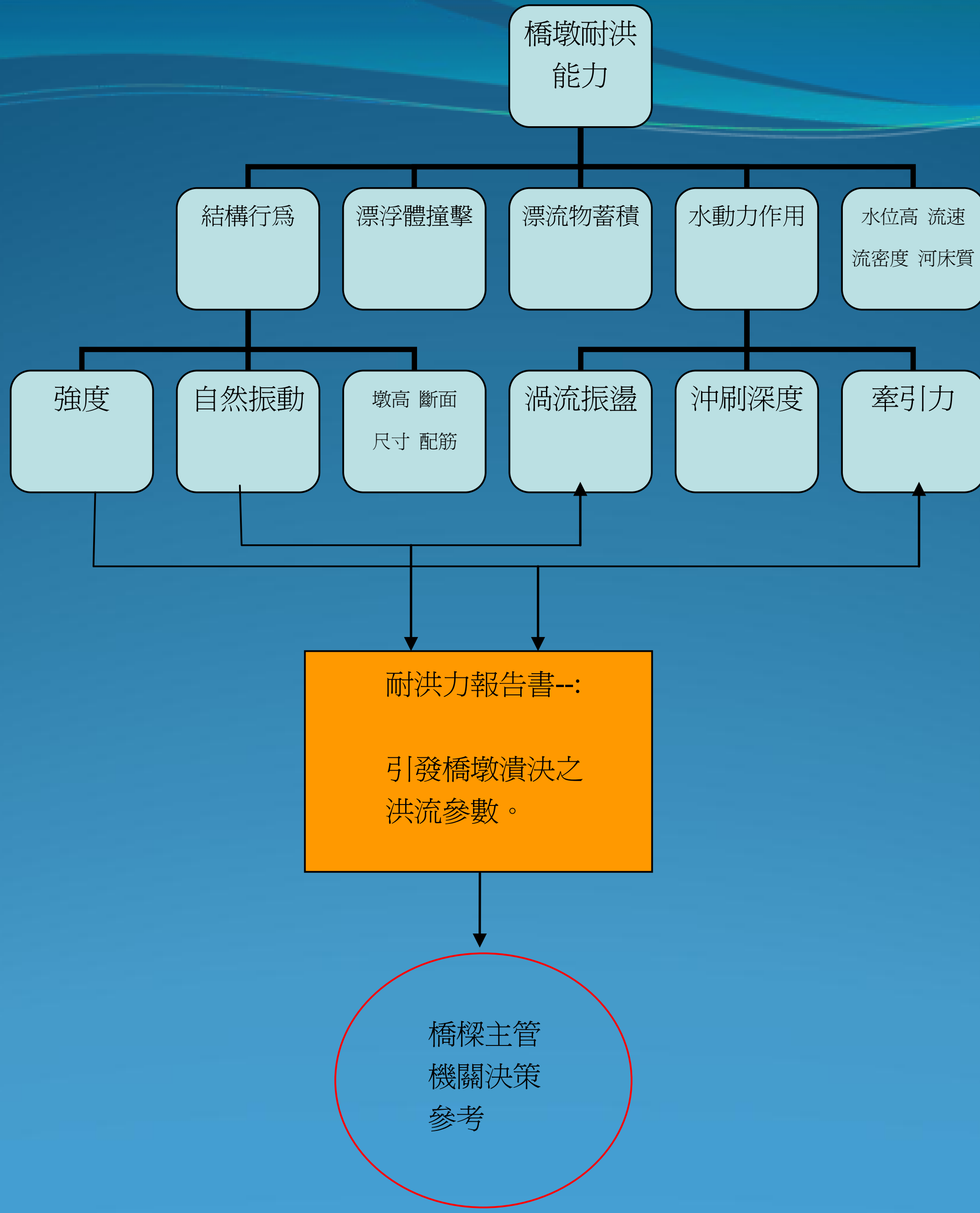


註：若須有漂浮體撞擊,漂流物蓄積二項時， 請另案協調。

EFFICIENT NUMERICAL MODEL

for studying

Bridge Pier Collapse in Floods

Authors
Thanut Kallaka, Ching-Jong Wang

BACKGROUND

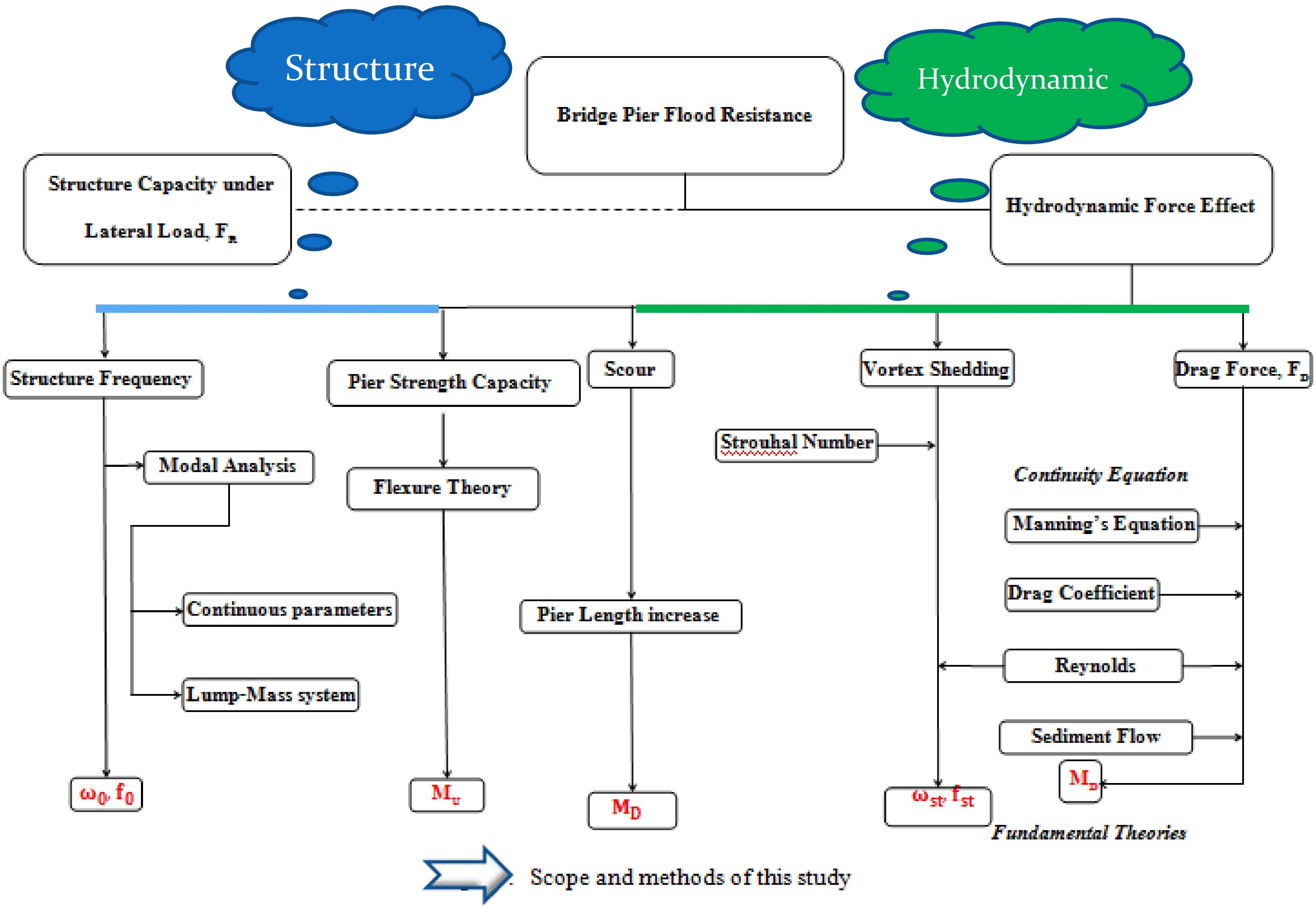
Bridge's failure due to high velocity flows

High scouring depths after many flood's phenomena

OBJECTIVE

- To find reasons behind the failure
  - hydrodynamic forces
  - scouring depths

- By analyzing the effects of
  - vortex frequencies and natural frequencies along pier columns
    - the resonance effect
  - scouring depths beneath pier columns
    - the bending moments



Structure
Bridge Pier Flood Resistance
Hydrodynamic
Structure Capacity under Lateral Load, F_R
Hydrodynamic Force Effect
Structure Frequency
Pier Strength Capacity
Scour
Vortex Shedding
Drag Force, F_D
Modal Analysis
Flexure Theory
Strouhal Number
Continuity Equation
Manning's Equation
Continuous parameters
Pier Length increase
Drag Coefficient
Lump-Mass system
Reynolds
Sediment Flow
ω_0, f_0
M_u
M_D
ω_{st}, f_{st}
M_D
Fundamental Theories
Scope and methods of this study

Scope of this study

- Geometries in 2 cases
  - Circular cross sections
  - Elliptical cross sections

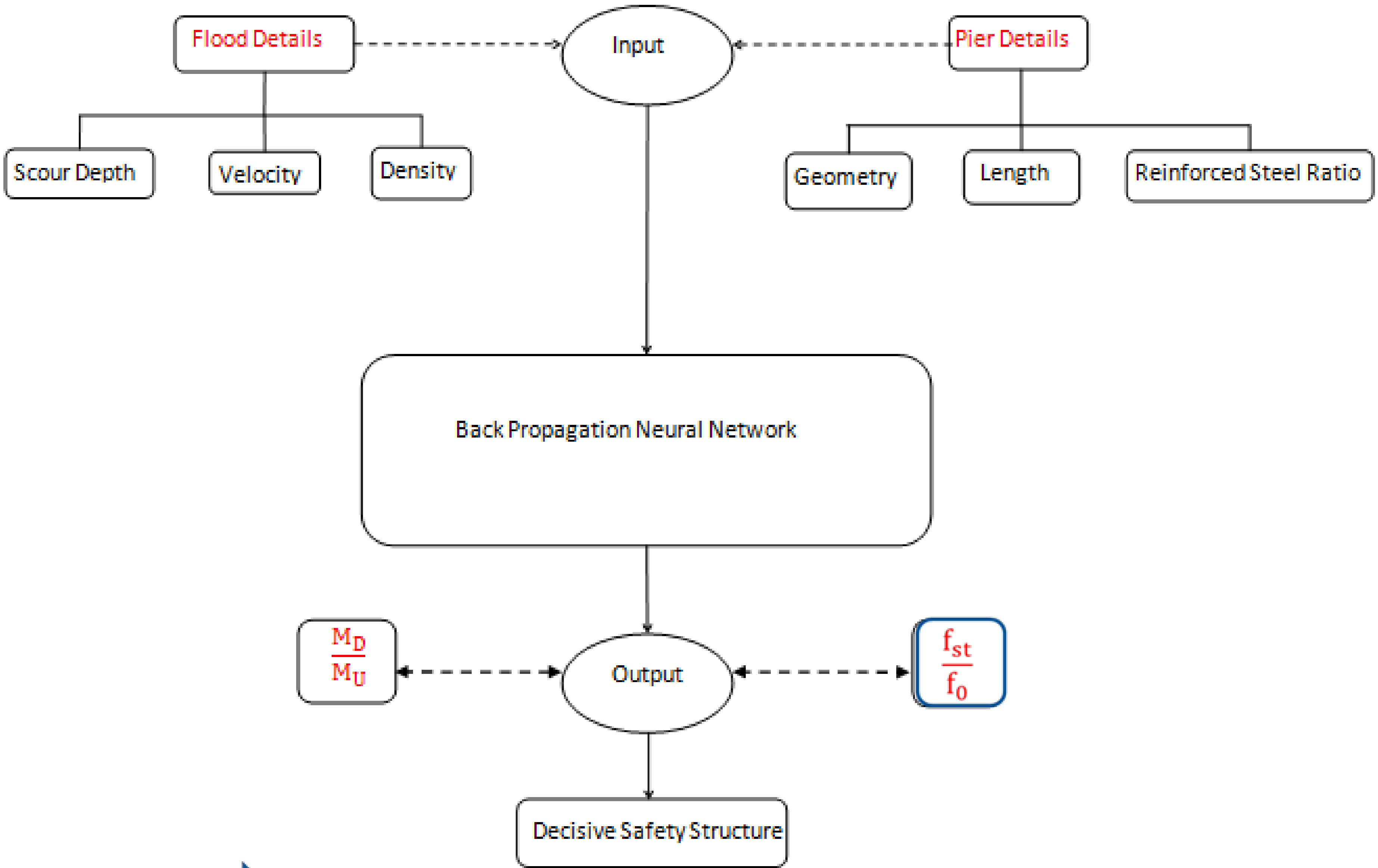
- The model of analysis
  - A single pier
  - A pile cap of foundation
  - A mass of a deck

Scope of this study *(cont.1)*

- The related experimental results by others
  - Drag coefficient or Strouhal number exceed the upper range
    - the conservative value is assumed
- The hydrodynamic effects
  - Velocity of the flood
  - Density of the flood
- A neural network application to predict any failure
  - Pier and Flood data

Failure types

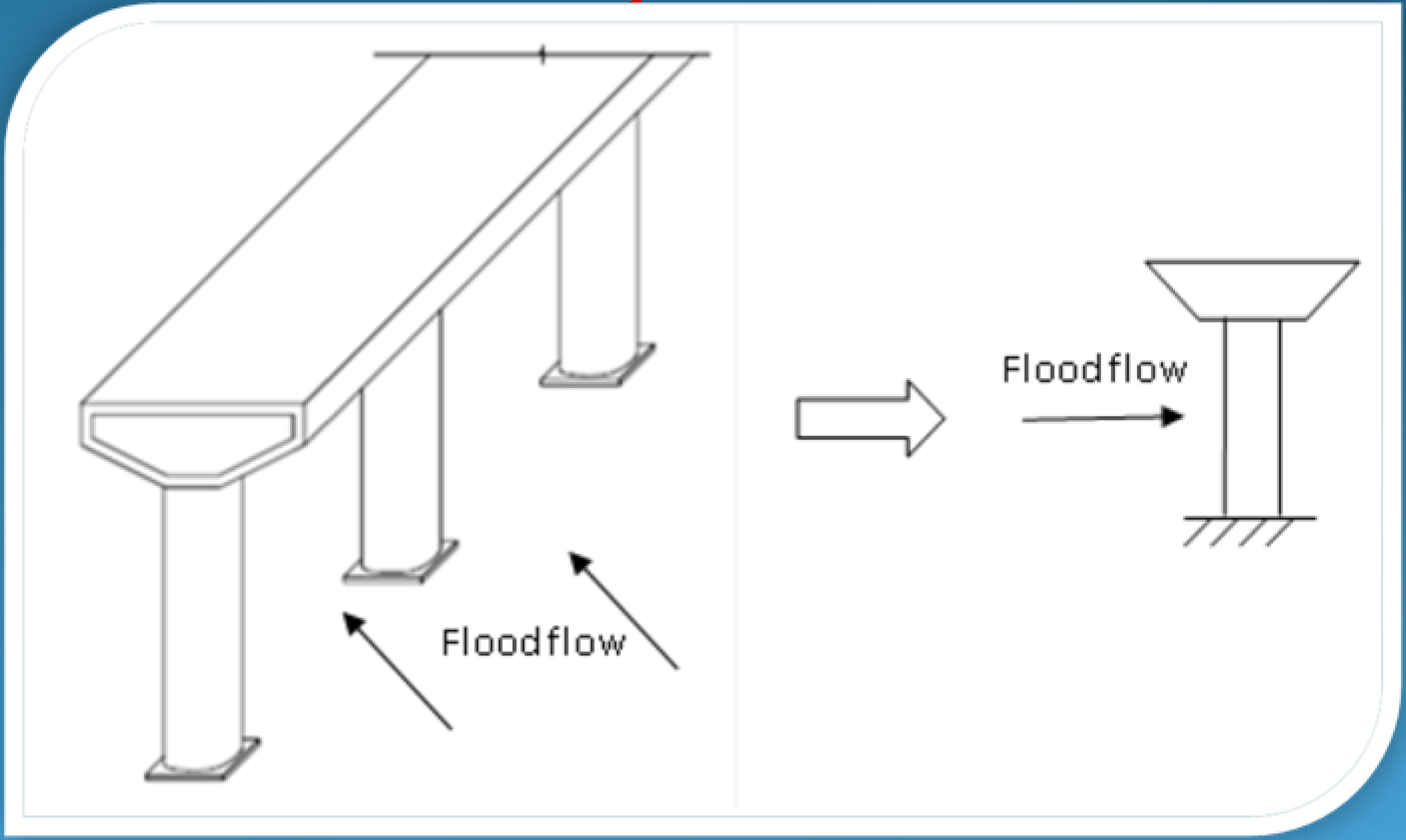
- The Frequency ratio is defined as
  - vortex shedding frequency divided by pier structural frequency
- The moment ratio is defined as
  - demanding moment from scouring effects divided by moment capacity of a section



Back Propagation Neural Network application to consider any safety on Pier's structure

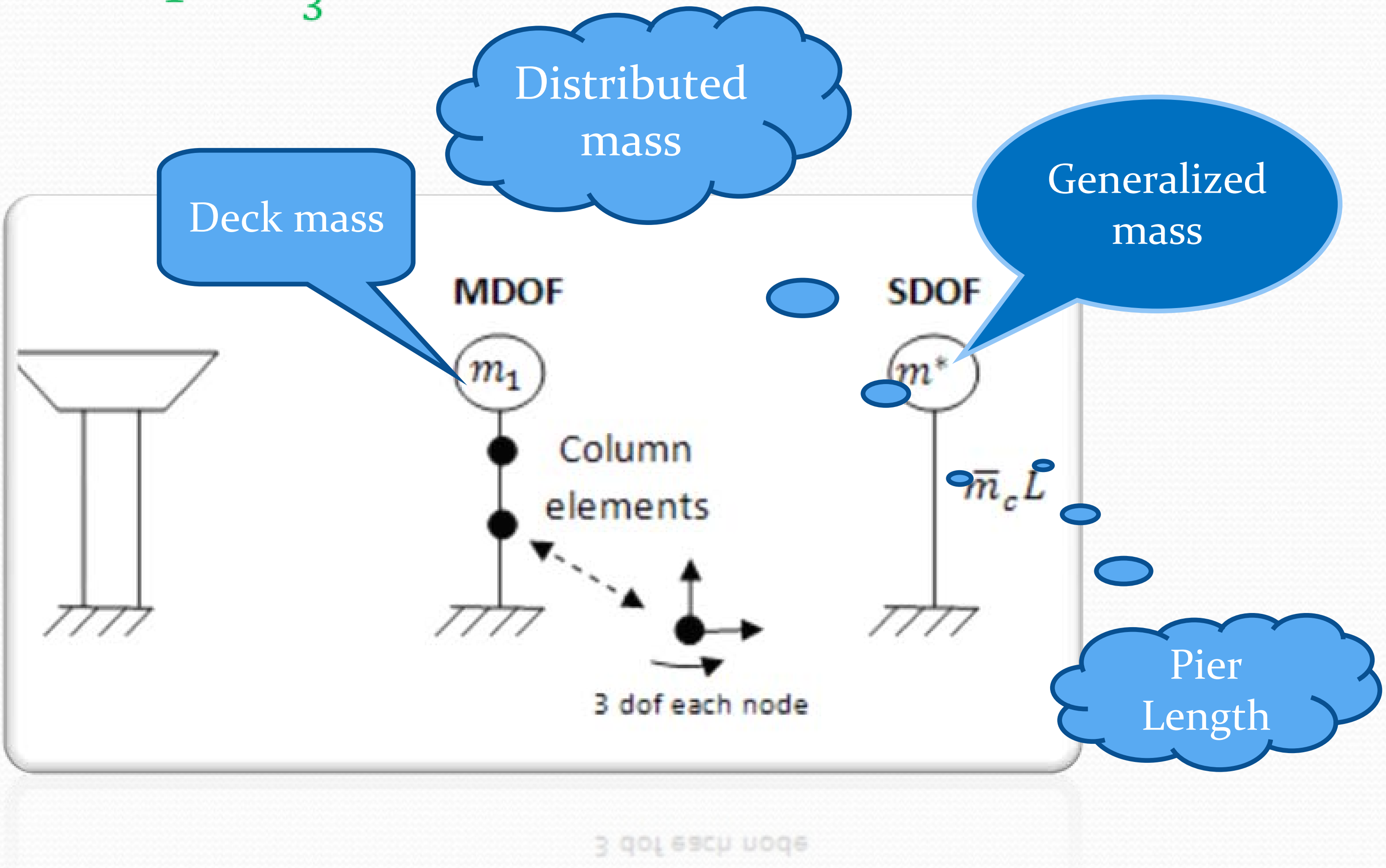
Bridge dynamics

◆ Simplified design methods applicable to regular bridge structures, 3D MDOF system



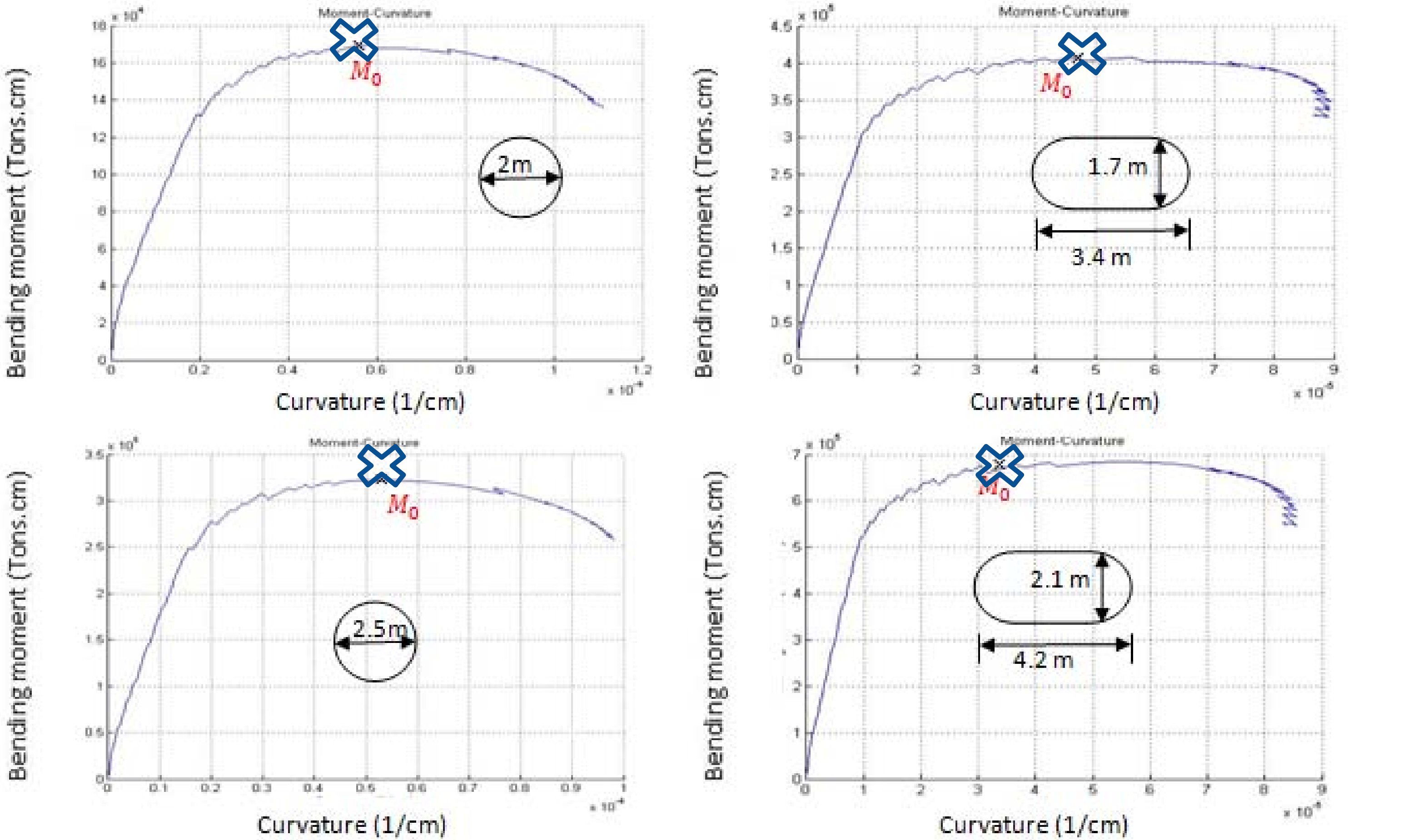
MASS CALCULATIONS

- $m^* = m_1 + \frac{\overline{m_c}L}{3}$



$f_c' = 0.21$ Tons/ cm^2

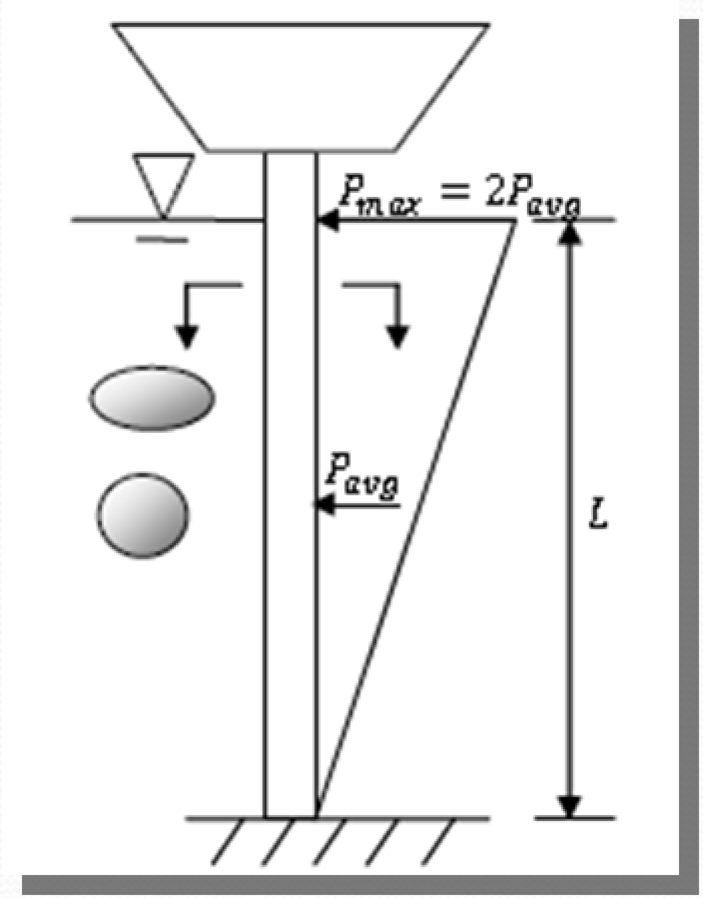
$f_y = 4.2$ Tons/ cm^2



Moment-Curvature for piers at reinforcing ratio of 1.5%

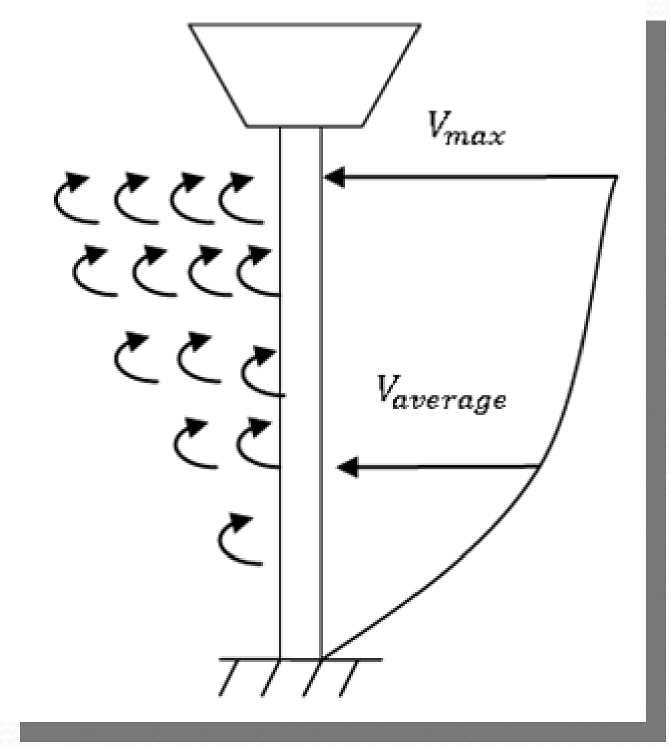
Hydrodynamic, drag force

- Water level is assumed at 90% of pier height
- $P_{avg} = \frac{1}{2} C_D \rho V_{avg}{}^2$

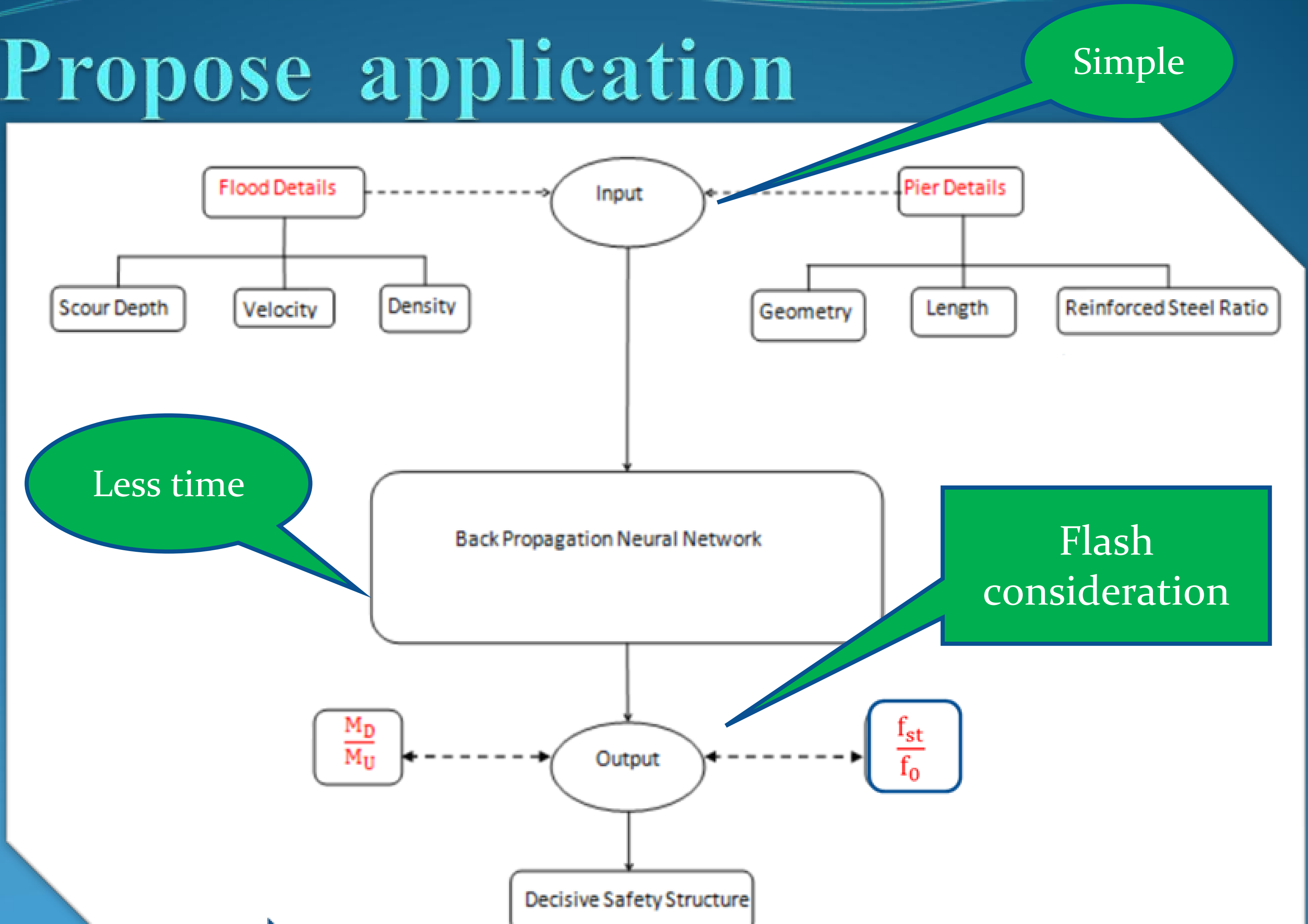


Vortex shedding

- Characterized by Strouhal frequency
  - $f_{st} = \frac{St \cdot V}{D}$, St=0.292 for Re $> 10^6$
- The velocity distribution over flow depth is as represented by a parabolic curve
  - Vary vortex shedding frequency
  - occurrence of resonance



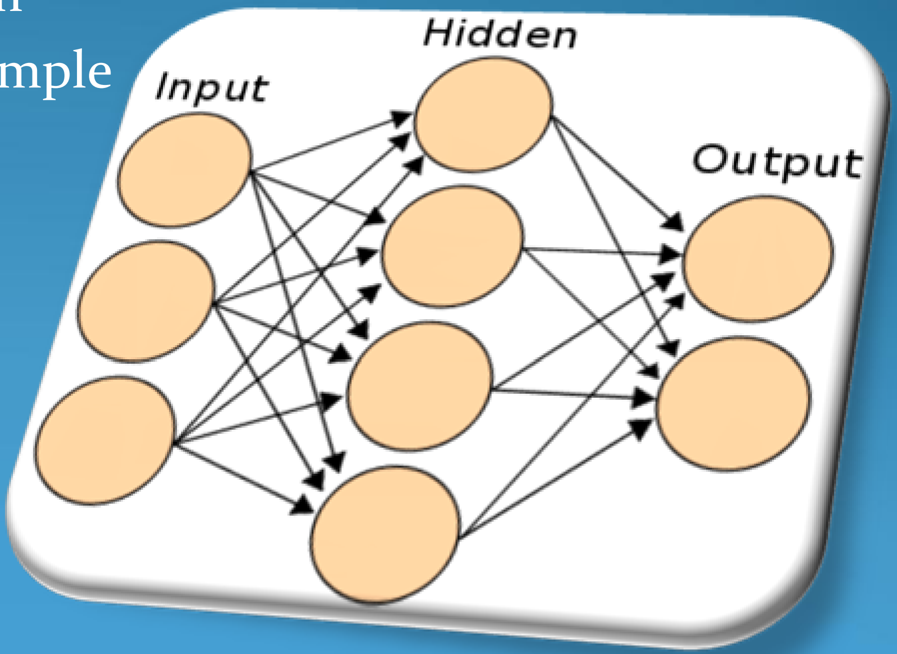
Propose application



Back Propagation Neural Network application to consider any safety on Pier's structure

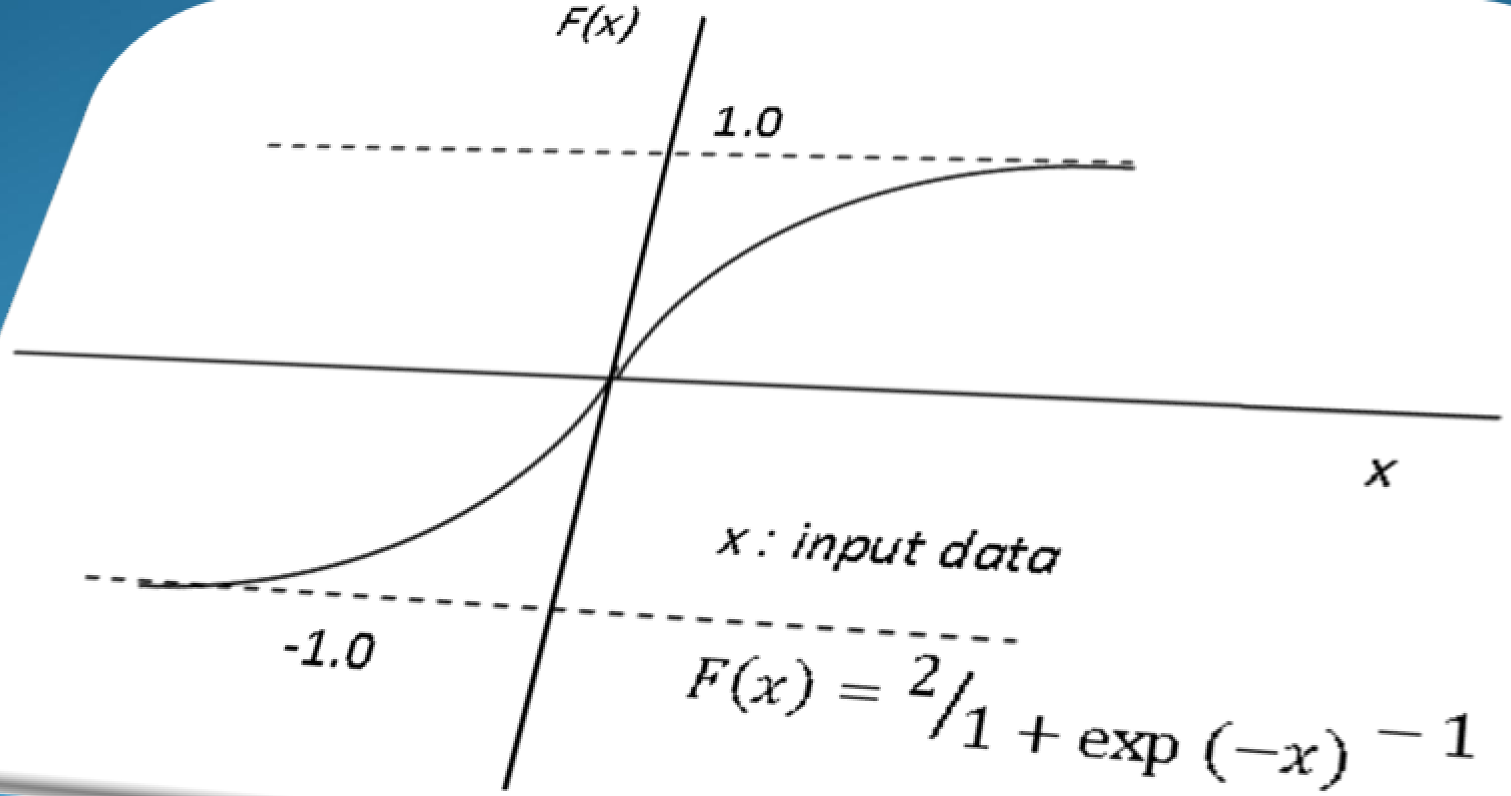
Neural Networks

- Supervised training is analogous to the learning behavior of a child's mind
  - as it is presented with samples of items from different categories along with the correct interpretation of each sample



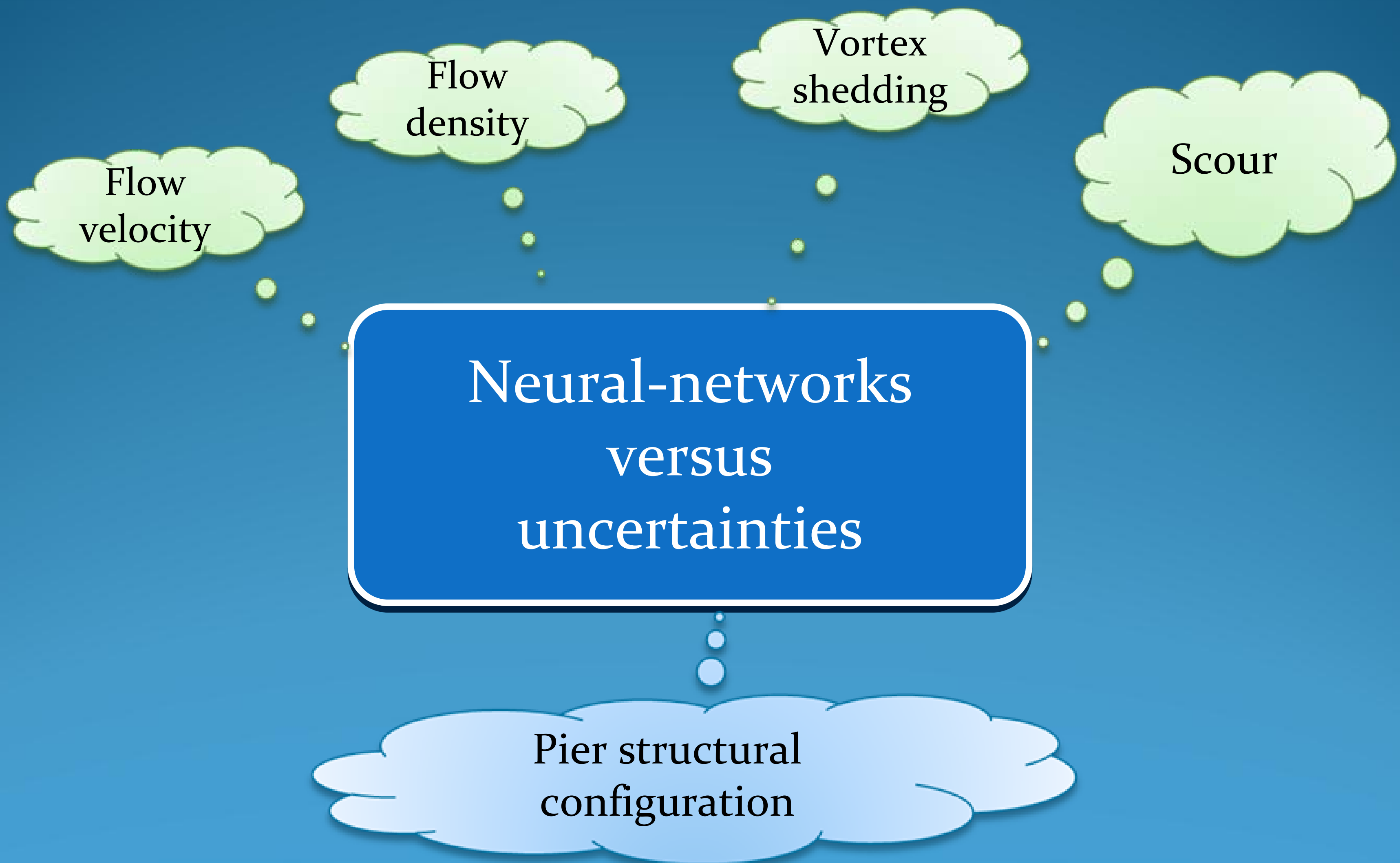
Activation function

Bipolar Sigmoid function

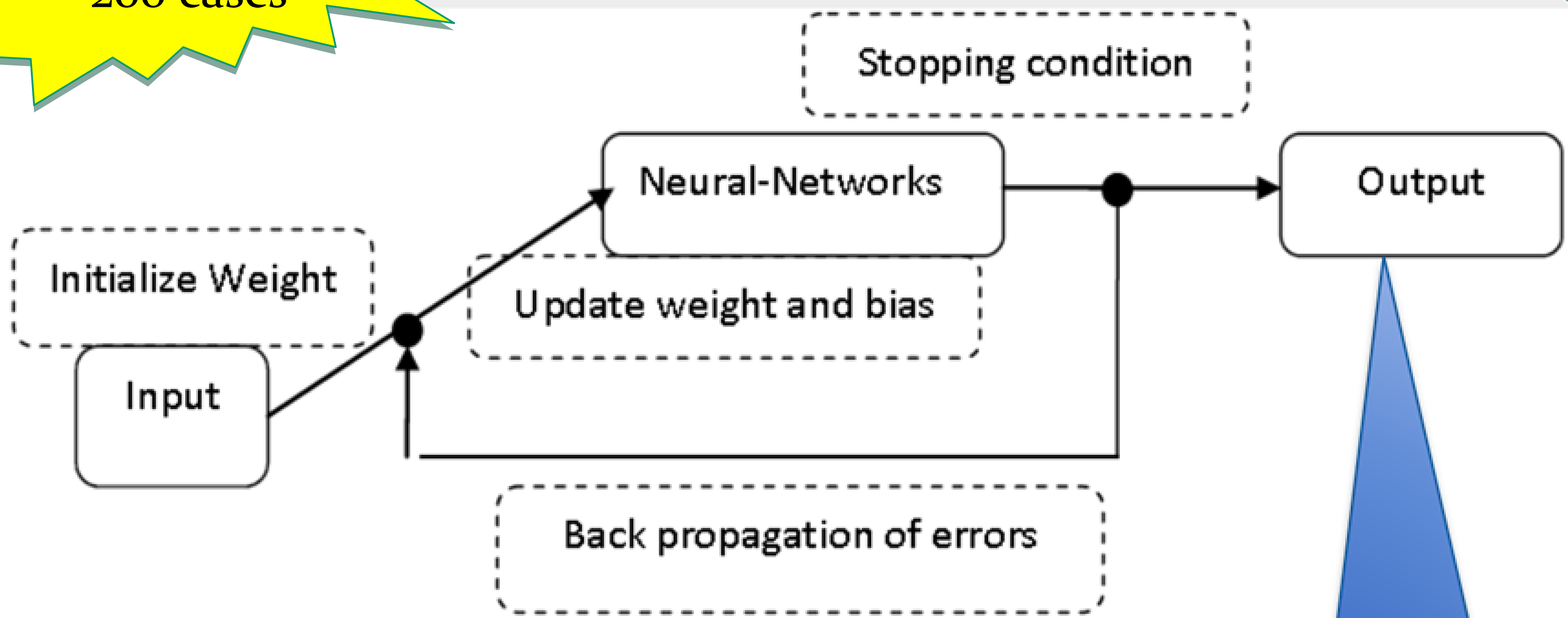


$$F(x) = {}^{2}/_{1 + \exp(-x)} - 1$$

Neural networks setup

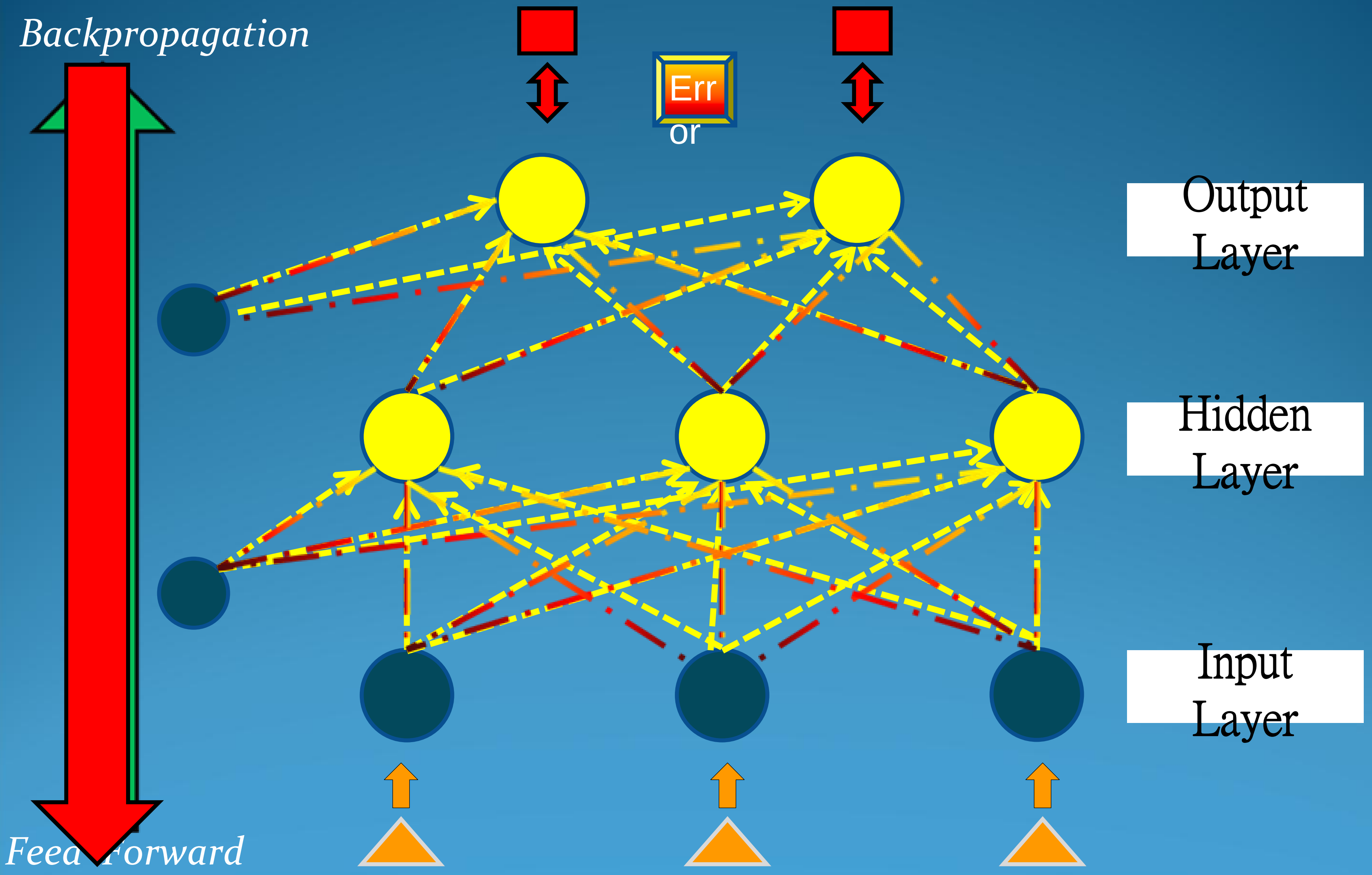


More than 200 cases

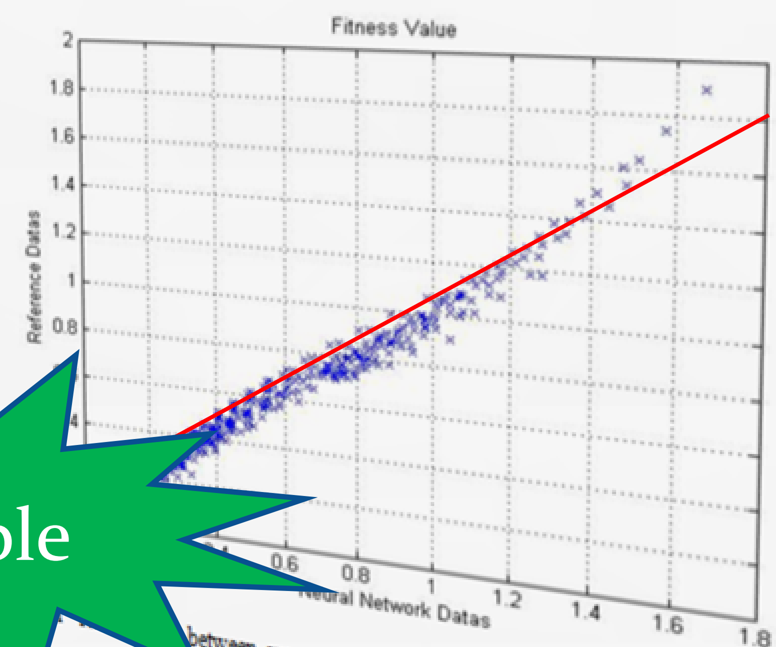


Limited by the size of training data

ALGORITHM

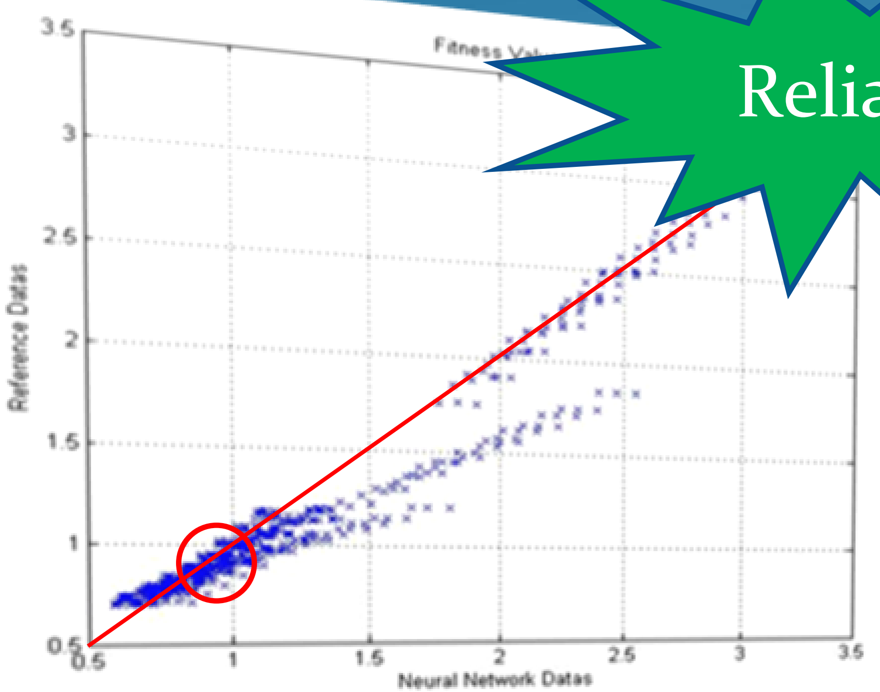

Backpropagation
Err
or
Output Layer
Hidden Layer
Input Layer
Feed Forward

Correlation study circular piers



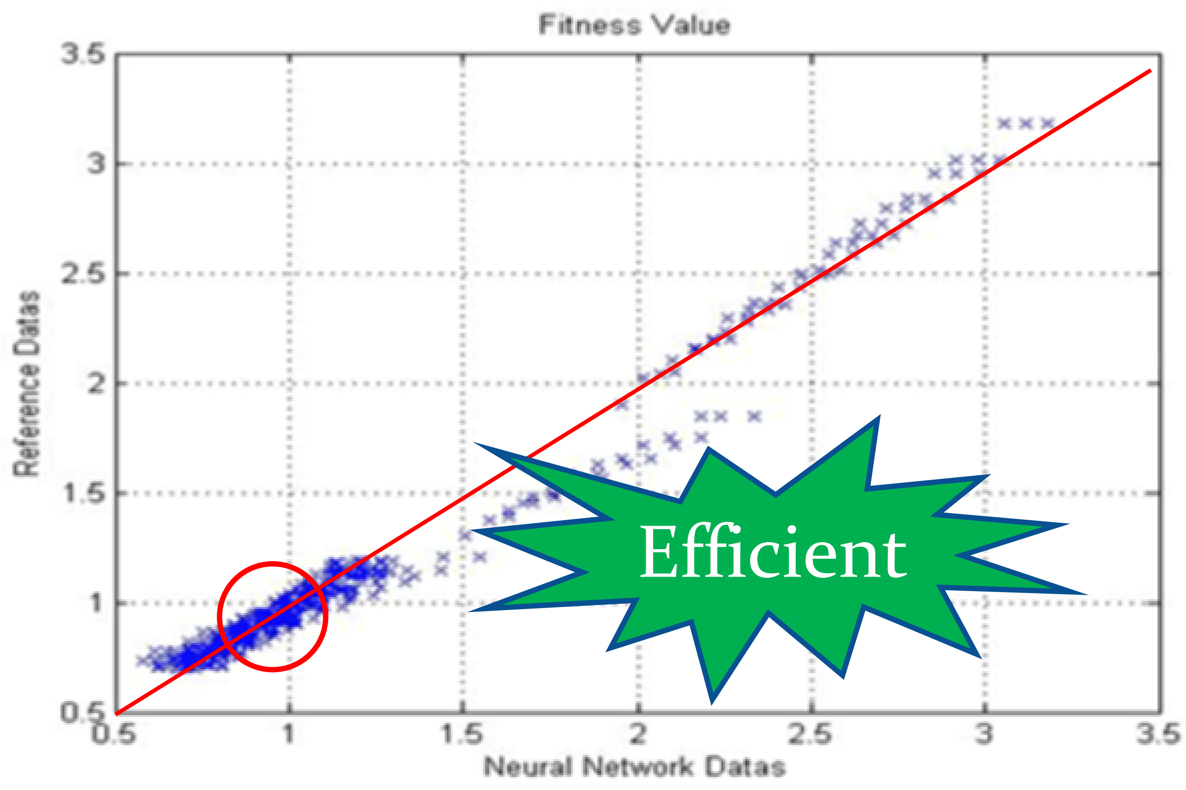
...between any moment ratio from neural-networks versus exact data in circular section of pier

Reliable



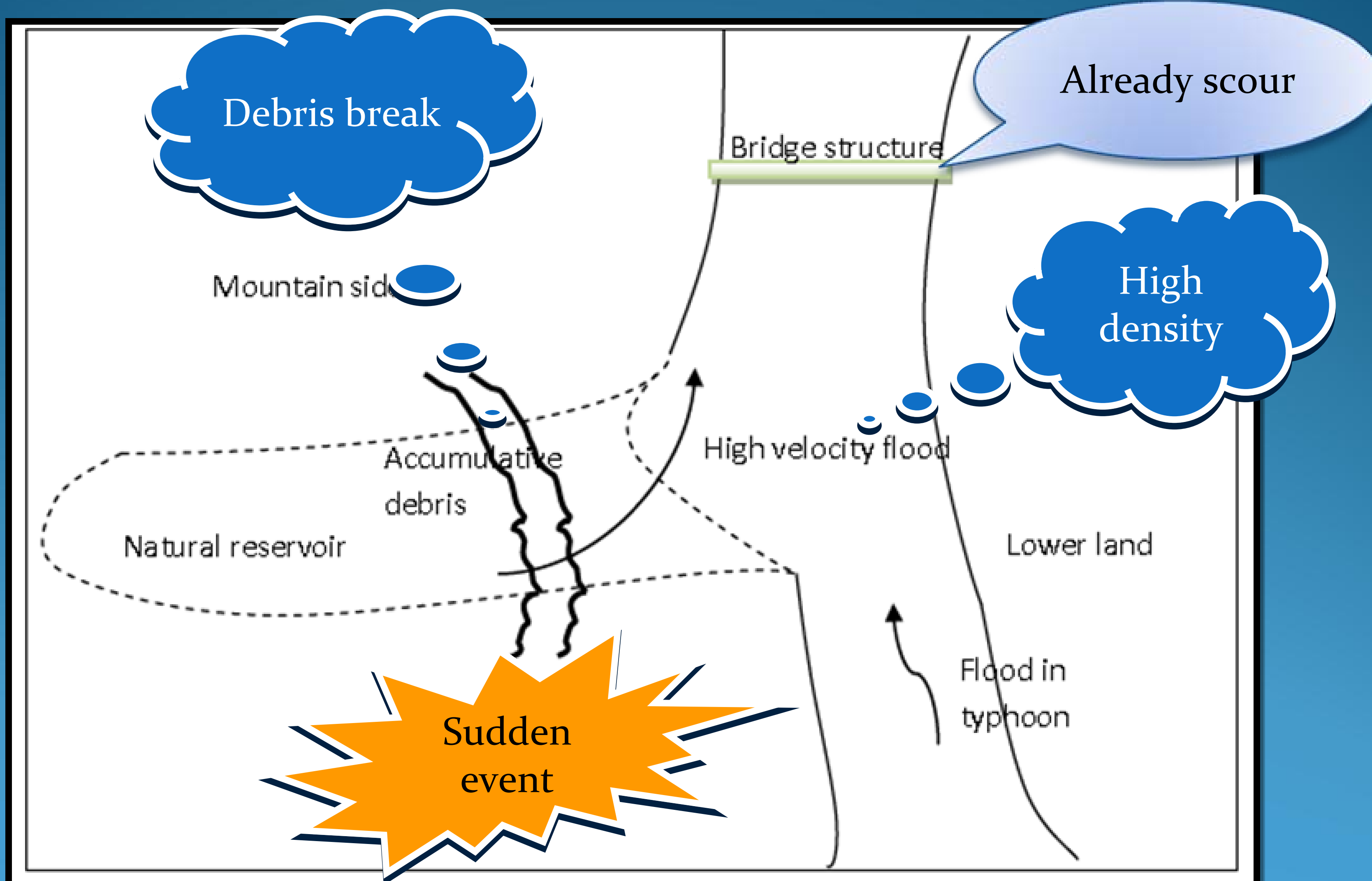
Relationship between any frequency ratio from neural-networks versus exact data in circular section of pier

Correlation study-elliptical piers



Relationship between any frequency ratio from neural networks versus exact data in elliptical section of pier

Case 1: A bridge in flood around mountain areas



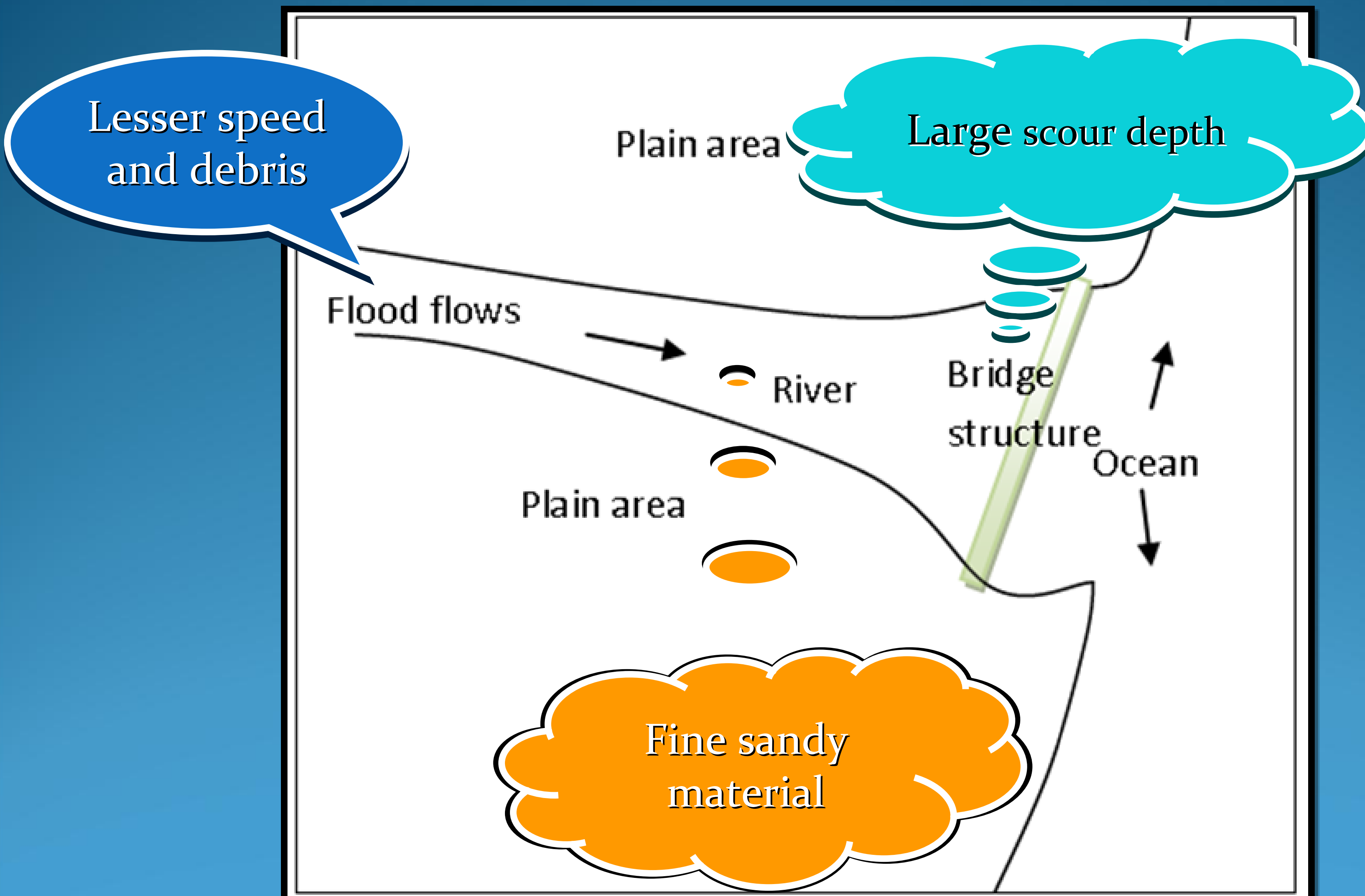
Resonance

Excessive moment

Flow density (g/cm^3)	Flow velocity (m/s)	Frequency ratio (f_{st}/f_0)		Moment ratio (M_D/M_0)	
		Calculation	Neural Networks	Calculation	Neural Networks
1	4	0.708058	0.859531	0.068022	0.020602
1	5	0.897366	0.970805	0.106285	0.060839
1	6	1.076839	1.092205	0.15305	0.107916
1	13	2.333151	2.27053	0.718485	0.740348
1	14	2.512624	2.476797	0.833273	0.884288
1.3	4	0.717892	0.806597	0.088429	0.075942
1.3	5	0.897366	0.924392	0.13817	0.124676
1.3	6	1.076839	1.054157	0.198965	0.181772
1.3	12	2.153677	2.113239	0.795861	0.775271
1.3	13	2.333151	2.327782	0.934031	0.921956
1.3	14	2.512624	2.544806	1.083255	1.078888
1.6	4	0.717892	0.767986	0.108836	0.131415
1.6	5	0.897366	0.893434	0.170056	0.189782
1.6	6	1.076839	1.032757	0.24488	0.258179
1.6	11	1.974204	1.953862	0.82307	0.795983
1.6	12	2.153677	2.175074	0.979521	0.945161
1.6	13	2.333151	2.400678	1.149577	1.104347
1.6	14	2.512624	2.62517	1.333237	1.269203

high impact force
(not considered in
this study)

Case 2: A bridge in flood around coastal areas



Flow density (g/cm^3)	Flow velocity (m/s)	Frequency ratio (f_{st}/f_0)	
		Calculation	*Neural Networks*
1	5	0.738353	0.812421
1	6	0.898329	0.933477
1	7	1.048051	1.063821
1	8	1.197772	1.202619
1.3	5	0.748608	0.81814
1.3	6	0.898329	0.94227
1.3	7	1.048051	1.075318
1.3	8	1.197772	1.216272
1.6	5	0.748608	0.809062
1.6	6	0.898329	0.935273
1.6	7	1.048051	1.070168
1.6	8	1.197772	1.212645

Vibration from vortex shedding

Large (lateral) vibration by resonance

Low to moderate speed

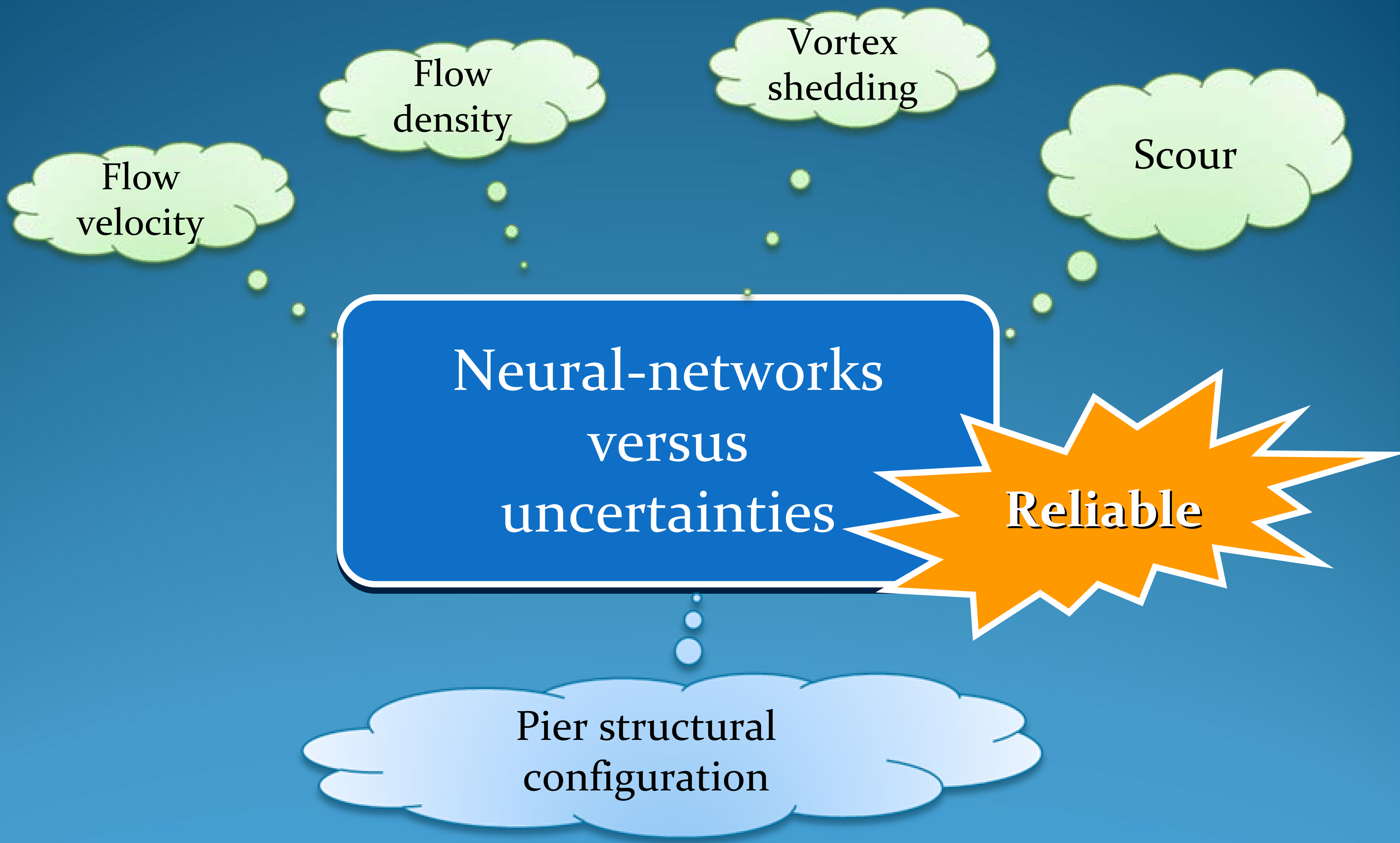
Case 3: An example of Thai bridge in flood

Simplify as single pier

Regarding total mass and stiffness

Good flexural capacity (due to multi-columns, against drag force, large moment of inertia)

Flow density (g/cm^3)	Flow velocity (m/s)	Frequency ratio (f_{st}/f_0)	
		Calculation	*Neural Networks*
1	4	0.8403	1.0244
1	5	1.0996	1.1905
1.3	4	0.8976	0.9236
1.3	5	1.1376	1.0975
1.6	4	0.9100	0.8840
1.6	5	1.1376	1.0658


Flow velocity
Flow density
Vortex shedding
Scour
Neural-networks versus uncertainties
Reliable
Pier structural configuration