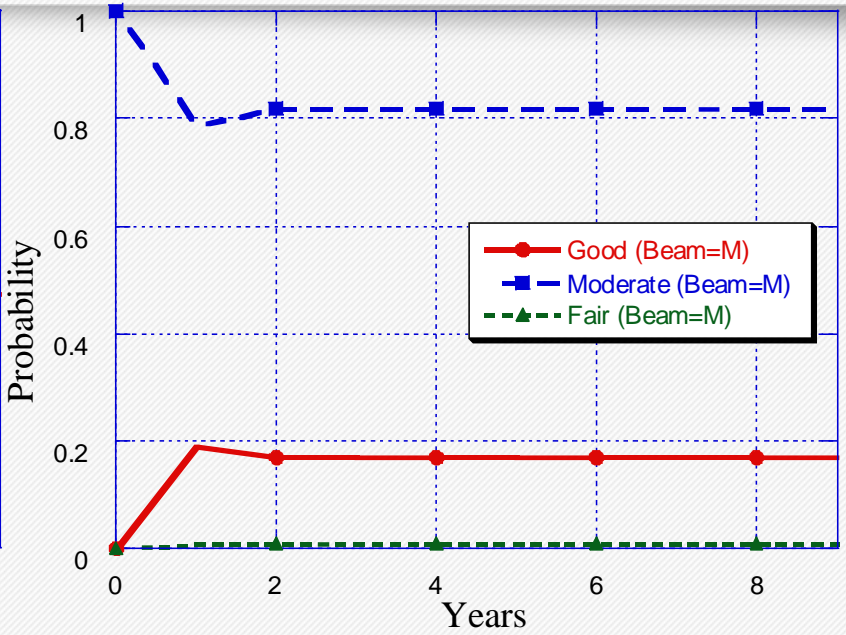
Scenario Model DBN (First Scenario)
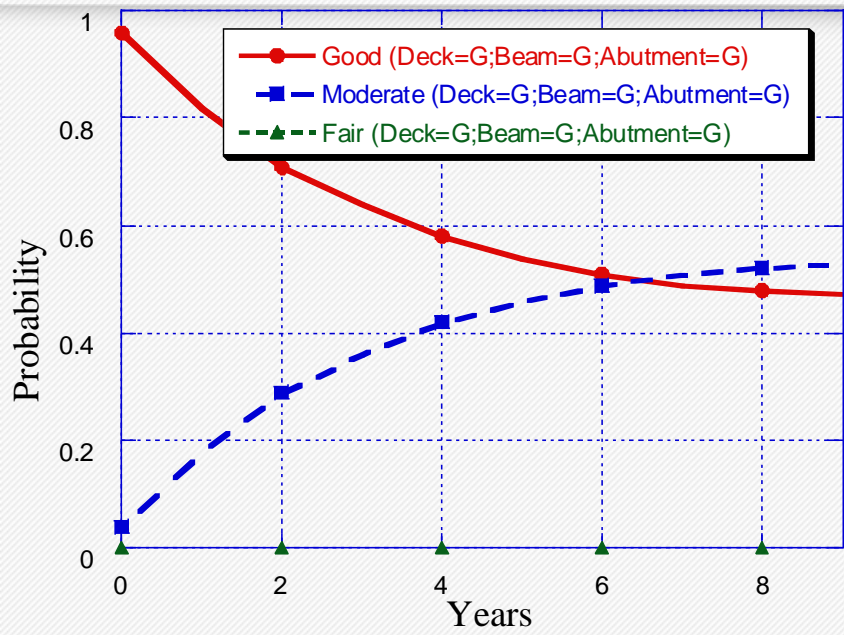
Deck is changed from G to F
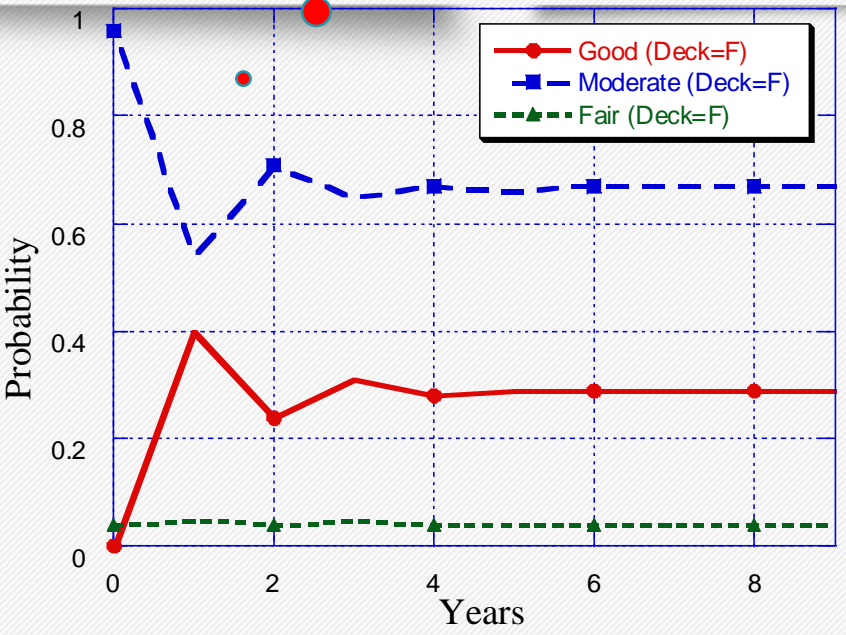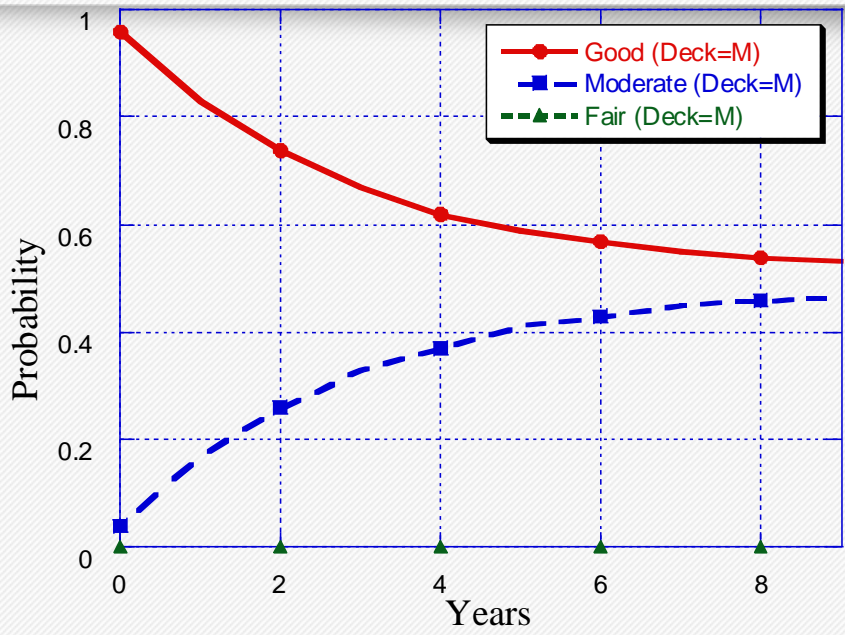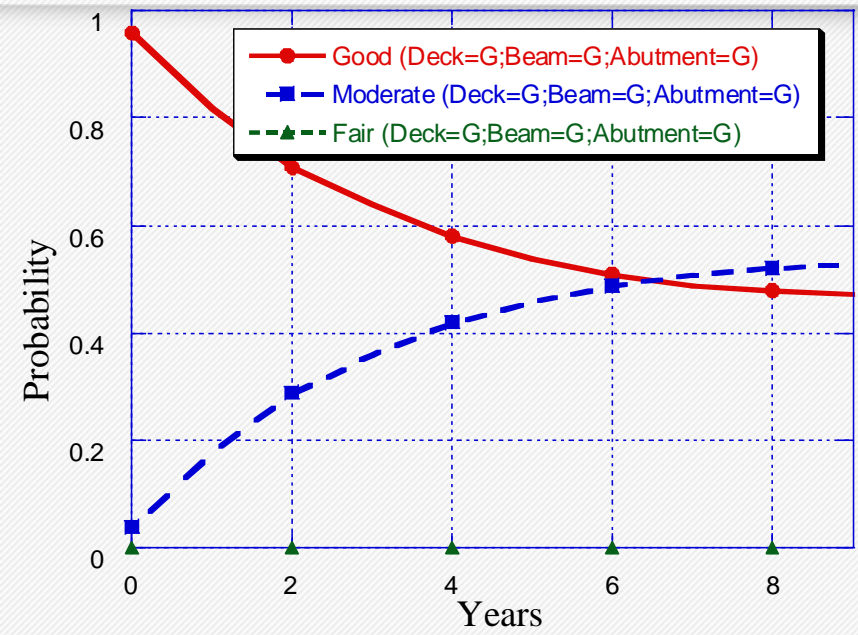
The Bridge condition is still "Good" even though the condition of the Deck is "Moderate".
The "Fail" Deck condition can change the bridge condition to be "Moderate".

Scenario Model DBN (2nd Scenario)
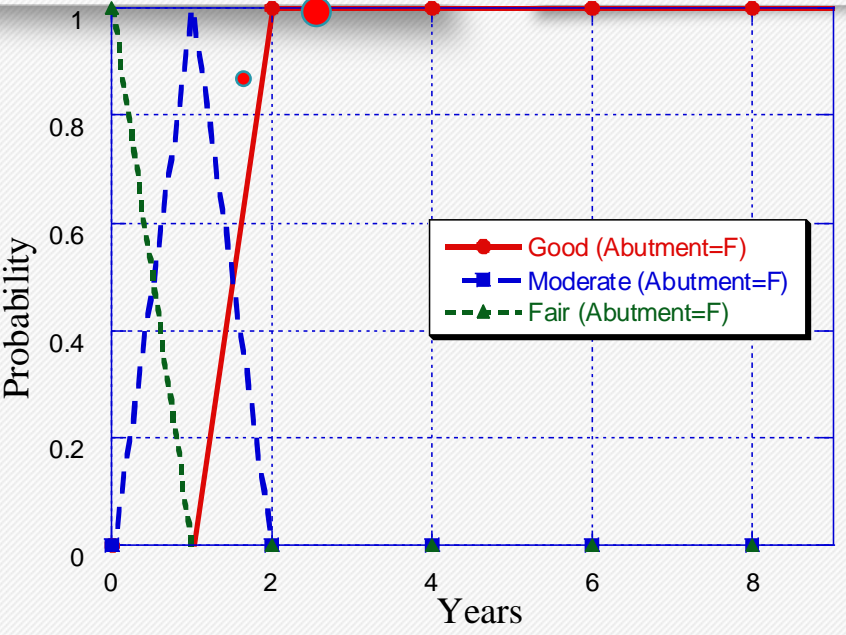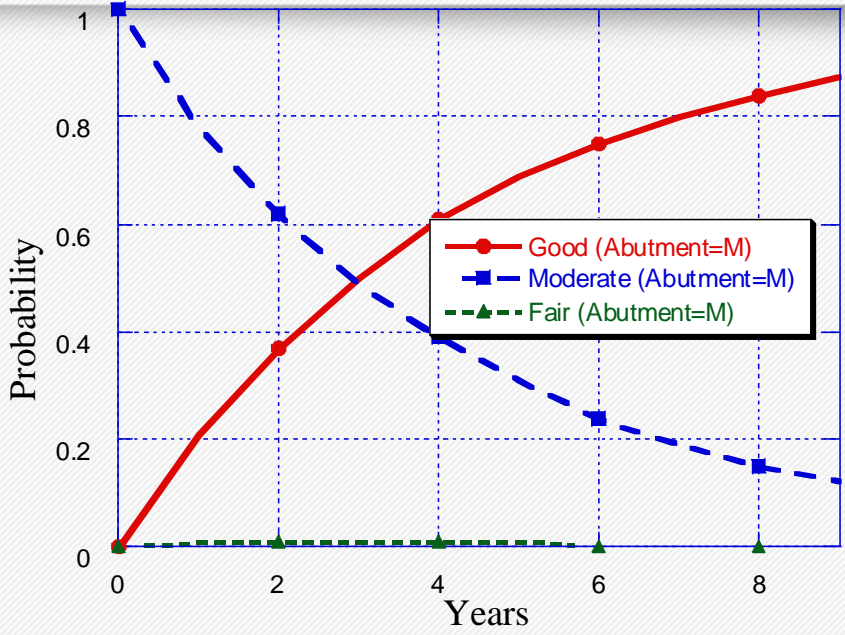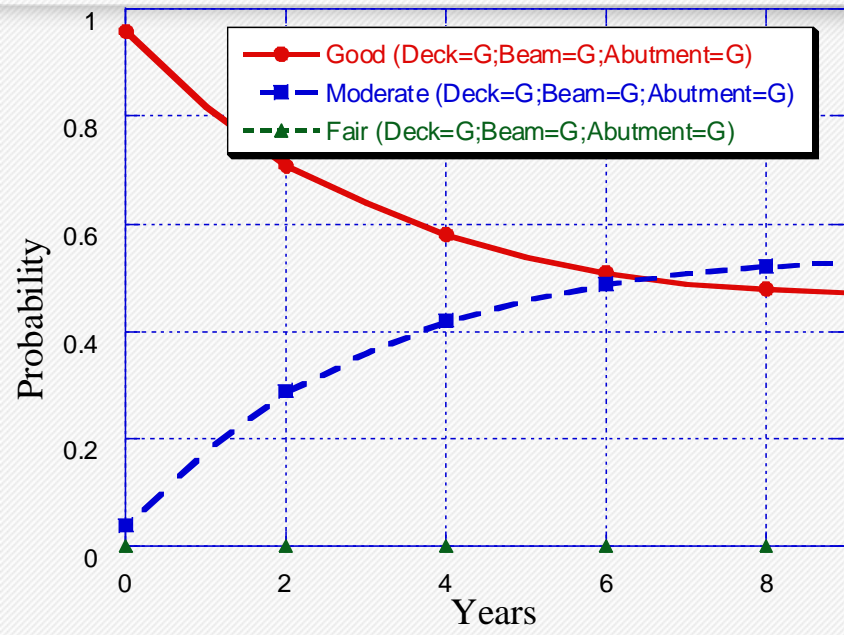
Beam is changed from G to F

The Bridge condition is strongly influenced by the Beam condition even though the deck and abutment conditions are "Good". This indicates that the effect of the Beam condition on the Bridge condition is very dominant.

Scenario Model DBN (3rd Scenario)

Abutment is changed from G to F

Bridge condition strongly influenced by Abutment condition also Abutment condition changed to "Fail", has an anomaly condition in the second year and later. This anomaly condition is estimated due to limited data changes in the Fail's Bridge condition.

Conclusion

1. **Conclusion:**
   a. The Dynamic Bayesian Updating Approach can be used to assess the Bridge condition accurately.
   b. Each bridge component contributes to determining the Bridge condition that the effect on the Bridge condition is provided by, from largest to smallest, the Abutment, Beam and Deck.

2. **Recommendation**:
   a. The Dynamic Bayesian Updating Approach can also be used as a guide for the maintenance and operation strategy of the bridge.
   b. To prevent the sudden collapse of the bridge, should pay very serious attention to the damage protection of abutments and beams.
   c. The model can also be used as an early warning system to prevent bridge failure, even though the model accuracy still needs to be improved.