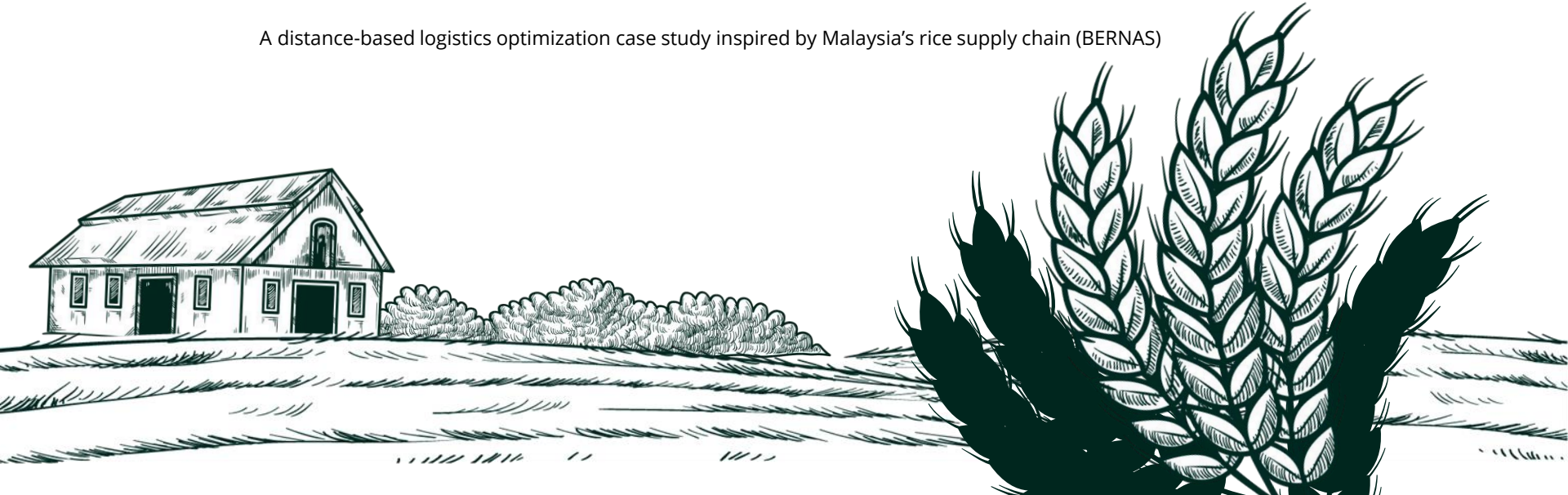
RICE TRANSPORTATION COST OPTIMIZATION USING INTEGER LINEAR PROGRAMMING

A distance-based logistics optimization case study inspired by Malaysia’s rice supply chain (BERNAS)



PARAMETER ESTIMATION FOR REAL-WORLD TRANSPORTATION MODEL

- Padiberas Nasional Berhad (BERNAS) is a Malaysia's official rice trading organization that carries out government policies to ensure stability of the domestic rice market and Malaysia's food security
- This project focus on the northern regions of Peninsular Malaysia which are Kedah, Perlis, Penang, and Perak as it represents major rice-producing zone in the country

Selected Location

Rice Mills

1. KBB Simpang Lima, Perak
2. KBB Bukit Besar, Kedah
3. KBB Sungai Limau, Kedah
4. KBB Bukit Raya, Kedah
5. KBB Utan Aji , Perlis
6. KBB Paya Keladi, Penang

Warehouse

a. Gudang BERNAS, Penang
b. Gudang Ray Synergy, Penang
c. Gudang CCW, Penang

Estimated Cost Matrix

Distance in KM (Google Maps)

RICE MILLS	WAREHOUSES a	b	c
1	54	47	42
2	89	86	88
3	81	79	80
4	87	85	84
5	157	156	158
6	28	26	27

Multiply by RM3/km

Cost Matrix

RICE MILLS	WAREHOUSES a	b	c
1	162	141	126
2	267	258	264
3	243	237	240
4	261	255	252
5	471	468	474
6	84	78	81

Demand = Supply = 1000 tons

Estimated Demand

The demand was distributed in an approximately balanced manner as the warehouse are centralized in Seberang Perai, Penang

Warehouse	Estimated Demand (tons)
a	350
b	300
c	350
Total	1000

Estimated Supply

Rice Mill	State	Percentage of Total Rice Production based on USDA Rice Explorer	Estimated Proportion		Estimated Supply (tons)
1	Perak	11%	11/62*100 = 18%		180
2	Kedah	37%	37/62*100 = 60%	25%	250
3	Kedah			15%	150
4	Kedah			20%	200
5	Perlis	9%	9/62*100 = 14%		140
6	Penang	5%	5/62*100 = 8%		80
Total		**62%**	**100%**		**1000**

PROJECT DESCRIPTION & PROBLEM FORMULATION

Padiberas Nasional Berhad (BERNAS) is the official rice trading organization in Malaysia. The company wants to optimize the transportation of processed rice from six rice mills to three warehouses across the northern region of Peninsular Malaysia. Each rice mill has a limited supply capacity based on regional paddy production estimates and each warehouse has a specific demand that must be fulfilled. The transportation cost from each rice mill to each warehouse are estimated based on travel distance with an assumed freight charge of RM3 per kilometer per ton.

BERNAS wants to:

- **Minimize** the total transportation cost.
- **Satisfy** the demand requirements at all warehouses.
- Ensure that supply limits at each rice mill are **not exceeded**.
- Route rice only through **feasible cost-defined** connections.

To derive a feasible and near-optimal transportation plan, this project applies Integer Linear Programming (ILP), where transported quantities are in whole numbers. Initial feasible solutions are manually calculated using three classical methods:

- **Northwest-Corner Method (NWC)**
- **Least-Cost Method (LCM)**
- **Vogel's Approximation Method (VAM)**

These solutions are then validated and optimized using Excel Solver, which applies the Simplex Method and tested under several what-if scenarios.

Decision Variable:

$\mathbf{x_{1a}}$: Amount transported from Simpang Lima to Gudang BERNAS
$\mathbf{x_{1b}}$: Amount transported from Simpang Lima to Gudang Synergy
$\mathbf{x_{1c}}$: Amount transported from Simpang Lima to Gudang CCW
$\mathbf{x_{2a}}$: Amount transported from Bukit Besar to Gudang BERNAS
$\mathbf{x_{2b}}$: Amount transported from Bukit Besar to Gudang Synergy
$\mathbf{x_{2c}}$: Amount transported from Bukit Besar to Gudang CCW
$\mathbf{x_{3a}}$: Amount transported from Sungai Limau to Gudang BERNAS
$\mathbf{x_{3b}}$: Amount transported from Sungai Limau to Gudang Synergy
$\mathbf{x_{3c}}$: Amount transported from Sungai Limau to Gudang CCW
$\mathbf{x_{4a}}$: Amount transported from Bukit Raya to Gudang BERNAS
$\mathbf{x_{4b}}$: Amount transported from Bukit Raya to Gudang Synergy
$\mathbf{x_{4c}}$: Amount transported from Bukit Raya to Gudang CCW
$\mathbf{x_{5a}}$: Amount transported from Utan Aji to Gudang BERNAS
$\mathbf{X_{5b}}$: Amount transported from Utan Aji to Gudang Synergy
$\mathbf{X_{5c}}$: Amount transported from Utan Aji to Gudang CCW
$\mathbf{X_{6a}}$: Amount transported from Paya Keladi to Gudang BERNAS
$\mathbf{X_{6b}}$: Amount transported from Paya Keladi to Gudang Synergy
$\mathbf{X_{6c}}$: Amount transported from Paya Keladi to Gudang CCW

Objective Function:

$$\textit{Minimize } Z = 162x_{\mathbf{1a}} + 141x_{1b} + 126x_{1c} + 267x_{2a} + 258x_{2b} + 264x_{2c} + 243x_{3a} + 237x_{3b} + 240x_{3c} + 261x_{4a} + 255x_{4b} + 252x_{4c} + 471x_{5a} + 468x_{5b} + 474x_{5c} + 84x_{6a} + 78x_{6b} + 81x_{6c}$$

Constraint:

$x_{1a}+x_{1b}+x_{1c}=180$
$x_{2a}+x_{2b}+x_{2c}=250$
$x_{3a}+x_{3b}+x_{3c}=150$
$x_{4a}+x_{4b}+x_{4c}=200$
$x_{5a}+x_{5b}+x_{5c}=140$
$x_{6a}+x_{6b}+x_{6c}=80$
$x_{1a}+x_{2a}+x_{3a}+x_{4a}+x_{5a}+x_{6a}=350$
$x_{1b}+x_{2b}+x_{3b}+x_{4b}+x_{5b}+x_{6b}=300$
$x_{1c}+x_{2c}+x_{3c}+x_{4c}+x_{5c}+x_{6c}=350$
$x_{ij} \geq 0$

MODEL IMPLEMENTATION

METHOD	NORTHWEST CORNER METHOD	LEAST COST METHOD	VOGEL'S APPROXIMATION METHOD	SIMPLEX METHOD (EXCEL SOLVER)
TOTAL TRANSPORTATION COST	254190	247290	246720	246660

SIMPLEX METHOD (EXCEL SOLVER)

	WAREHOUSES			SUPPLY	RICE SHIPPED
RICE MILLS	Gudang BERNAS	Gudang Ray Synergy	Gudang CCW		
KBB Simpang Lima, Perak	0	0	**180**	180	180
KBB Bukit Besar, Kedah	0	**250**	0	250	250
KBB Sungai Limau, Kedah	**130**	**20**	0	150	150
KBB Bukit Raya, Kedah	0	**30**	**170**	200	200
KBB Utan Aji, Perlis	**140**	0	0	140	140
KBB Paya Keladi, Penang	**80**	0	0	80	80
DEMAND	350	300	350	**1000**	
RICE SHIPPED	350	300	350		

Optimal Solutions:

- KBB Simpang Lima → Gudang CCW = 180 tons
- KBB Bukit Besar → Gudang Ray Synergy = 250 tons
- KBB Sungai Limau → Gudang BERNAS = 130 tons
- KBB Sungai Limau → Gudang Ray Synergy = 20 tons
- KBB Bukit Raya → Gudang Ray Synergy = 30 tons
- KBB Bukit Raya → Gudang CCW = 170 tons
- KBB Utan Aji → Gudang BERNAS 140 tons
- KBB Paya Keladi → Gudang BERNAS = 80 tons

Total Transportation Cost:

$$= (180 \times 126) + (250 \times 258) + (130 \times 243) + (20 \times 237) + (30 \times 255) + (170 \times 252) + (140 \times 471) + (80 \times 84) = 246{,}660$$

SCENARIO ANALYSIS

- Test two what-if scenarios to reflect realistic disruptions that may occur in the rice supply chain such as surge in demand or limitation in supply.
- The model become unbalanced, thus needs to include dummy rice mills.
- Unmet demand penalty cost of RM600 was introduced to all dummy routes.
  - Why RM600? Because it exceeds max actual transportation cost (RM474) to discourage the solver from relying on unmet demand

Cost Matrix with Unmet Penalty Cost

RICE MILLS	WAREHOUSES		
	Gudang BERNAS	Gudang Ray Synergy	Gudang CCW
KBB Simpang Lima, Perak	162	141	126
KBB Bukit Besar, Kedah	267	258	264
KBB Sungai Limau, Kedah	243	237	240
KBB Bukit Raya, Kedah	261	255	252
KBB Utan Aji, Perlis	471	468	474
KBB Paya Keladi, Penang	84	78	81
Dummy	600	600	600

SCENARIO 1: INCREASE DEMAND AT WAREHOUSE

- Increase demand at Gudang Ray Synergy from **300 tons to 400 tons**

RICE MILLS	WAREHOUSES			SUPPLY	RICE SHIPPED
	Gudang BERNAS	Gudang Ray Synergy	Gudang CCW		
KBB Simpang Lima, Perak	0	0	**180**	**180**	180
KBB Bukit Besar, Kedah	0	**250**	0	**250**	250
KBB Sungai Limau, Kedah	0	**150**	0	**150**	150
KBB Bukit Raya, Kedah	**30**	0	**170**	**200**	200
KBB Utan Aji, Perlis	**140**	0	0	**140**	140
KBB Paya Keladi, Penang	**80**	0	0	**80**	80
Dummy	**100**	0	0	**100**	100
DEMAND	**350**	**400**	**350**	**1100**	
RICE SHIPPED	350	400	350		

Total Transportation Cost: RM 306,060

SCENARIO 2: DECREASE SUPPLY AT RICE MILLS

- Reduced Supply at KBB Bukit Besar from **250 tons to 200 tons**

RICE MILLS	WAREHOUSES			SUPPLY	RICE SHIPPED
	Gudang BERNAS	Gudang Ray Synergy	Gudang CCW		
KBB Simpang Lima, Perak	0	0	**180**	**180**	180
KBB Bukit Besar, Kedah	0	**200**	0	**200**	200
KBB Sungai Limau, Kedah	**130**	**20**	0	**150**	150
KBB Bukit Raya, Kedah	**30**	0	**170**	**200**	200
KBB Utan Aji, Perlis	**140**	0	0	**140**	140
KBB Paya Keladi, Penang	0	**80**	0	**80**	80
Dummy	**50**	0	0	**50**	50
DEMAND	**350**	**300**	**350**	**1000**	
RICE SHIPPED	350	300	350		

Total Transportation Cost: RM 263,460

CONCLUSION

1. The ILP model helped BERNAS minimize transportation costs while meeting all supply and demand needs.
2. **Optimal cost achieved:** RM246,660 (Simplex Method of Excel Solver the best other manual methods).
3. **Increase demand and reduce supply** : Both Scenario 1 and Scenario 2 show the increasing optimal cost allocation from its original settings when there is a changes in both demand and supply.