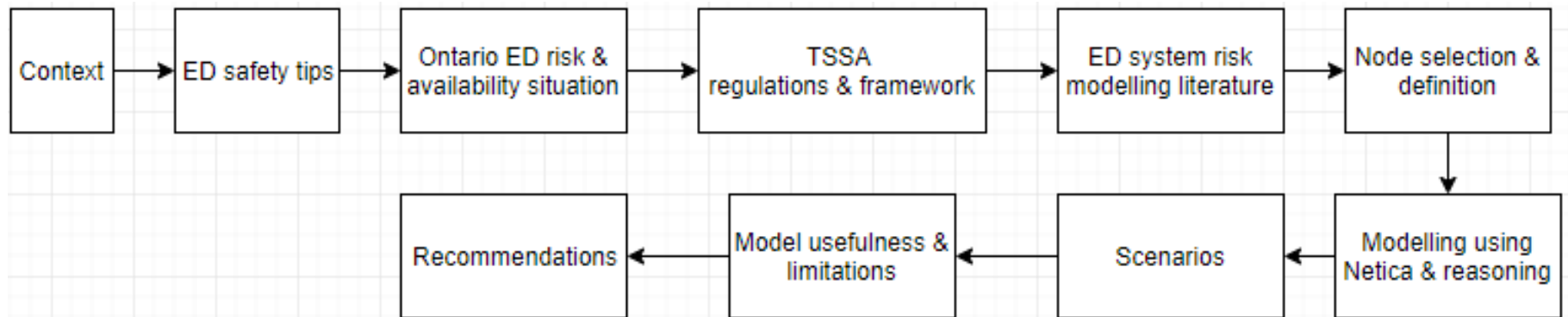# Modelling the impact of regulatory control on the risk and availability of elevator devices to users in Ontario
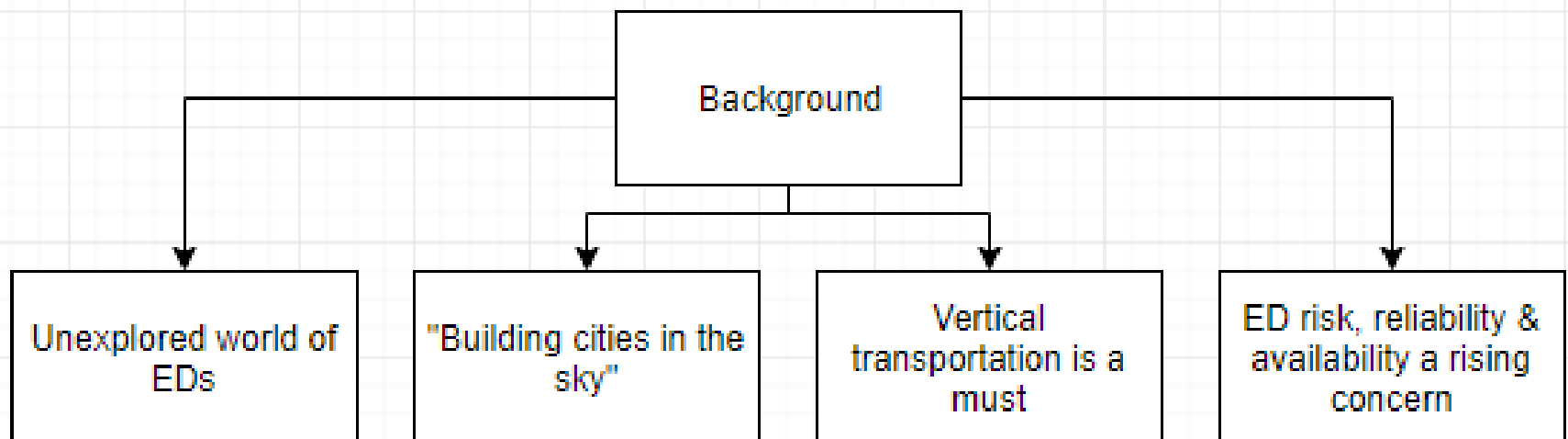
Presented to,
Technical Standards &
Safety Authority (TSSA),
Government of Ontario
Canada

By,
Krishnan Moni
MSc Data Analytics
Supervisor: Prof. Lesley Walls
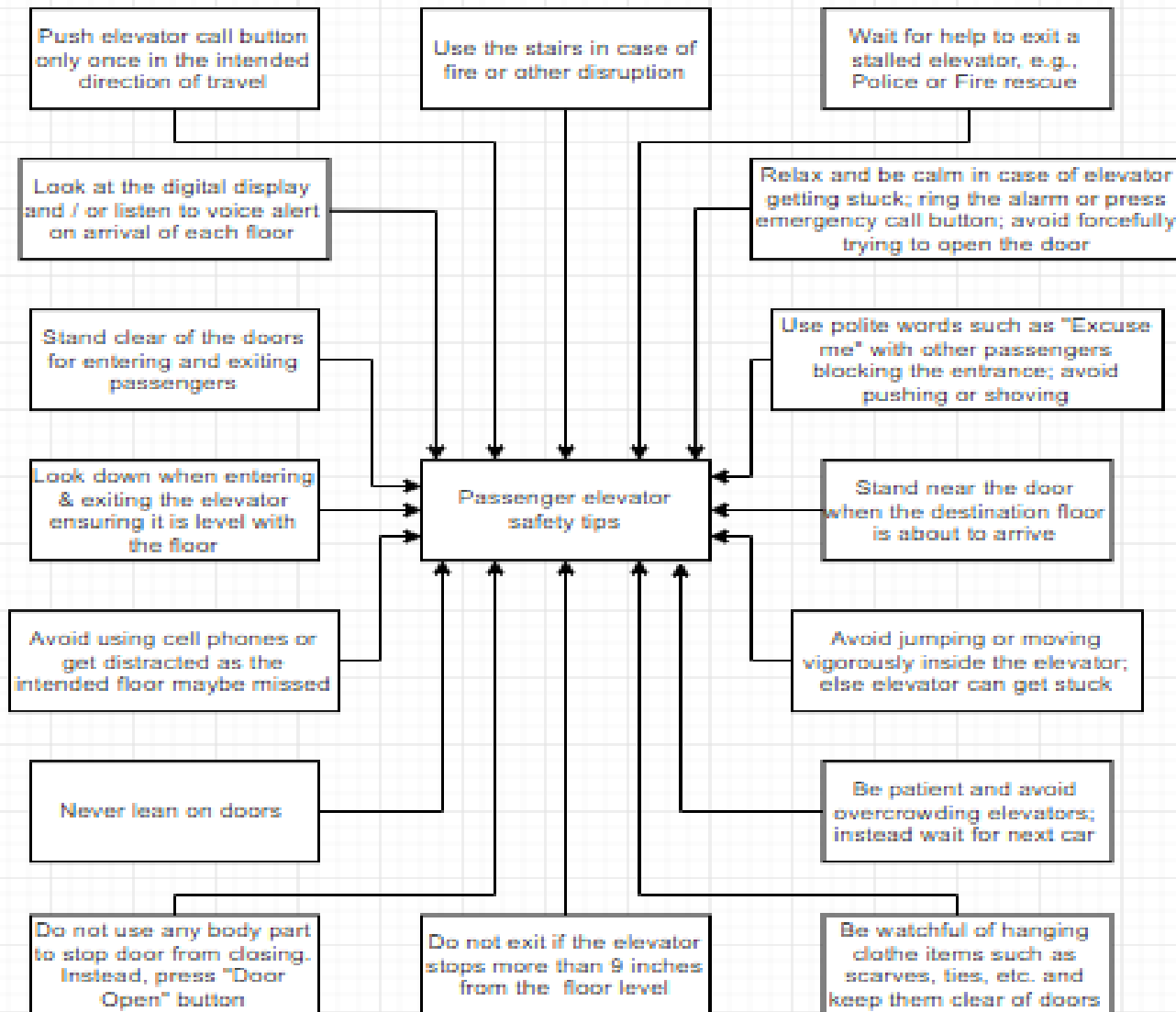Strathclyde Business School
October 2018

Agenda

Context

Passenger elevator safety tips

Push elevator call button only once in the intended direction of travel	Use the stairs in case of fire or other disruption	Wait for help to exit a stalled elevator, e.g., Police or Fire rescue
Look at the digital display and / or listen to voice alert on arrival of each floor		Relax and be calm in case of elevator getting stuck; ring the alarm or press emergency call button; avoid forcefully trying to open the door
Stand clear of the doors for entering and exiting passengers		Use polite words such as "Excuse me" with other passengers blocking the entrance; avoid pushing or shoving
Look down when entering & exiting the elevator ensuring it is level with the floor	Passenger elevator safety tips	Stand near the door when the destination floor is about to arrive
Avoid using cell phones or get distracted as the intended floor maybe missed		Avoid jumping or moving vigorously inside the elevator; else elevator can get stuck
Never lean on doors		Be patient and avoid overcrowding elevators; instead wait for next car
Do not use any body part to stop door from closing. Instead, press "Door Open" button	Do not exit if the elevator stops more than 9 inches from the floor level	Be watchful of hanging clothe items such as scarves, ties, etc. and keep them clear of doors

- >75% elevator incidents are owing to user carelessness
- TSSA must create safety awareness of elevator devices

Escalator & moving walk safety tips
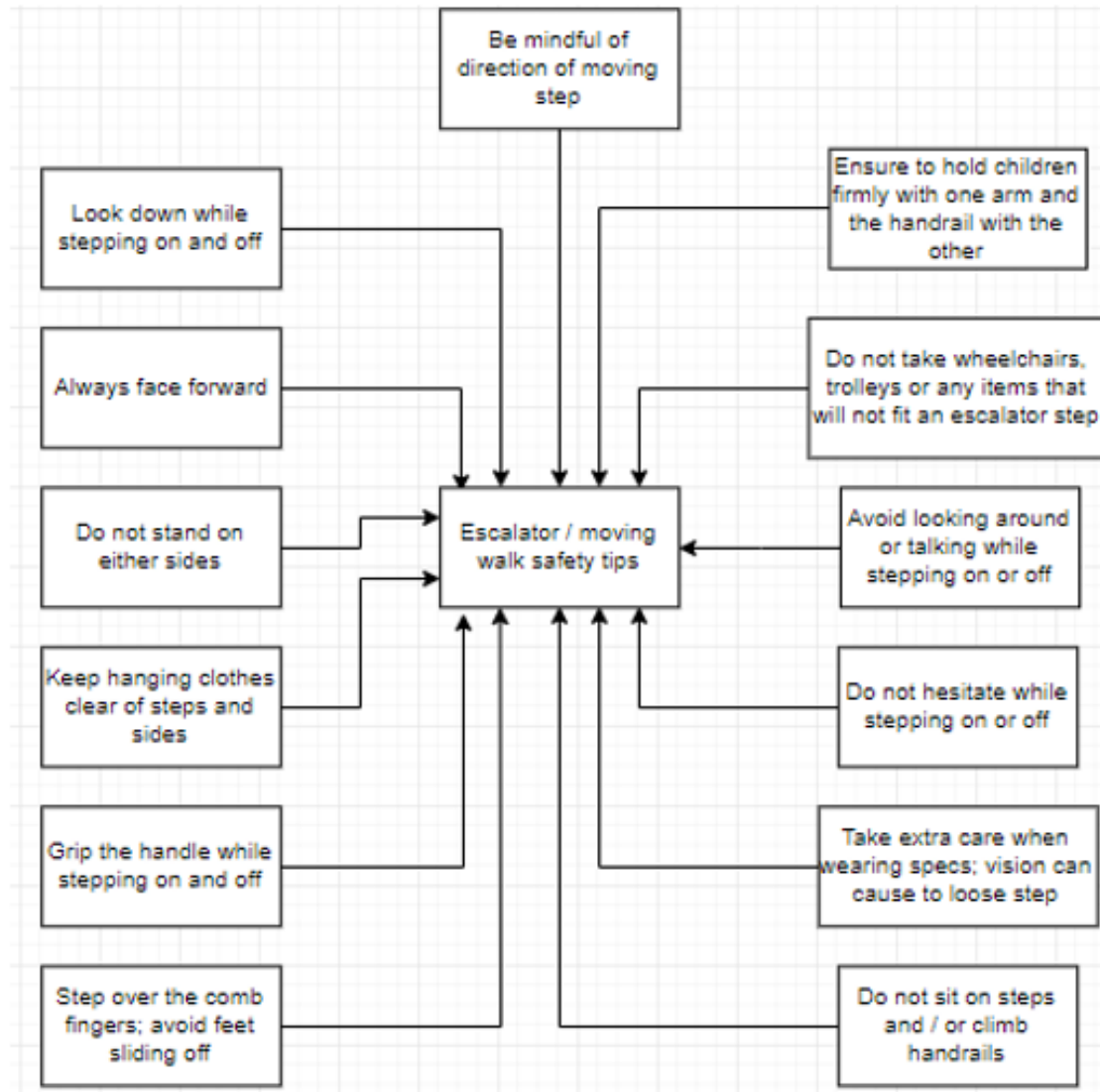
Ontario EDs population at risk

|	
Existing passenger elevator	41,677
Existing freight elevators	2696
Existing escalators	2071
Existing moving walks	43
Existing dumbwaiters	1153
Passenger elevator installation	933
Freight elevator installation	30
Escalator installation	88
Dumbwaiter installation	4
Elevator Code	ASME A17.1-2010 / CSA B44.10

Building Purpose	Toronto
Residential (%)	82
Office (%)	15
Hotel & Other (%)	3

- Data as of 2016
- ~50% of Canada's EDs are in Ontario
- ~10% increase in number of EDs in last 5 years

Building purpose (2017)

Ontario ED user concerns

- World's first jurisdiction to setup elevator repair timelines
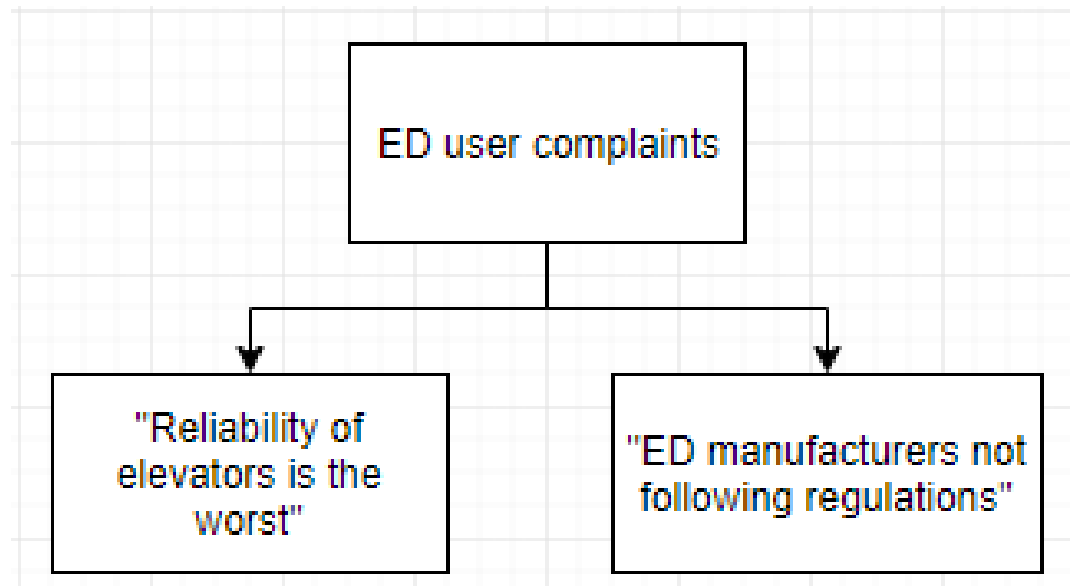
Ontario ED availability situation
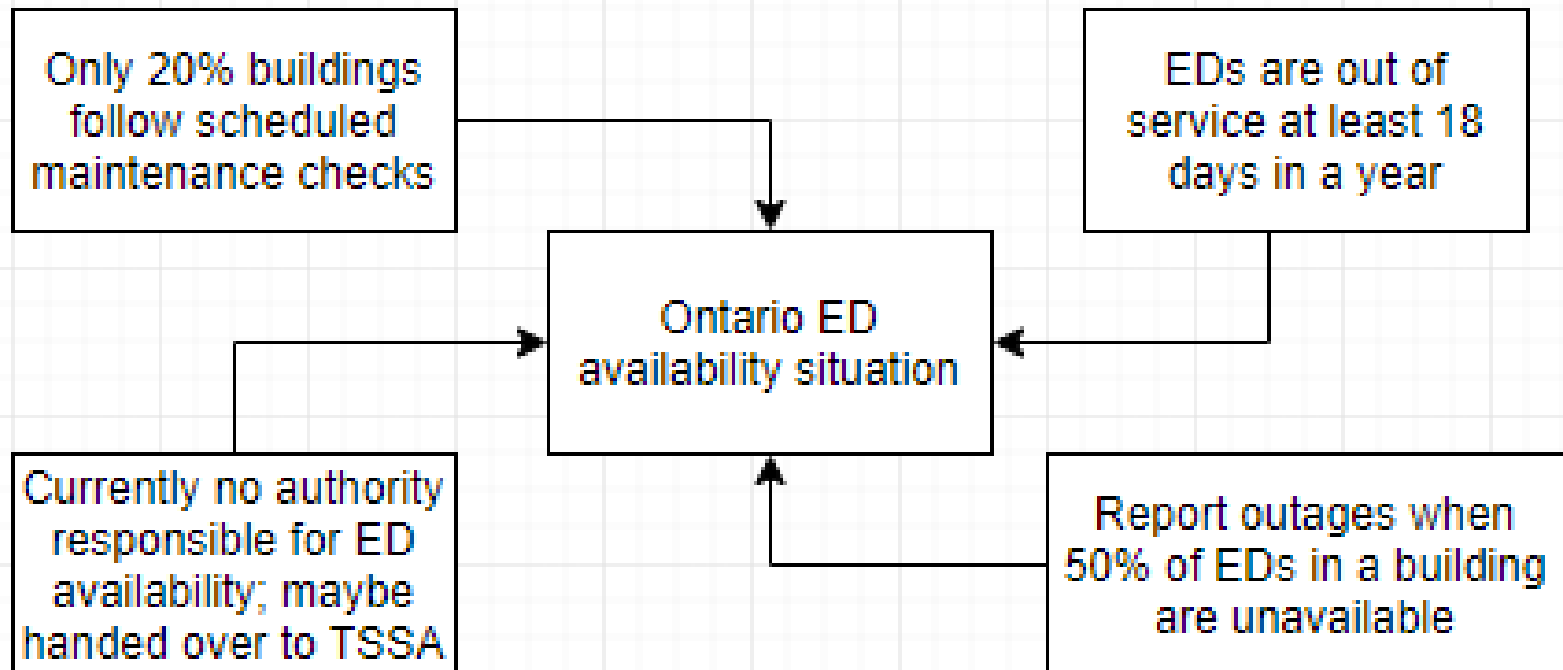
Ontario EDs hazard stats
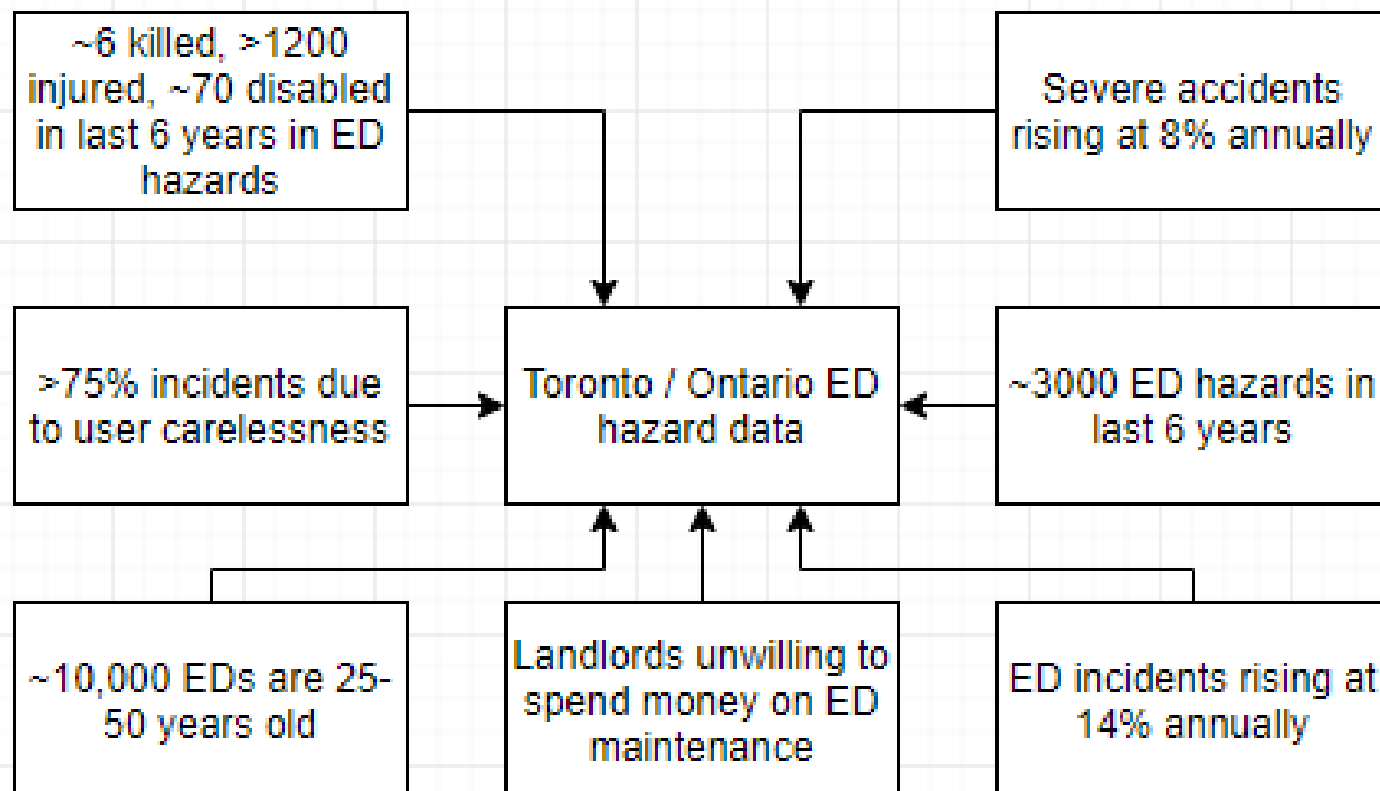
Ontario ED regulatory framework

Organization name	Technical Standards and Safety Authority (TSSA)
Region served	Territory of Ontario
CEO / President	Bonnie Rose
ED safety Act / Bill	Technical Standards & Safety Act, 2000
Founded	1997
Organization type	Self-funded / Not-for-profit
Head office	Toronto
Total employees	~400
Elevator code	ASME A17.1-2010 / CSA B44.10
Purpose & Areas of service	Ensure public safety in EDs, Ski Lifts, Amusement Devices, Stuffed Articles, Fuels, Boilers, Pressure Vessels

Ontario ED & building regulations

Authority for enforcing building requirements	Ministry of Municipal Affairs
Min requirement for elevator in buildings	Seven stories or more
Authority for enforcing fire requirements	Ministry of Municipal Affairs
ED requirements in case of fire	Residential buildings more than 18m high need at least one firefighter elevator and at least one in care homes
Authority for ED safety & availability	TSSA, Ontario
National regulation & standard for elevator safety	NBC of Canada, A17.1 / CSA B44
State / Provincial regulation for building & elevator safety	Ontario Building Code, Ontario Fire Code, Building Code Act
Municipal regulation for building & elevator safety	Ontario Fire Code, Building Code Act, Ontario Building Code
Minimum time for repairing faulty ED	7 days for long term care homes; 14 days for all other buildings
Responsibility of ensuring maintenance & repair of EDs	Building owner and elevator contractor having license from TSSA
Safety precautions for members of public & compensation for injured or inconvenienced	Primarily keep building occupants informed well in advance of faulty elevators; no info on compensation for injured

ED risk modelling – Literature (1/2)

Model	Combination of PN, Bow-tie & FTA models (Vileiniskis, M & Remenyte-Prescott, R, 2016)
Purpose	Develop elevator risk & reliability framework
Methodology	Constructed based on elevator's operating condition, component degradation, operation & maintenance; probabilistic outputs of PN fed as inputs into Bow-Tie to calculate risk estimates of top event; then perform Monte Carlo simulation to predict performance & failure of elevator components; these failures are modeled using FTA and Boolean Logic

Model	FTA for elevator risk & availability modelling (TSSA, 2017)
Purpose	Determine elevator non-availability
Methodology	Determined in terms of hazards to passengers and measured in terms of probability of a fatal accident per year; then compared with a risk acceptability criteria of a probability of 1 out of xx fatalities per year

ED risk modelling – Literature (2/2)

Model	Multi-State Fuzzy Bayesian Network (Zhang, R. et al., 2014)
Purpose	To determine exact value of fault probability of elevator components by extending Bayesian Nets with Fuzzy Theory
Methodology	A Bayesian Net model of the elevator's horizontal vibration was built based on the logical relationship between factors; importance degree of factors affecting elevator's horizontal vibration is retrieved by importance analysis; elevator is maintained and checked using this importance degree; three state space {0,1,2} was used to represent various states of elevator components

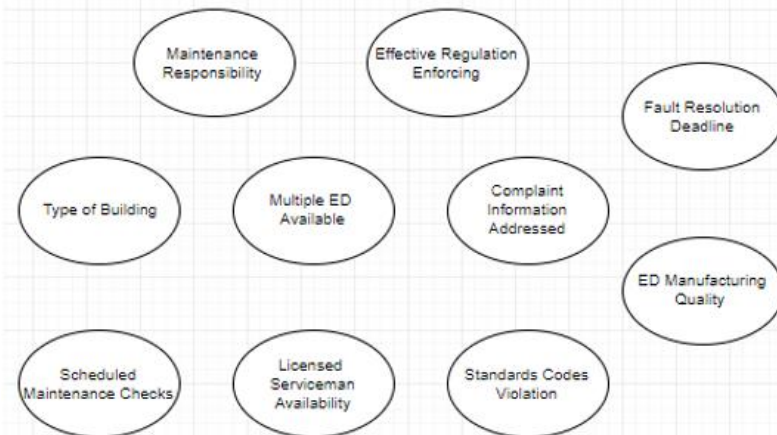|	
Model	Risk estimation using ALARP model (Rogova, E., 2017)
Purpose	To label different levels of elevator risk and to quantitatively define the class of risk
Methodology	Safety Integrity Level (SIL) of the braking system of a moving walk was analyzed; accidents happening in moving walks were classified into four consequence levels; this way the relationship between brakes unavailability and resulting consequences was studied;

Purpose of model & node selection process
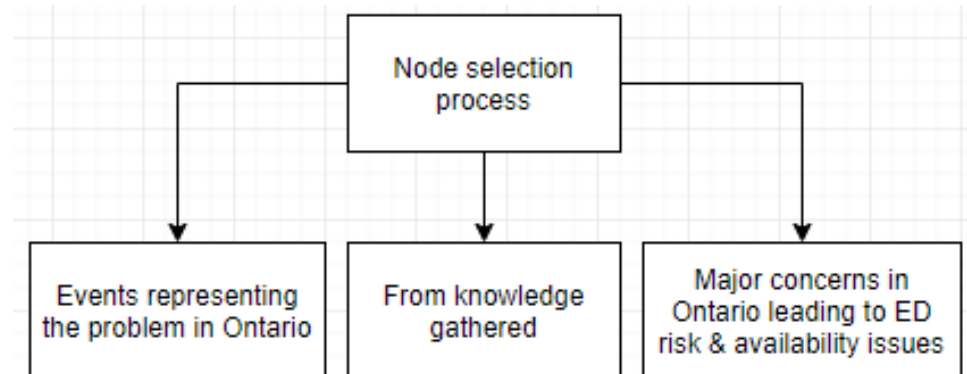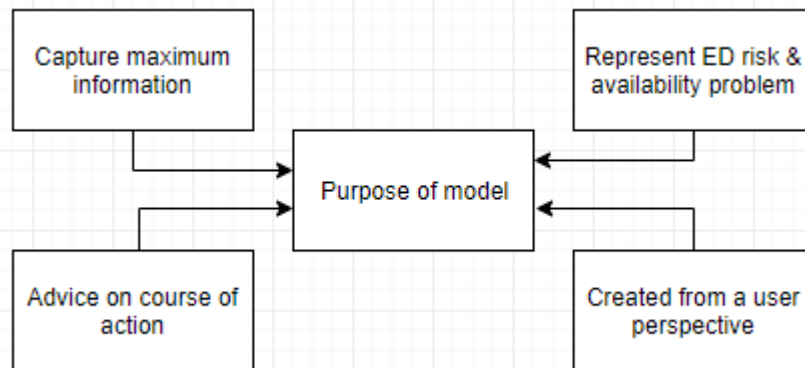
Consequence & variable nodes definition

| Consequence Node	Definition
ED Hazard Occurs	Defined as the probability of the event of human casualties and / or damage caused to the ED or its associated parts
ED Unavailable	Defined as the probability of the event of ED not functional at any point of time
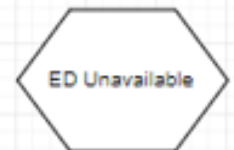
| Variable	Definition
Type of Building	Defined as the purpose of a building
Multiple ED Available	Defined as whether there are more than one ED available in a building
Maintenance Responsibility	Defined as the person (group) responsible for ensuring ED maintenance happens
Scheduled Maintenance Checks	Defined as whether maintenance checks of EDs happen on time as scheduled
Licensed Serviceman Availability	Defined as whether an authorized serviceman for replacing or modernizing ED is available
Standards Codes Violation	Defined as the degree of violation of building and ED regulations
ED Manufacturing Quality	Defined as the degree of quality of the available ED
Fault Resolution Deadline	Defined as the timeline (days) provided by the authorized serviceman to replace or modernize ED
Effective Regulation Enforcing	Defined as whether the ED authority is effectively enforcing the regional building and ED standards and codes
Complaint Information Addressed	Defined as how quickly the building owner or representative addresses user complaint on ED repair or unavailability

Decision nodes definition

Decision Node	Definition
Penalize Defaulter	Defined as the decision to take disciplinary action by the user of the model against the stakeholder or ED user in the event of violating building or ED regulations / laws / standards / codes, leading to ED hazard or unavailability. The form of penalty would be determined by the model user according to the level of offense committed by the wrong-doer
Compensate victims	Defined as the decision to take necessary steps by the user of the model to repay users in the event of human casualty if an ED hazard occurs. The form of reimbursement would be determined by the model user, according to the level of ED hazard and unavailability occurred
Modernize or replace ED	Defined as the decision to take by the user of the model whether to modernize or replace the ED in the case where it has been advised by the licensed serviceman to do so while performing maintenance checks. Such a decision would be taken only in cases where a regular repair or maintenance checks would not be suitable, owing to the present poor condition of the ED.
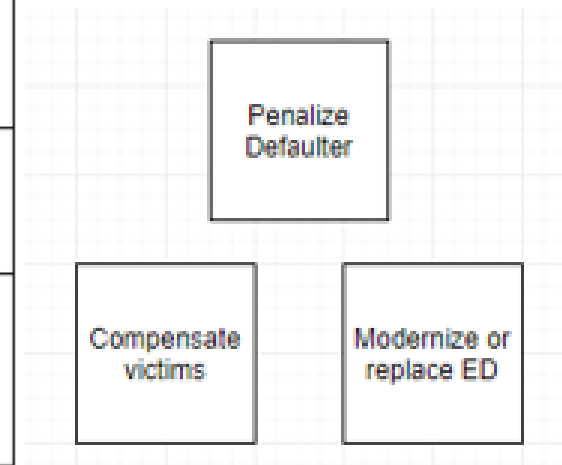
ID model & logic followed
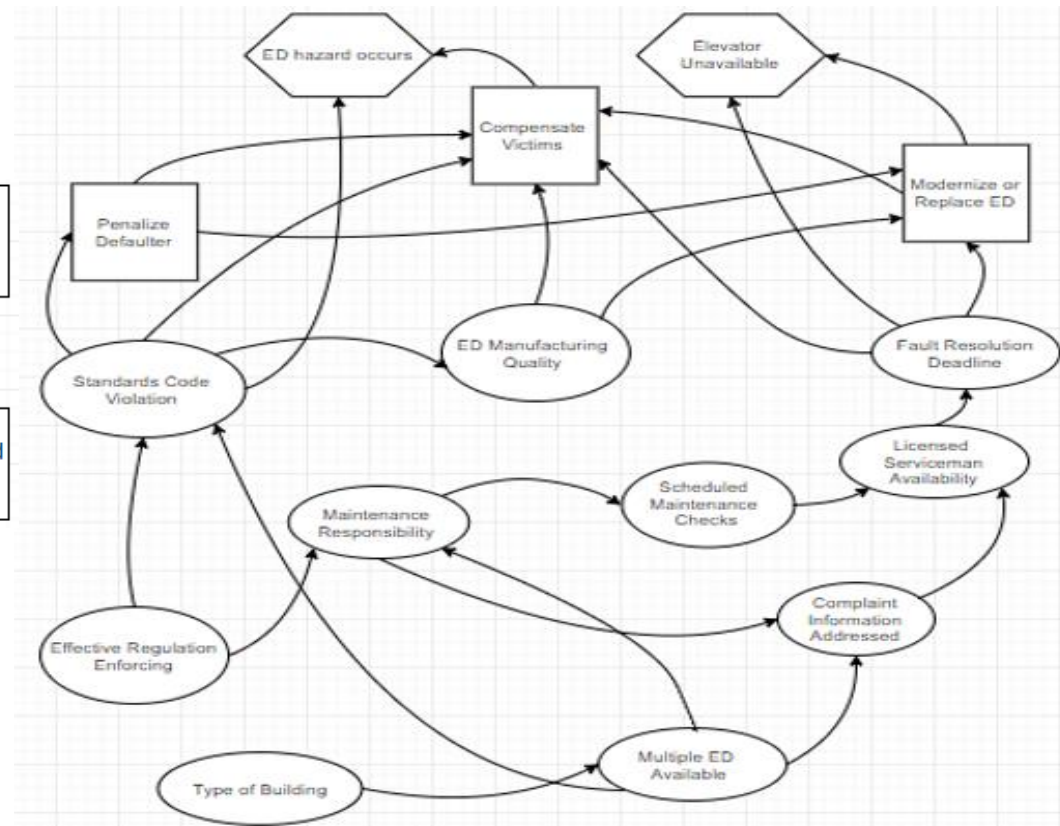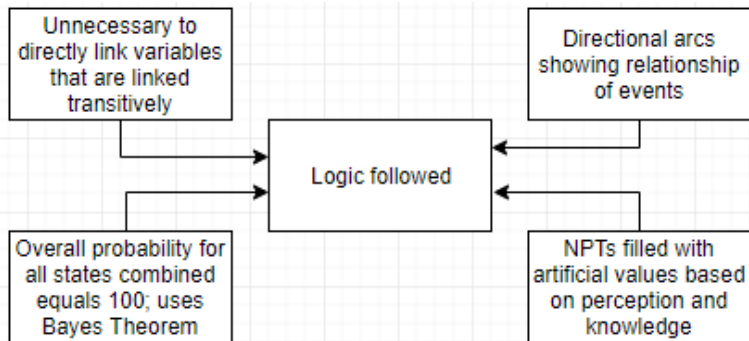
Netica tool features for modelling
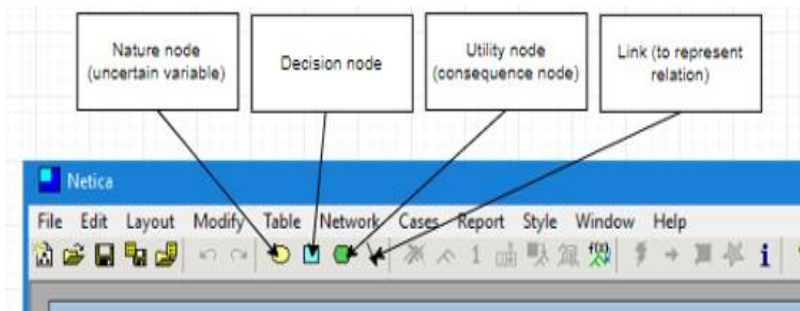
Filling in NPTs

Node labeling

ID modelling in Netica

Removal of links to / from decision nodes means, that link is not relevant to the decision for all possible NPTs – performed by Netica during compilation
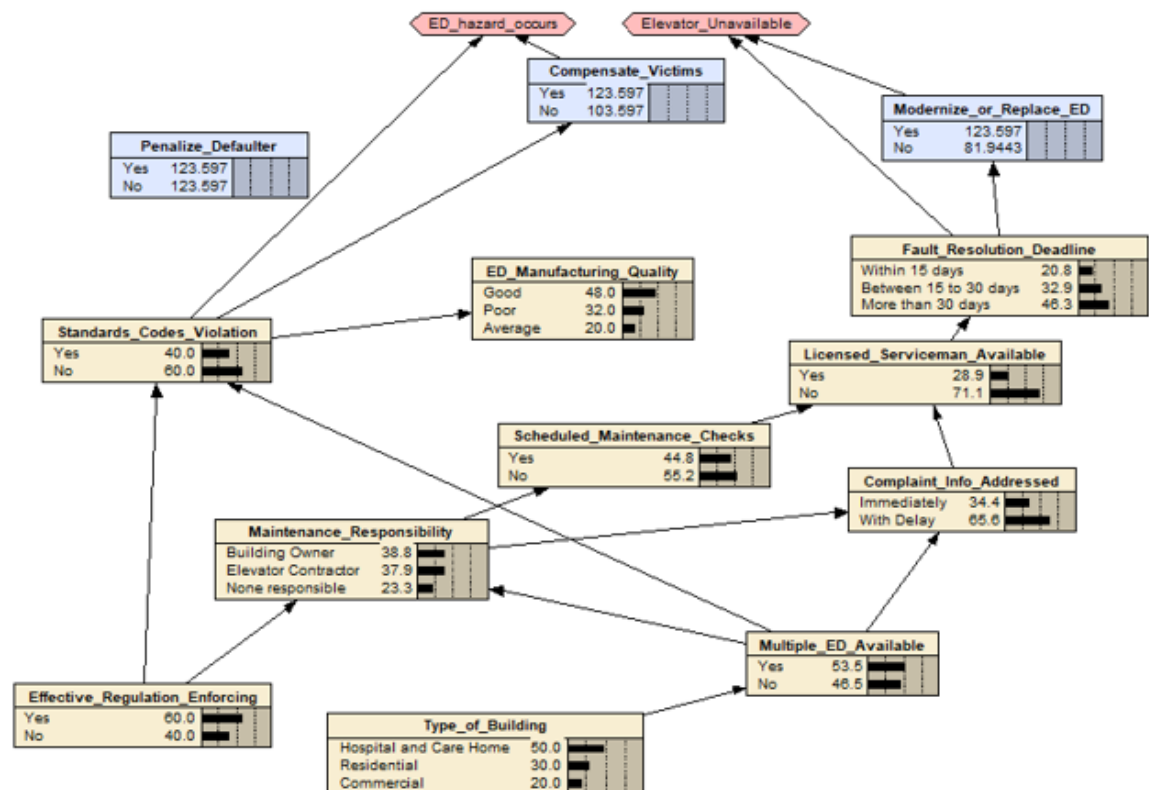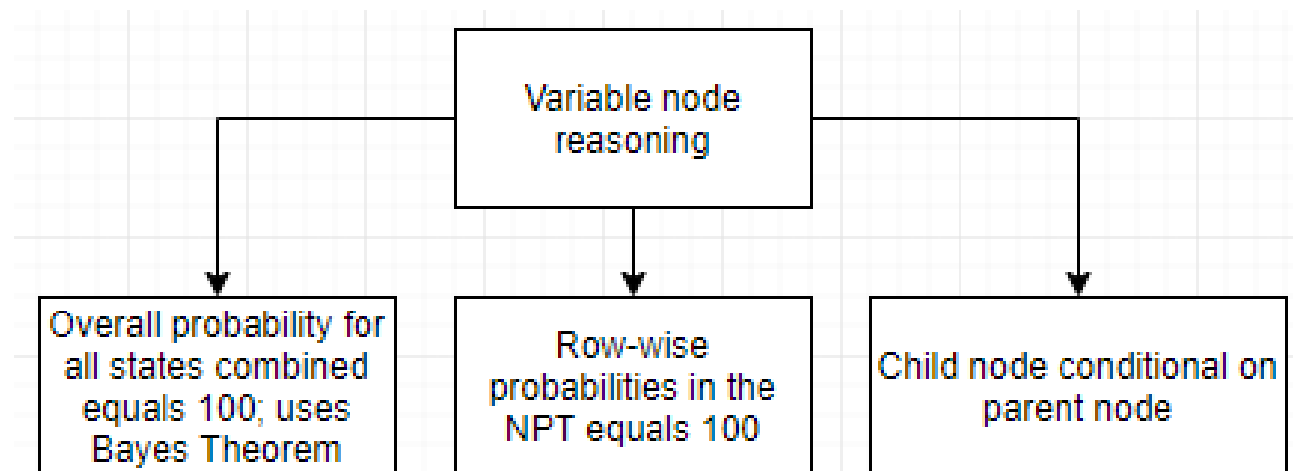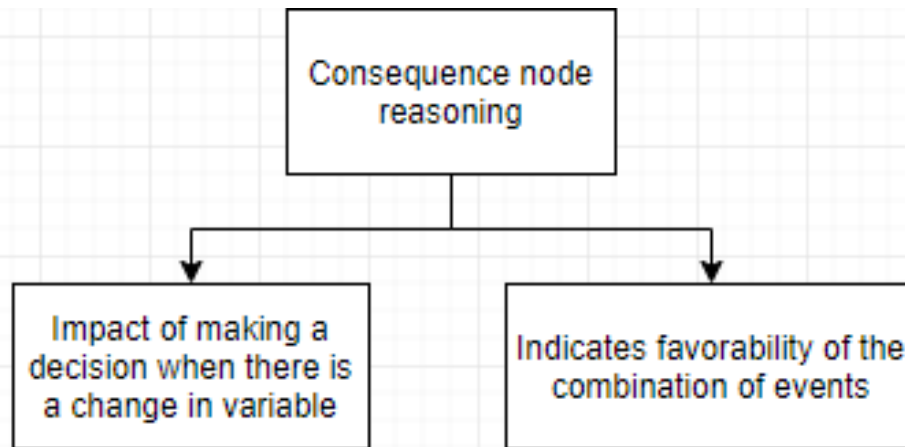
Variable node reasoning

Variable node reasoning

- Overall probability for all states combined equals 100; uses Bayes Theorem
- Row-wise probabilities in the NPT equals 100
- Child node conditional on parent node

Consequence Node reasoning

Consequence node reasoning
- Impact of making a decision when there is a change in variable
- Indicates favorability of the combination of events

Node: ED_hazard_occurs			
Deterministic ▾	Function ▾		
Compensate_Victims	Standards_and_Codes_violation	ED_hazard_occurs	
Yes	Yes	100	
Yes	No	20	
No	Yes	80	
No	No	0	

Decision node reasoning

Penalize_Defaulter		
Yes	123.597	
No	123.597	

| Compensate_Victims		
Yes	123.597	
No	103.597	

Modernize_or_Replace_ED		
Yes	123.597	
No	81.9443	

Output by Netica;
opt for state with
higher utility (not
% values)
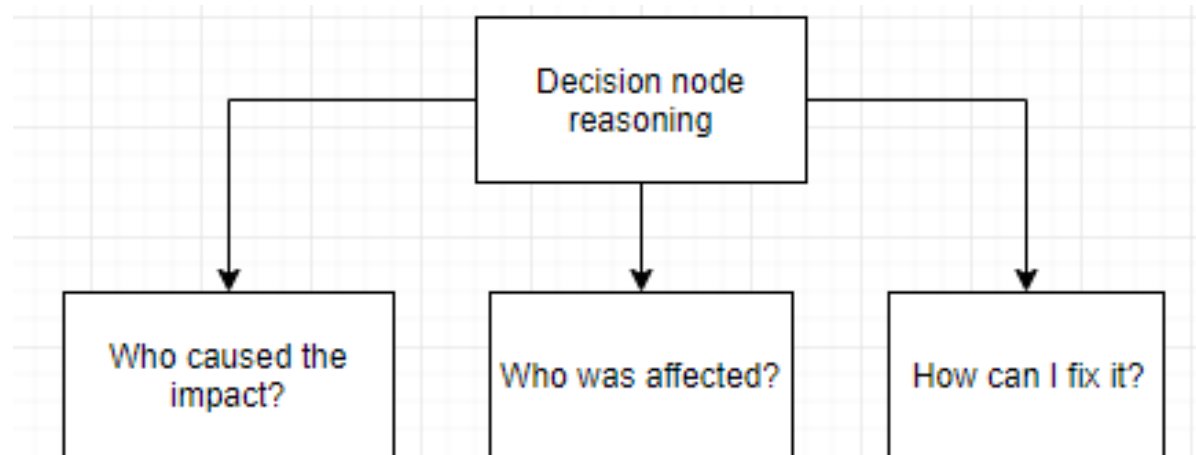
Scenario - Selecting a variable state

- Selecting a state shows 100% evidence of event

- Note change in utilities of decision nodes and other associated variables

- Netica immediately recompiles & reruns model
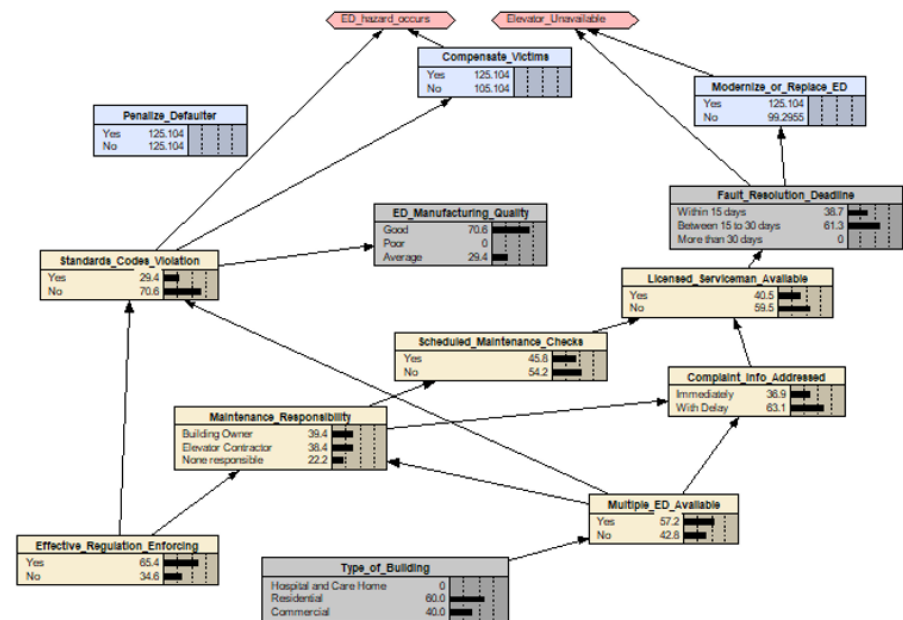
- Note color change of changed node
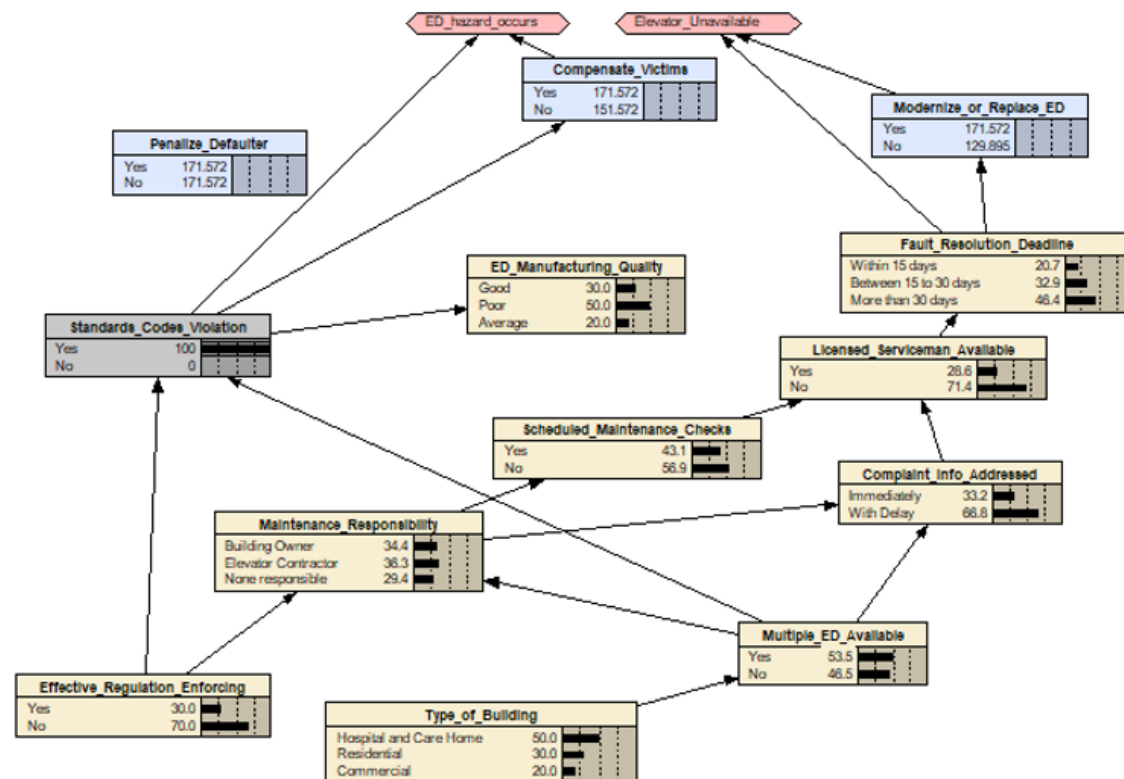
Scenario – Drag black bar

- Drag black bar next to each probabilities back & forth

- Notice change in probabilities & utilities
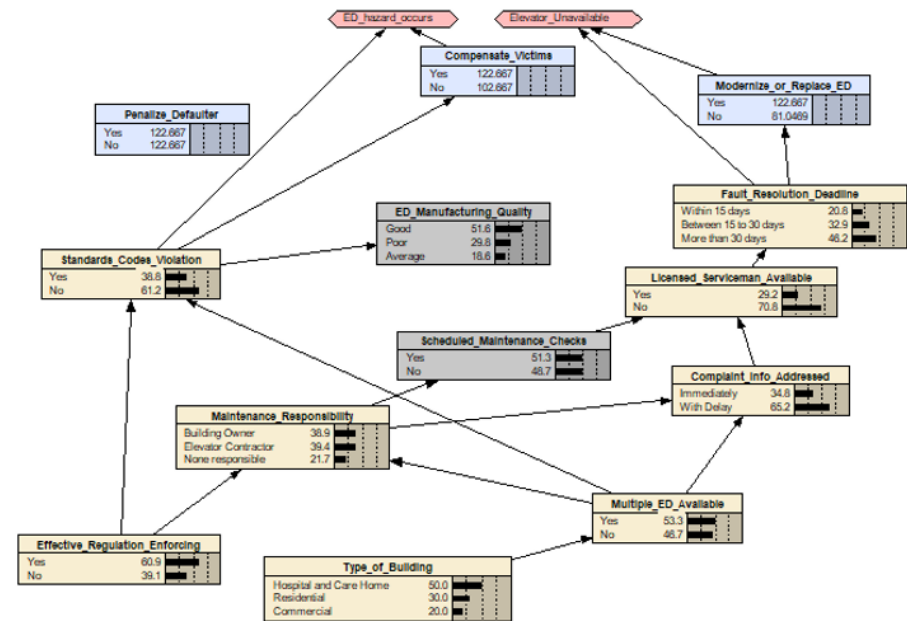
Scenario – Deselecting state

- Deselecting a variable's state, leaves other two states selected

- Notice change in utilities and probabilities

Scenario – Node removal & addition

- Remove a node by first deleting arcs to / from the variable and then delete the node itself

- Shows updated probabilities of all nodes

- Add a new node simply by dragging a new node to the interface
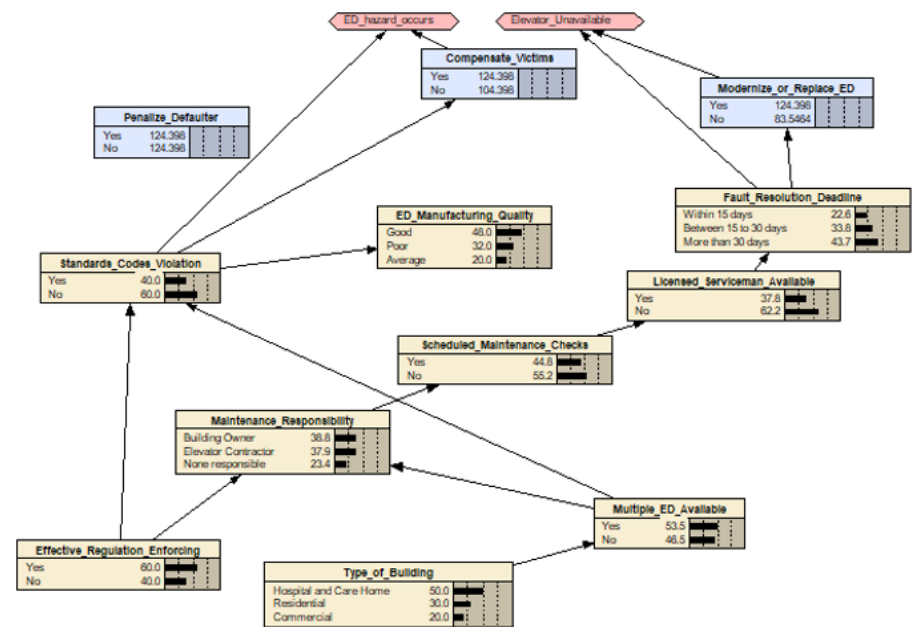
Model usefulness & limitations

- Reliable to a certain extent
- Identify concerns with certain combination of events
- Answers specific questions and problems
- Useful for real-time business purpose decision making
- Helps users share understanding of the impact of events and decisions

- Variable selection varies depending on understanding of the problem
- Model is currently 'biased', resulting in same type of decisions irrespective of inputs
- Useful to have stronger evidence for events for better decisions

Recommendations

- It is only a 'model' (representation of reality); not a 'decision-maker' – ultimate decision to be taken by TSSA considering output from model as guidance

- BBNs & IDs are useful techniques to model any complex problems for decision analysis

- ED risk & availability problem analyzed better through IDs than conventional method, like FTA

For more information or questions

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