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# Data Generation using Monte Carlo Simulation for Reinforced Concrete Highway Bridge Defect of BIMs

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## ☐ Introduction

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## ☐ Background

- ✿ Bridge Integrity Management System (BIMs)
- ✿ Fault Tree method
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## ☐ References

- ❑ In Malaysia, there are more than 10 000 bridges manage by JKR, KTMB, DBKL and LLM (Idris & Ismail, 2007).
- ❑ With a huge number of bridges to be monitor and several issue related to the bridge management in Malaysia due to numbers of ageing bridge, the low fund for maintenance and occurrence of catastrophic bridge failure (King, 2001), will contribute to the issue on the cost of inspection and maintenance which must be given priorities in the future maintenance process.
- ❑ The comprehensive assessment and management system is essential to develop in order to reduce cost related to bridge performance assessment and which bridge should be given the priorities to be maintained first.
- ❑ Also, in current situation of increasing of traffic demands and ageing bridge, it is significant to have an effective method for deciding which bridges need inspection and maintenance first and which ones can be less observation, thus the need to prioritize.

# *Problem statement and significant of research*

- ❑ Bridge assessment practice in Malaysia uses a system called bridge management system (BMS).  
The system:
  - based on condition evaluation and cost optimisation (Weng et al., 1991; Omar, King & Hashim, 1992).
  - The inspection frequencies are time-based.
  - More concern on the prediction of occurrence of failure rather than the consequences of the failure during the decision making process.
- ❑ Since repair and maintenance fund are limited, the new practical management system is essential to be developed to rank the necessity of repair, strengthening and replacement by prioritise the inspection first and considering both probability of failure and its consequences during the decision making stage
- ❑ Thus, the cost of inspection of bridges that categorized in good condition may reduce by increasing the interval of the next inspection.
- ❑ This approach for decision making in asset integrity management system is more recognised as risk-based approach.
- ❑ Since the risk assessment method has been successfully implemented in structural integrity management of offshore platform structure with long term reduction in operating and assessment cost (O'Connor et al., 2005; Straub, Sorensen & Faber, 2006), it is possible to develop the bridge management system using the same approach.

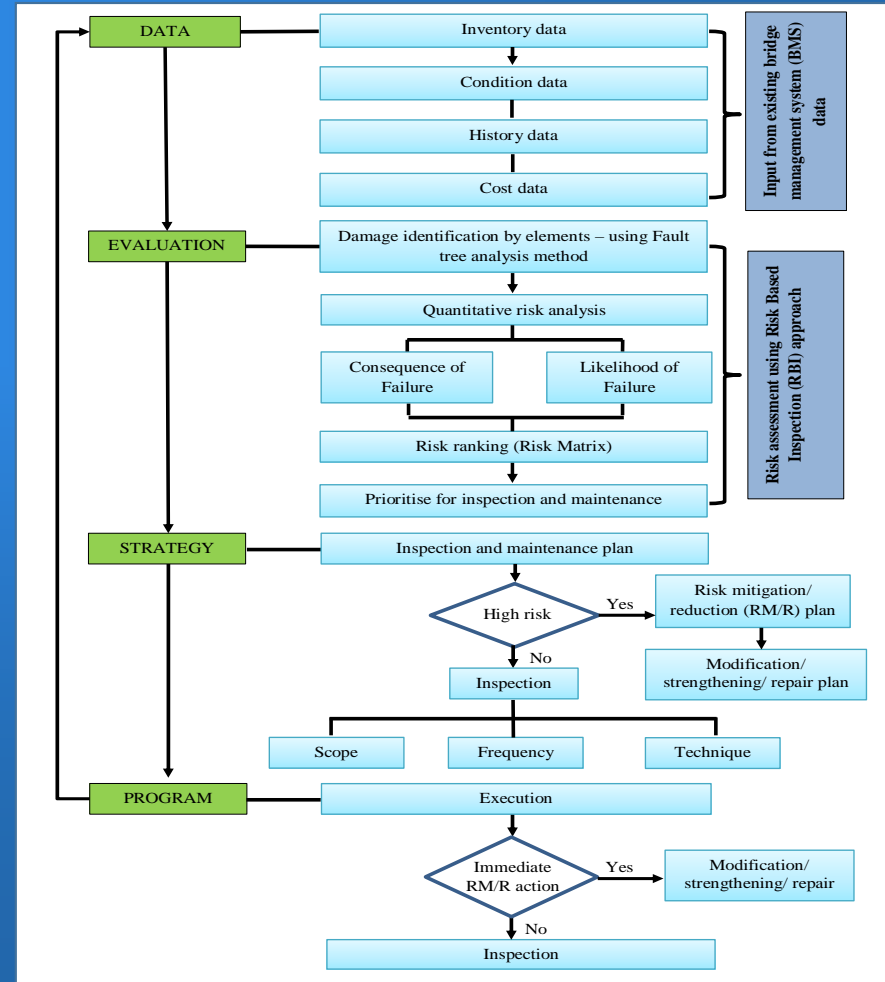
To identify of the bridge performance indicator in the form of cause-consequence scenario, which is most significant to the structural integrity.

To proposed framework for Bridge Integrity Management System (BIMs) of concrete highway bridge using risk-based approach in Malaysia.

To create risk matrix in prioritizing ranking of bridge inspection for future risk mitigation or maintenance action.

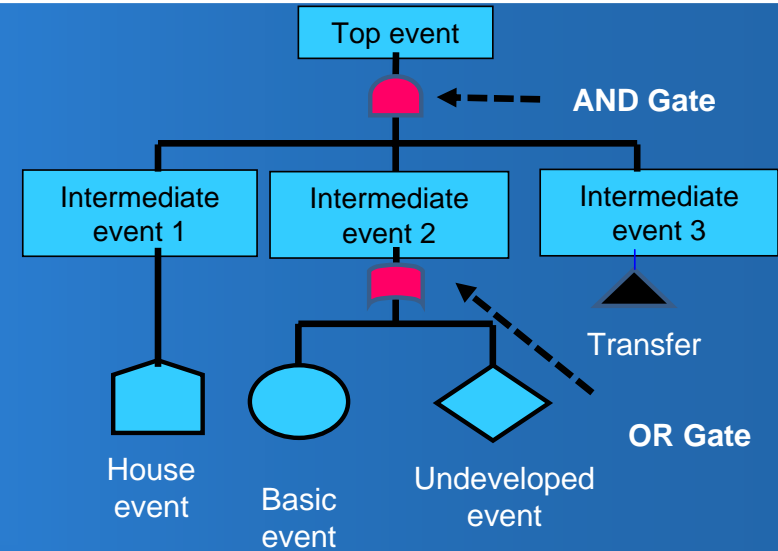
- ❑ In order to determine risk, a model for causes and outcomes identification of failure is developed
- ❑ Since the collected data are insufficient for the statistical analysis, the data simulation is necessary to generate data. The aim of this paper is to present the data generation using Monte Carlo Simulation for some basic event parameters that causes the bridge defect which identified based on developed model of causes identification failure.

- ❑ The propose framework of BIMs was emulated from Structural Integrity Management System (SIMS) of offshore structure
- ❑ This study only focuses on data preparation and evaluation phase.



# Fault Tree method (FT)

- ❑ Used to identify the combinations of event which could cause a major accident.
- ❑ A deductive approach of failure analysis, starting with a potential undesirable event called TOP event and then determining all the possible way that cause the TOP event occurred using logical gates such as AND/OR gates to combine the causal event.



Authors	Year	Description
McDaniel et al.	2013	The use of risk assessment approach through FT analysis <a href="#">to identify the event that could lead to the bridge collapse which based on case study</a> for a specific bridge type known as segmental concrete box girder bridge. The model help in identifying countermeasures to minimize risk
Zhu et al.	2008	The FT method has been used in risk assessment <a href="#">to model the probability of the deterioration of concrete bridge due to poor durability that exposed to aggressive environments</a> . The model was used to identify the important of risk for bridge components and their relative severity and to rank the performance trends of bridges
Johnson	1999	Uses the FT analysis <a href="#">to shows the interactions of the complex processes of erosion at bridge piers and abutments in order to determine the probability of bridge failure</a> due to scour and channel instability.

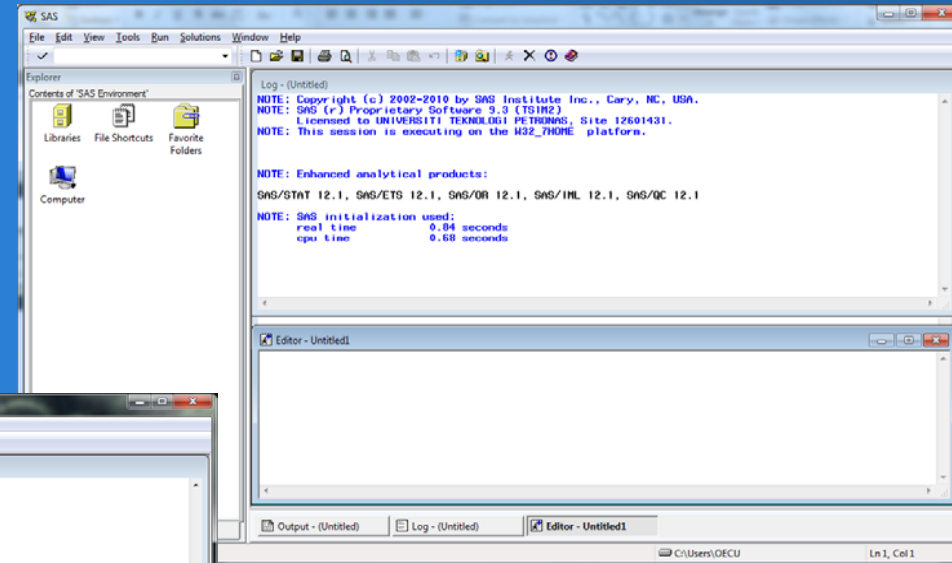
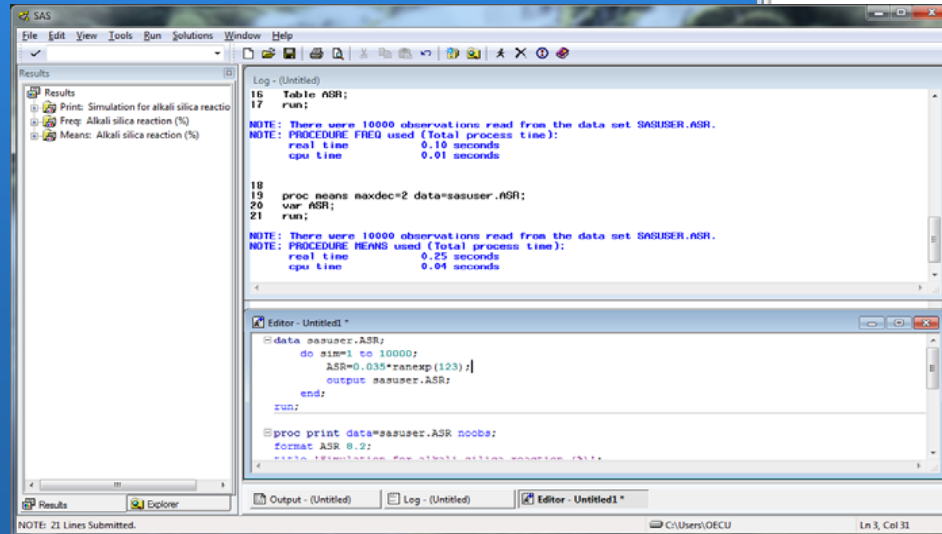
- ❑ One of simulation method for generating data.
- ❑ Based on estimation of random number using computer model to generate the distribution of required certain sample sizes rather than doing manually either by experimental work or collecting data.
- ❑ Needs for sampling distribution pattern which can be determined through theoretical concept, observed data or past research studies.
- ❑ Considered when there are difficulties in getting data through experimental work, having missing data or not enough data for analysis.

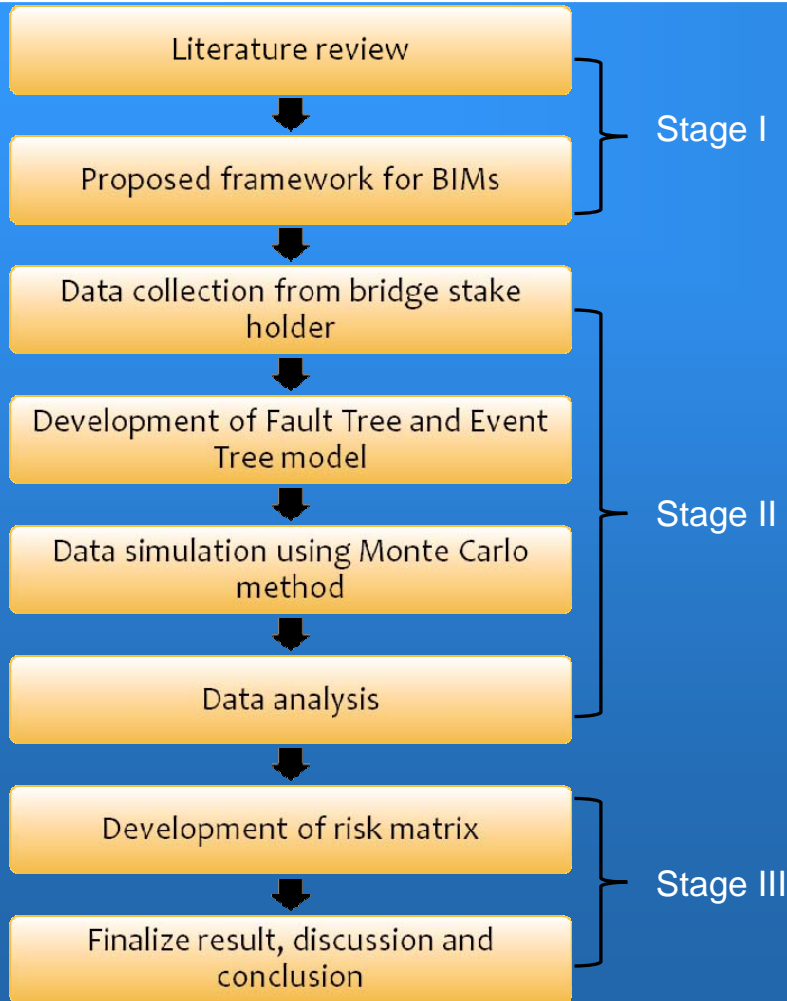
Authors	Year	Description
Nogueira and Leonel, Ossai , Carrasco and Chang , Zevgolis and Bourdeau	2013, 2013, 2005, 2010	Example studies of using Monte Carlo method in various engineering field (reinforced concrete structure, pipeline, wastewater, retaining wall) which applied in studies area related to system reliability analysis, risk assessment and development of predicted model.
Xie et al.	2014	Uses Monte Carlo method to calculate the reliability indices of existing RC beams of highway bridges for predicting the probability of failure of the existing highway bridges
Ali et al.	2012	Present Monte Carlo simulation in the research of concrete highway bridges for developing time dependent statistical model for rebar steel area and live load extreme effect which contribute to the process of reliability analysis.



# Statistical Analysis System (SAS) software

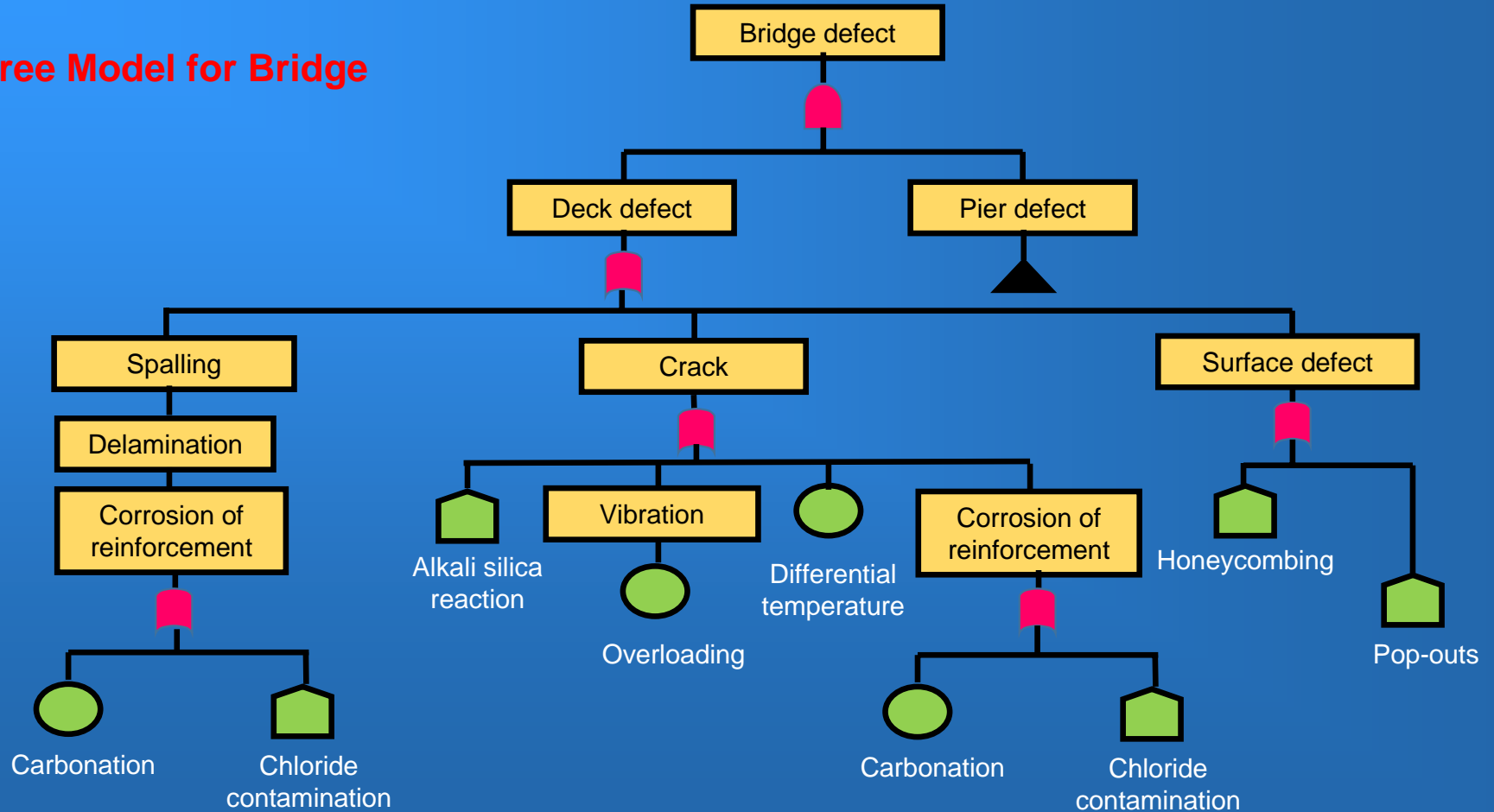
- ❑ Is rarely use in engineering studies compare to medicine and pharmaceutical.
- ❑ Has a combination of variety of built in statistical procedures and mathematical function with programming capabilities (Fan et al., 2008).
- ❑ Suitable with Monte Carlo Simulation.



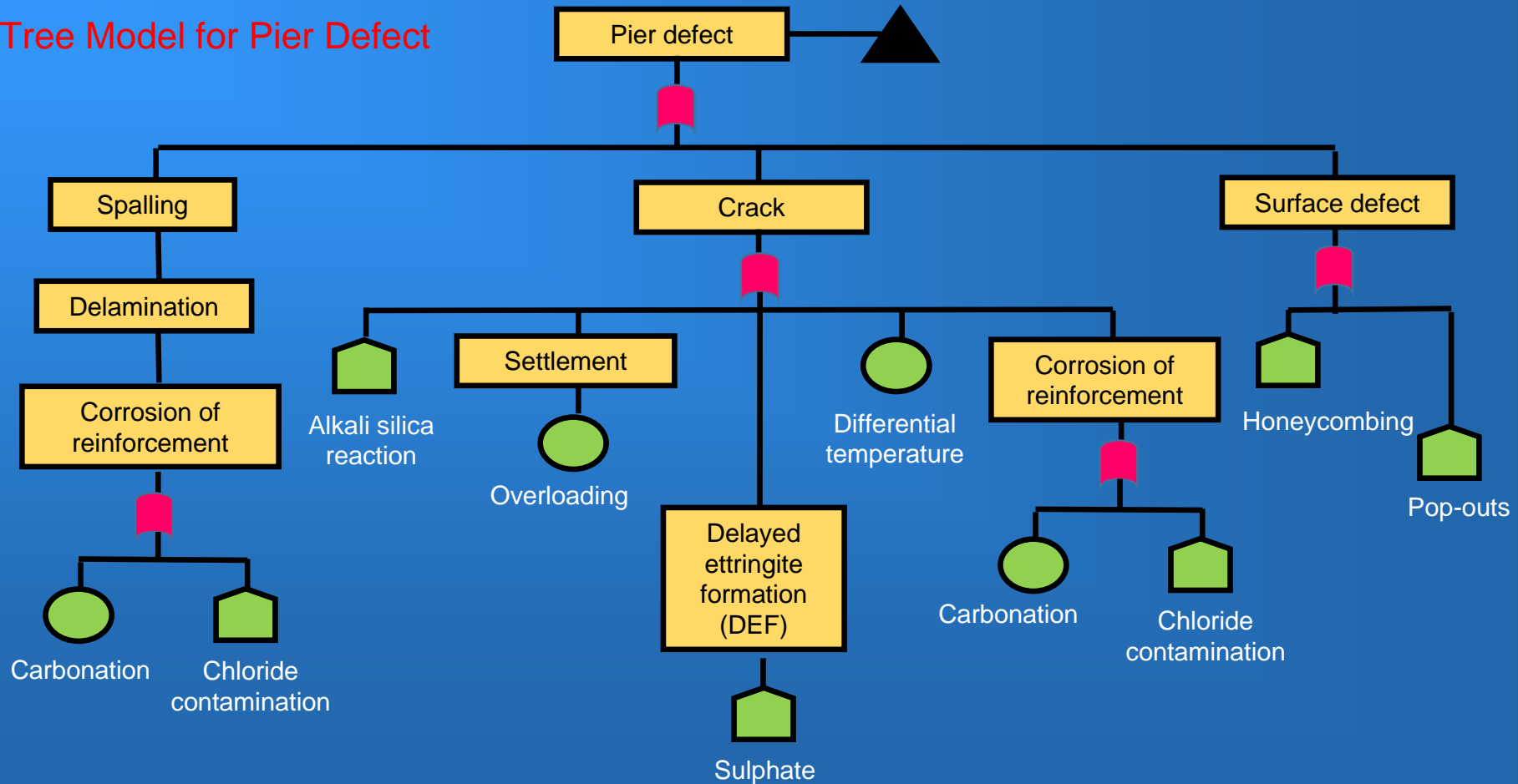


- ❑ The literature review was conducted to identify current types and technique used for bridge management worldwide, generally and specifically practiced in Malaysia and to identify the factors that may affect the performance of bridge.
- ❑ The potential causes of bridge defect was identified through FT model based on the literature review (Sianipar & Adams, 1997; LeBeau & Wadia-Fascetti, 2007; Zhu et al., 2008; King & Ku Mahamud, 2009; McDaniel et al., 2013) and existing bridge performance assessment data which is known as condition rating data.
- ❑ The bridge data was extracted from current practiced system (BMS) which known as JKR-BMS.
- ❑ Due to some missing data and not enough data for both causes and the consequence of bridge failure, the Monte Carlo Method is used for data simulation in getting more data for statistical calculation.
- ❑ For sampling, Monte Carlo simulation begin with the determination of theoretical value range (Kamaitis, 2002; Idris & Ismail, 2007) for each parameter involve. A trial of simulation is according to the specified type pf distribution. The resulting output are described in terms of frequency, minimum and maximum values, mean and standard deviations.

## Fault Tree Model for Bridge Defect



## Sub-Fault Tree Model for Pier Defect



- Table shown the summary of Monte Carlo simulation for data generation of environmental impact and chemical action on bridge defect.

Name	unit	Mean	Std Dev	Min	Max	Assume Distribution pattern
Carbonation Depth	mm	3.11	3.62	0.0	40.0	Exponential
Chloride	%	0.03	0.04	0.0	0.4	Exponential
ASR	%	0.03	0.04	0.0	0.4	Exponential
Sulphate	%	0.35	0.36	0.0	4.0	Exponential
DEF	%	2.5	1.43	0.0	5.0	Uniform

- Carbonation depth, chloride, ASR and sulphate are assumed to occur naturally within time and most impact take quit a long time to be detected (Technical Guidance on the Appraisal of Existing Structures, 1992; Kamaitis, 2002). Thus, the distribution pattern is considered as exponential type
- DEF is assumed as uniform distribution pattern based on a reported study that shown the effect of DEF could occur at the early age of bridge structures (Andra & Maier, 2009).

# Conclusion and Future Direction

- ❑ The bridge defect model is built as a part of risk analysis for the purpose of to evaluate the risk of bridge failure.
- ❑ FT model is used to identify the causes and mechanism of bridge defect.
- ❑ Due to lack of data for statistical analysis in order to determine the risk value, data generation using Monte Carlo simulation is used.
- ❑ As a start, the data which generate using random number generator is SAS software was considered only from the basic event that causes the bridge defect involving carbonation, chloride, ASR, DEF and sulphate which identified through FT model.
- ❑ The distribution types of sampling are considered as exponential and uniform
- ❑ future research - to finalize the overall bridge data in FT model using Monte Carlo simulation and analysis.

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