Bana
Consulting Engineers
Civil & Structural

Rethinking the Application of Engineering: Structural Analysis of Economic Impact Risk Propagation in Infra_Structures.

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Objectives of Presentation

- Exhibit a Model Impact Propagation
- Illustrate Structural concept application
- Show convergence between Structural & Economic concepts
- To encourage Engineers to take interest and explore Engineering applications in other disciplines.

What is Infra_Structure

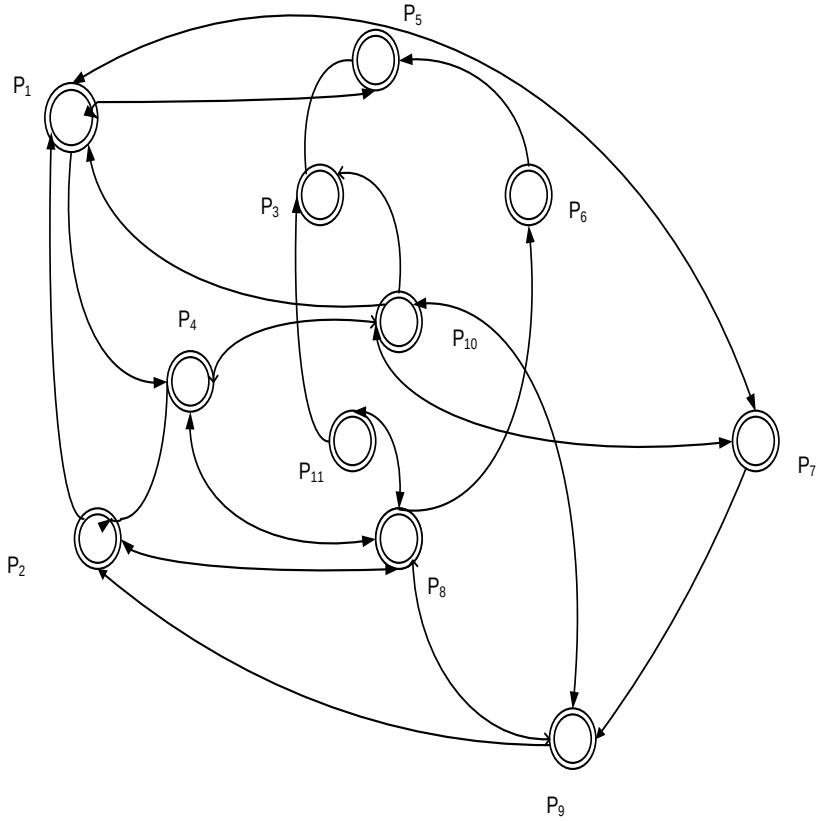
Network of a nation's assets which runs the economy. Examples:

- **Transport Infrastructure(road, air, sea, rail, etc)**
- **Energy & Power Grid**
- **Communication (Telephone, internet, etc)**
- **The Environment (Ecosystem & Biodiversity)**
- **Banking & Finance,**

Generally:

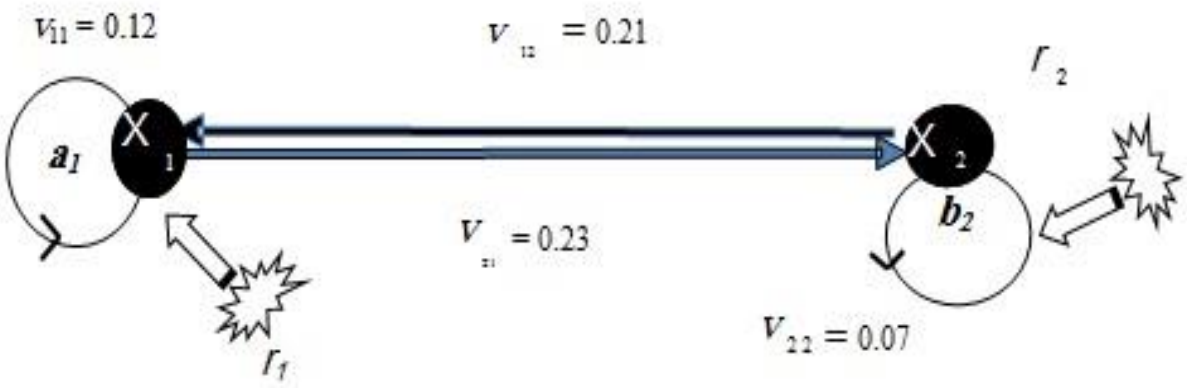
- **public assets and services**
- **natural assets and natural resource-based industries**

Infra-structures Connectivity



Interdependent , Dependent, Isolated

Model Impact Transfer



		(a_1) x_1	(b_2) x_2
Power & Grid	(a_1) x_1	0.12	0.23
Telecommunication	(b_2) x_2	0.21	0.07

$$V = \begin{bmatrix} 0.12 & 0.23 \\ 0.21 & 0.07 \end{bmatrix}$$

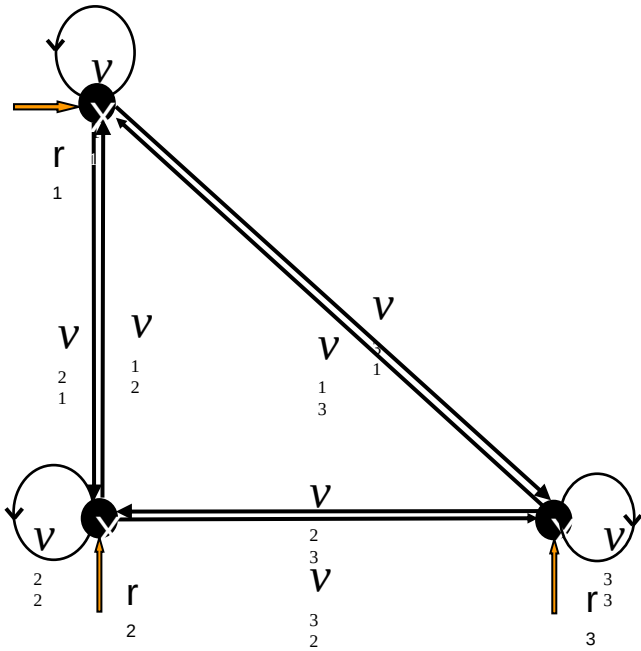
Wassily Leontief's Economic Model

$$\underline{x} = V\,\underline{x} + \underline{r}$$

$$x_i = \sum_{j=1}^{n} v_{ij} x_j + r_i$$

$$\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} v_{11} & v_{12} \\ v_{21} & v_{22} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + \begin{pmatrix} r_1 \\ r_2 \end{pmatrix}$$

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} = \begin{pmatrix} v_{11} & v_{12} & v_{13} \\ v_{21} & v_{22} & v_{23} \\ v_{31} & v_{32} & v_{33} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} + \begin{pmatrix} r_1 \\ r_2 \\ r_3 \end{pmatrix}$$



THREE CONNECTED INFRASTRUCTURES

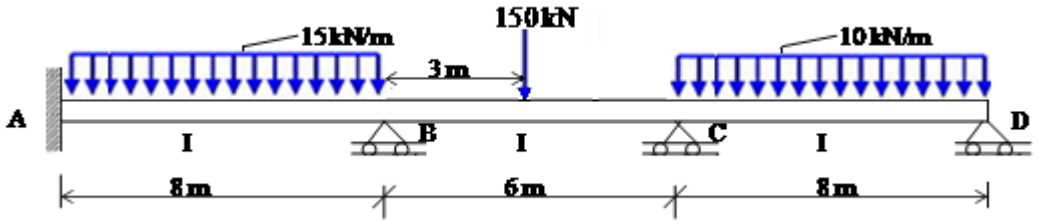
Infrastructure		*Infrastructure*			*External impact ($millions)*
		*Vulnerability coefficient**			
Infrastructure		x_1	x_2	x_3	r_i
Energy Power & Grid	*(a)* x_1	0.16996914	0.01293909	0.0001588	35.00
Telecommunication	*(b)* x_2	0.00709946	0.02742048	0.0063821	35.00
Banking & Finance	*(c)* x_3	0.01810804	0.01188828	0.0229375	35.00

EXTRACT DATA FROM INPUT OUTPUT BY INFRASTRUCTURES

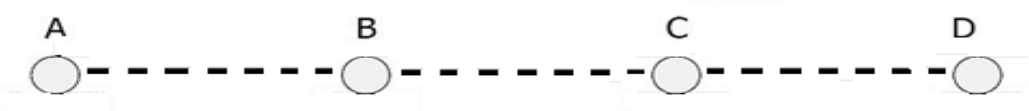
	USE	1201 Oil and gas	2501 Petroleum and coal products	2701 Iron and steel	3601 Electricity supply	3701 Water supply; sewerage and drainage services	4201 Construction trade services	6101 Road transport	7101 Communication services	7301 Banking	8601 Health services
SUPPLY											
1201	Oil and gas	509	12 863	123	923	0	0	4	77	0	34
2501	Petroleum and coal products	144	658	176	372	116	374	3 574	516	0	131
2701	Iron and steel	51	0	3 377	50	41	868	13	27	0	11
3601	Electricity supply	79	37	437	3 745	231	51	67	285	4	146
3701	Water supply; sewerage and drainage services	1	13	58	59	327	29	183	187	1	53
4201	Construction trade services	88	169	31	1 161	313	22 586	21	1 367	0	19
6101	Road transport	42	67	431	168	48	724	1 611	500	4	189
7101	Communication services	28	62	69	317	106	158	1 054	1 223	285	566
7301	Banking	89	17	19	591	352	311	201	388	749	562
8601	Health services	0	1	1	2	4	0	0	86	0	381

Use / Supply	1201 Oil and gas	2501 Petroleum and coal	3601 Electricity supply	3701 Water supply; s/w	6101 Road transport	7101 Communication services	7301 Banking	Total Industry Uses T4	Final Uses (Q1 to Q7) T5	Total Supply T6
7301 Banking	89	17	591	352	201	388	749	18 586	14 068	32 654
Vulnerability factors	0.00272	0.00052	0.018108	0.01078	0.00616	0.01189	0.02294	0.569168	0.430832	1

STRUCTURAL ANALYSIS ANALOGY
MOMENT DISTRIBUTION



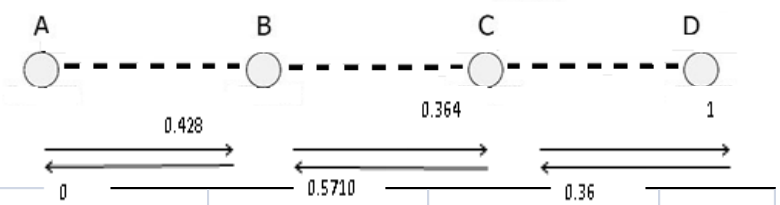
A model structure with impact loads (Total = 350kN)



Model Infrastructure Network System: Supports (infrastructures) and Beams (links)

Model Network System: Distributing factors (Vulnerability Coefficients).

MOMENT DISTRIBUTION =IMPACT PROPAGATION



Joint/Node	A	B		C		D
Member/Connectivity	AB	BA	BC	CB	CD	DC
Distribution Factors/Vulnerability Coefficients	**0**	**0.4284**	**0.5716**	**0.64**	**0.36**	**1**
Computed end moments	-80	80	-112.5	112.5	-53.333	53.333
Cycle 1						
Balance & Distribute		13.923	18.577	-37.867	-21.3	-53.333
Carry-over	6.962		-18.934	9.289	-26.667	-10.65
Cycle 2						
Balance & Distribute		8.111	10.823	11.122	6.256	10.65
Carry-over	4.056		5.561	5.412	5.325	3.128
Cycle 3						
Balance & Distribute		-2.382	-3.179	-6.872	-3.865	-3.128
Carry-over	-1.191		-3.436	-1.59	-1.564	-1.933
Cycle 4						
Balance & Distribute		1.472	1.964	2.019	1.135	1.933
Carry-over	0.736		1.01	0.982	0.967	0.568
Cycle 5						
Balance		-0.433	-0.577	-1.247	-0.702	-0.568
Summed up moments (**consequences**)	**-69.437**	**100.69**	**-100.69**	**93.748**	**-93.748**	**0**

Stiffness factors (Vulnerability factors)

Stiffness

By definition it can be written as Eq. (5-33):

$$DF_i \text{ (vulnerability coefficient)} = \frac{k_i}{\sum_{j=1}^{j=n} k_j}$$

For i^{th} node with n links joining at the node.

$$\text{Stiffness, } k = \frac{EI}{L}$$

$$k_{AB} = k_{BA} = \frac{4EI}{L} = \frac{4EI}{8} = 0.5000$$

$$k_{BC} = k_{CB} = \frac{4EI}{L} = \frac{4EI}{6} = 0.6667$$

$$k_{CD} = k_{DC} = \frac{3EI}{L} = \frac{3EI}{8} = 0.3750$$

$$M_{AB} = -M_{BA} = -\frac{wl^2}{12} = -\frac{(15)(8)^2}{12} = -80\ kN.m$$

$$M_{BC} = -M_{CB} = -\frac{wl}{8} = -\frac{(150)(6)}{8} = -112.5\ kN.m$$

$$M_{CD} = -M_{DC} = -\frac{wl^2}{12} = -\frac{(10)(8)^2}{12} = -53.333\ kN.m$$

Total Vulnerability Coefficient Factors at a Node:

$$DF_1 + DF_2 + DF_3 = \frac{k_1}{k_1+k_2+k_3} + \frac{k_2}{k_1+k_2+k_3} + \frac{k_3}{k_1+k_2+k_3} = 1$$

$\Rightarrow$ Total Vulnerability Coefficient Factors = 1

$$DF_{AB} = \frac{K_{BA}}{K_{BA}+K_{wall}} = \frac{0.5EI}{0.5+¥ \text{ (wall stiffness)}} = 0.0$$

vulnerability of A to B, v_{AB}

$$DF_{BA} = \frac{K_{BA}}{K_{BA}+K_{BC}} = \frac{0.5EI}{0.5EI+0.667EI} = 0.4284$$

vulnerability of B to A, v_{BA}

$$DF_{BC} = \frac{K_{BC}}{K_{BA}+K_{BC}} = \frac{0.667EI}{0.5EI + 0.667EI} = 0.5716$$

vulnerability of B to C, v_{BC}

$$DF_{CB} = \frac{K_{CB}}{K_{CB}+K_{CD}} = \frac{0.667EI}{0.667EI + 0.37500EI} = 0.64$$

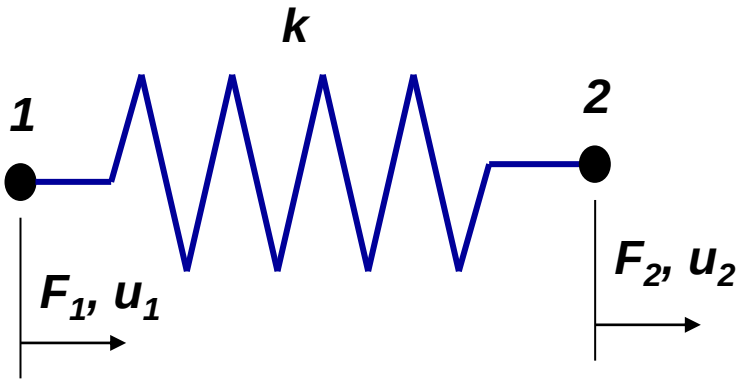
vulnerability of C to B, v_{CB}

$$DF_{CD} = \frac{K_{CD}}{K_{CB}+K_{CD}} = \frac{0.3750EI}{0.667EI+0.375EI} = 0.36$$

vulnerability of C to D, v_{CD}

$$DF_{DC} = \frac{K_{DC}}{K_{DC}} = 1.00$$

vulnerability of D to C, v_{DC}



- spring with nodes 1 and 2 has stiffness k
- axial displacements at nodes = u_1, u_2
- axial forces at nodes = F_1, F_2

$$\begin{Bmatrix} F_1 \\ F_2 \end{Bmatrix} = \begin{bmatrix} k & -k \\ -k & k \end{bmatrix} \begin{Bmatrix} u_1 \\ u_2 \end{Bmatrix}$$

$$\{F^e\} = [k^e]\{U^e\}$$

Example

Adobe Acrobat
Document

QUESTION TIME