


**CPEC ROUTE OPTIMIZATION:
TECHNOLOGY & DECISION MAKING**


Dr. Rameez Khalid

IBA Institute of
Business Administration
Karachi
Leadership and Ideas for Tomorrow



AGENDA

- A. Research
 - *Objectives*
 - *Methodology*
- B. Background
 - *CPEC: Benefits & Challenges*
 - *Cement Industry*
- C. Results
 - *Mathematical Model*
 - *Simulation Model*
 - *Conclusions*



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RESEARCH

- Use of Quantitative Approaches using Technology is few and far between in emerging markets.*
- CPEC's Decisions:
 - locations /capacities of highways (alignment & lanes);
 - locations of interchanges and SEZs;
 - locations of congestion, accidents and floods etc.;
 - traffic rules for better management, and;
 - impact of decisions on costs of: land acquisition, construction, Right of Way (ROW), tariff, toll, transportation and fuel etc.;

*Finding from interviews

(Mohmand and Wang, 2013)

Pakistan has weak transport infrastructure

Highways only 3% of the entire road network

Freight Journeys 2-4 times longer than in Europe

Losses to GDP 4-6% annually for logistical inefficiencies

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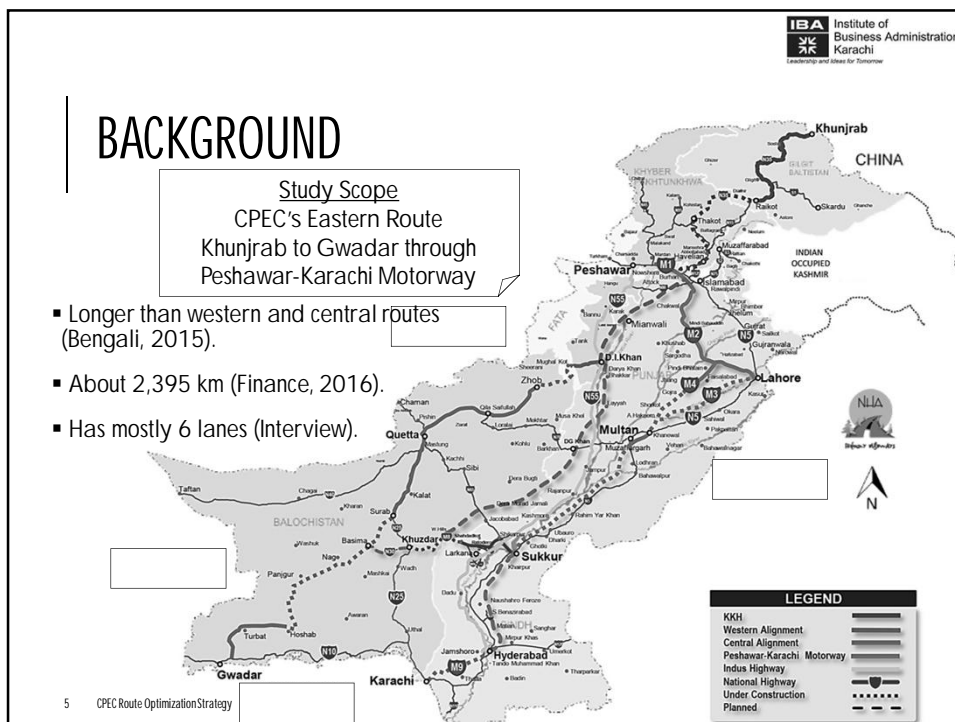
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RESEARCH

- OBJECTIVES
 1. Showcase a Strategy for Optimizing CPEC's Routes using Technology
 2. Apply Quantitative Approaches for CPEC's Decision Making
 3. Suggest better Locations of 'Interchanges' or Validate the already suggested ones on CPEC's Routes
 4. Propose Optimal Combination of Interchanges for Cement Sector on CPEC's Eastern Route
- METHODOLOGY
 1. Secondary Research
 2. Primary Research: 6 Unstructured Interviews
 3. Mathematical Model: Mixed-Integer Linear Programming
 4. Witness Simulation Model: Discrete-Event Simulation

Entity	Number of Interviews
GOVT. (HIGHWAY & PORT)	2
LOGISTICS' COMPANY	2
CEMENT INDUSTRY	2

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Article	CPEC's Benefits for Pakistan	CPEC's Challenges for Pakistan
(Zhiqin and Yang, 2016)	Source of Potential Synergy;	Security, Terrorism and Political Issues; Cultural differences and practices
(Javaid, 2016)	Energy and Infrastructure Projects; Gwadar Port Development; FDI	Indian Threat; Security Concerns
(Abid and Ashfaq, 2015)	Economic development; Overcoming energy crisis; Infrastructure development; Removal of Poverty; Prosperity	External and internal threats; Political unrest; Security Issues; Administrative Issues
(Bengali, 2015)	Western Route: Cheapest to construct; Jobs; National Integration	Eastern Route: Most expensive to construct and can cause political instability between provinces; Western & Central Route: Security Threats
(Sial, 2014)	Change in Govt. unlikely to reverse development under CPEC; Economic outlook seems positive	Political instability; Economic constraints; Geostrategic dynamics; Security threats;

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BACKGROUND

Study Scope
 Cement Industry
 along CPEC's Eastern Route

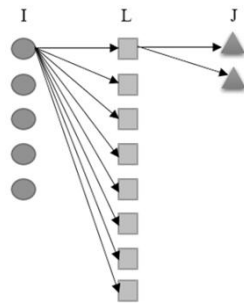
(Choangalia et al., 2016)

Cement Industry one of the oldest in Pak.
 Raw material (limestone and clay) found in abundance
 Pakistan in Cement 5th largest exporter
 14th largest producer
 Consumption is low at 140 kg per Capita
 (Global avg. of 400 kg)

- Cement Industry (APCMA, 2017)
 - Pakistan's Total Plants: 24;
 - Total Production Capacity: 45.6 M mt;
 - Exports: 13.5%;
 - Exports by Sea: ~6% (Study Scope)
 - Imported Coal: used for heating
 - 1 ton Cement: requires ~150 kg Coal

RESULTS

- Mathematical Model
 - Two flows were modeled:
 - (a) Cement: Cluster > Interchange > Port
 - (b) Coal: reverse flow (as imported)
 - MIL solved using MS Excel Solver



Minimize

$$\sum_{i \in I} \sum_{l \in L} dist_{il} f_{il} K_i y_{il} + \sum_{l \in L} \sum_{j \in J} dist_{lj} f_{lj} x_{lj}$$

Subject to:

$$\sum_{i \in I} x_{ij} = D_j ; \forall j \in J$$

$$\sum_{j \in J} x_{lj} \leq \sum_{i \in I} K_i y_{il} ; \forall l \in L$$

$$\sum_{i \in I} K_i \geq \sum_{j \in J} D_j$$

$$\sum_{l \in L} y_{il} = 1 ; \forall i \in I$$

$$y_{il} \in \{0,1\} ; \forall i \in I, \forall l \in L$$

$$x_{lj} \geq 0 ; \forall l \in L, \forall j \in J$$

$$K_i, D_j \in \{integer\} ; \forall i \in I, \forall j \in J$$

RESULTS

Inputs - Costs, Capacities, Demands

Source	Destination Interchange (Transportation Cost in PKR)					Capacity
	Int-1	Int-2	Int-3	Int-4	Int-5	
Cluster-1	517	3,420	4,698	27,832	30,384	14,778
Cluster-2	3,564	1,318	686	21,006	23,558	4,595
Cluster-3	3,096	565	846	26,460	29,012	14,769
Cluster-4	27,837	26,417	20,592	522	3,074	9,678
Cluster-5	30,083	28,663	22,838	2,768	216	2,556
Demand			$dist(ij) * f(ij)$		$k(i)$	

Decision Variables

Source	Destination Interchange				
	Int-1	Int-2	Int-3	Int-4	Int-5
Cluster-1	1	0	0	0	0
Cluster-2	0	0	1	0	0
Cluster-3	0	0	1	0	0
Cluster-4	0	0	0	1	0
Cluster-5	0	0	0	0	1

Interchange	Final Destination (Transportation Cost in PKR)	
	Port-1	Port-2
Int-1	24,948	36,216
Int-2	22,554	33,822
Int-3	22,068	33,336
Int-4	1,757	13,025
Int-5	562	10,800
Demand	37,101	9275

Interchange	Final Destination (Truckloads)	
	Port-1	Port-2
Int-1	14778	0
Int-2	0	0
Int-3	19364	0
Int-4	2959	6719
Int-5	0	2556

Constraints

Source	Int-1	Int-2	Int-3	Int-4	Int-5	Y(i)
Cluster-1	0	0	0	0	0	1
Cluster-2						1
Cluster-3						1
Cluster-4						1
Cluster-5	Port-1	Port-2				1
Unmet Dema	0	0				-

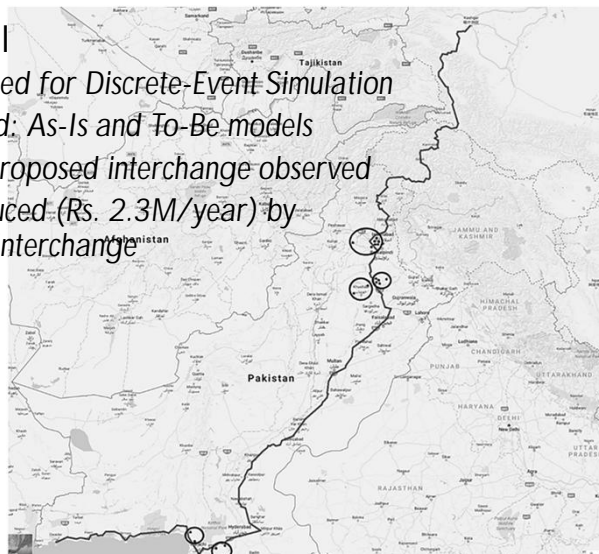
Source	Int-1	Int-2	Int-3	Int-4	Int-5
Cluster-1	14778	0	0	0	0
Cluster-2	0	0	4595	0	0
Cluster-3	0	0	14769	0	0
Cluster-4	0	0	0	9678	0
Cluster-5	0	0	0	0	2556

Objective Function

Cost = PKR 945,216,016

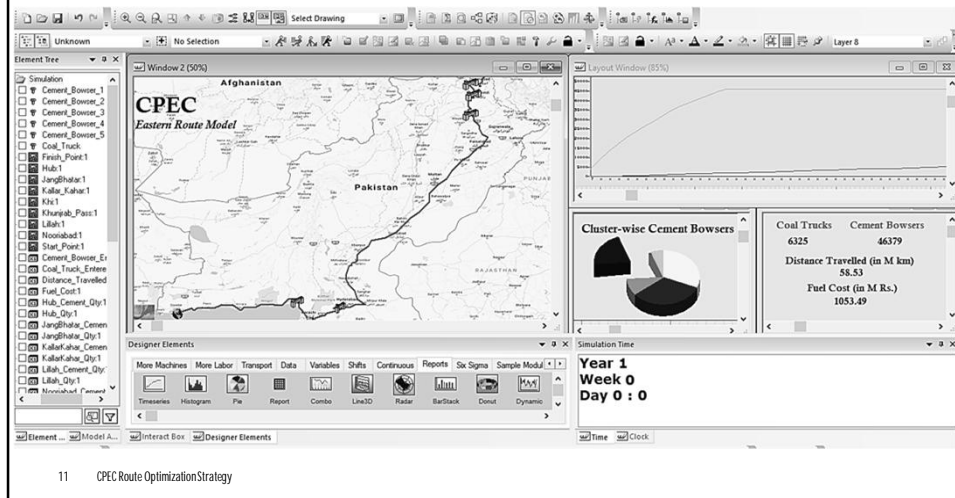
RESULTS

- Simulation Model
 - Witness Software used for Discrete-Event Simulation
 - 1 year was simulated: As-Is and To-Be models
 - Improvements with proposed interchange observed
 - > 1% fuel costs reduced (Rs. 2.3M/year) by suggesting only one interchange



RESULTS

Simulation Model



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CONCLUSIONS

As-Is

Details	Coal Trucks	Cement Bowers from				
		Cluster-1	Cluster-2	Cluster-3	Cluster-4	Cluster-5
No. Entered	6325	14778	4595	14769	9678	2559
No. Shipped	6325	14778	4595	14769	9678	2559
Avg Time (in days)	1	1.38	1.15	1.32	0.11	0.07

Details	Karachi - Hub	Karachi - Nooriabad	Nooriabad - Lillah	Lillah - KallarKahar	KallarKahar - JangBhatar
Trucks In	2908	49796	38799	33578	16794
Trucks Out	2908	49796	38799	33578	16794
% Busy	5.52	95.12	95.42	92.46	58.8
% Idle	94.48	4.88	4.58	7.54	41.2

To-Be

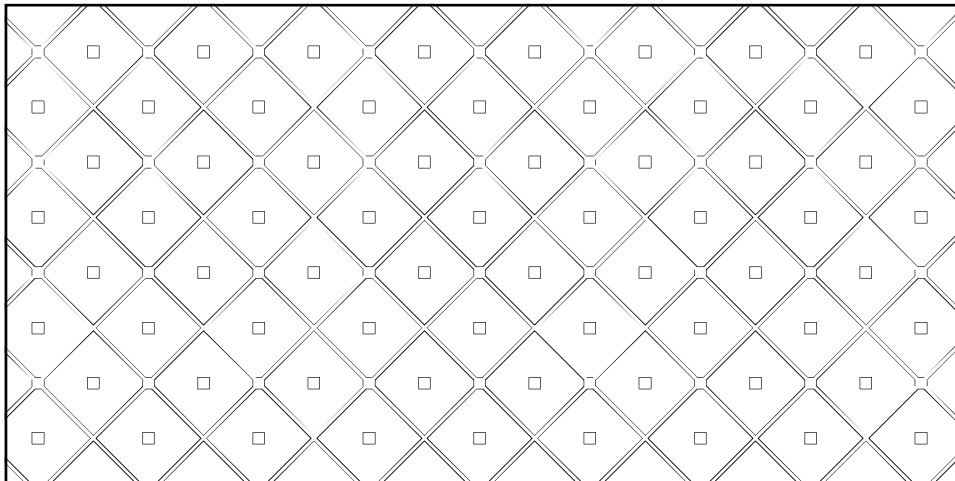
Details	Coal Trucks	Cement Bowers from				
		Cluster-1	Cluster-2	Cluster-3	Cluster-4	Cluster-5
No. Entered	6325	14778	4595	14769	9678	2559
No. Shipped	6325	14778	4595	14769	9678	2559
Avg Time	1.03	1.49	1.15	1.32	0.11	0.07

Details	Karachi - Hub	Karachi - Nooriabad	Nooriabad - Lillah	Lillah - KallarKahar	KallarKahar - DhokiPannun
Trucks In	2908	49796	38799	33578	16794
Trucks Out	2908	49796	38799	33578	16794
% Busy	5.52	95.12	95.42	92.49	62.16
% Idle	94.48	4.88	4.58	7.51	37.84

CONCLUSIONS

- Optimized combination resulted from mathematical model; Simulation Results showed improvements with suggested interchange
- Recommendation: Quantitative Approaches can be incorporated in decision making by following the discussed strategy: data collection > mathematical model > simulation
- Further Research:
 - *Conducting sensitivity analysis for finding significant parameters;*
 - *Developing What-If scenarios of the Witness simulation model;*
 - *Bringing local consumption of cement in scope of the models;*
 - *Taking applicable taxes, tariffs and tolls into account;*
 - *Collecting data for more industries for replication;*
 - *Developing models with other objective functions.*

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THANK YOU! | Questions?

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