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BatKedge is a battery production company based in Bordeaux, France. To produce batteries, BatKedge needs to buy around 2.45 million tons of a chemical component from 6 suppliers in Europe: 3 factories are part of the BatKedge group and 3 are partner companies. BatKedge has received bids from these factories for next year.

The table below summarizes these offers and the relevant information concerning the 6 suppliers. For example, supplier A is a plant belonging to the Kedge group offering the chemical component at €49.5 per ton, delivered by train. Supplier A has an annual production capacity of 300,000 tons. Finally, as part of its concern for the environment, BatKedge has introduced an environmental assessment criterion for its suppliers. The higher the score, the more environmentally friendly the chemical component treatment process. The score obtained by supplier A is 15.

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Price (€/tonne) | 49.5 | 50 | 61 | 63.5 | 66.5 | 72.5 |
| Kedge/Partner | Kedge | Kedge | Partner | Kedge | Partner | Partner |
| Truck/Train | Train | Truck | Train | Truck | Truck | Train |
| Environmental Criterion | 15 | 16 | 18 | 20 | 21 | 23 |
| Capacity (mt/an) | 300 | 600 | 510 | 655 | 575 | 450 |

As part of its commitment to eco-responsibility, BatKedge wants all the chemical components used in the production of its batteries to achieve an average score of 19. In addition, to improve relations with the trade unions, BatKedge has also committed to sourcing 50% of its supplies from the Group's factories. Finally, receipt of components by rail is currently limited to 1,200 thousand tons and 1,440 thousand tons by truck.

It is clear that BatKedge's main objective is to formulate a procurement plan that minimizes the cost of supplying the chemical component. The cheapest chemical component is the component from suppliers A, B and C. However, the cheapest components also have a lower environmental score, which contradicts BatKedge's environmental objectives, which are to have an average score of 19. One strategy would be to contract only with Suppliers whose environmental score is at least 19. This strategy would effectively eliminate suppliers A, B and C, which is unfortunate as these are the three cheapest suppliers. In fact, a more intelligent strategy would be to diversify supplies. For example, sourcing equal quantities from suppliers C (score 18) and D (score 20) would give an average score of 19.

**SETS**

I: suppliers = {A, B, C, D, E, F}

**PARAMETERS**

$p_i$: $price\ per\ ton$ (€/ton)$for\ each\ supplier\ i \in I$

$\alpha_i$: $\begin{cases} 1\ if\ the\ type\ of\ group\ is\ kedge\ for\ each\ supplier\ i \in I \\ 0\ otherwise \end{cases}$

$\beta_i$: $\begin{cases} 1\ if\ the\ type\ of\ transport\ is\ truck\ for\ each\ supplier\ i \in I \\ 0\ otherwise \end{cases}$

$ec_i$: $environmental\ assesment\ criterion\ for\ each\ supplier\ i \in I$

$c_i$: $capacity\ in\ thousands\ of\ tons\ (m * ton)\ for\ each\ supplier\ i \in I$

$r_i$: $receipt\ of\ components\ for\ each\ supplier\ i \in I$

$T$: $total\ capacity\ of\ chemical\ component\ in\ thousand\ of\ tones, 2450$

**VARIABLES**

$x_i$: $amount\ of\ thousands\ of\ tones\ of\ chemical\ component\ for\ each\ supplier\ i \in I$

**OBJECTIVE FUNCTION**

$$minimize\ z: \sum_i x_i * p_i$$

**CONSTRAINS**

1. The receipt of components by rail is currently limited to 1,200 thousand tons and 1,440 thousand tons by truck.

$$\sum_i x_i * \beta_i \leq 1440$$

$$\sum_i x_i * (1 - \beta_i) \leq 1200$$

2. BatKedge has committed to sourcing 50% of its supplies from the Group's factories.

$$\sum_i x_i * \alpha_i \geq \sum_i \frac{x_i}{2}$$

3. BatKedge wants all the chemical components used in the production of its batteries to achieve an average score of 19.

$$\sum_i x_i * ec_i \geq 19 * \sum_i x_i$$

4. BatKedge needs to buy around 2.45 million tons of a chemical component from 6 suppliers in Europe.

$$\sum_i x_i = T$$

5. Annual production capacity for each supplier.

$$x_i \leq c_i \quad \forall i \in I$$

6. Non negativity constrains.

$$x_i \geq 0 \quad \forall i \in I$$

Questions:

1) How much of the chemical component should BatKedge purchase from each supplier to minimize the cost of supply?

| Categories | Supplier A | Supplier B | Supplier C | Supplier D | Supplier E | Supplier F |
|---|---|---|---|---|---|---|
| Quantities | 300 | 573,75 | 260 | 351,25 | 515 | 450 |

2) What will BatKedge's total cost of supply be?

| Categories | Supplier A | Supplier B | Supplier C | Supplier D | Supplier E | Supplier F |
|---|---|---|---|---|---|---|
| Subtotal | € 14 850,00 | € 28 687,50 | € 15 860,00 | € 22 304,38 | € 34 247,50 | € 32 625,00 |

| | |
|---|---|
| **Total** | € 148 574,38 |

3) What will be BatKedge's average supply cost?

| | | | | | | |
|---|---|---|---|---|---|---|
| Subtotal | € 14 850,00 | € 28 687,50 | € 15 860,00 | € 22 304,38 | € 34 247,50 | € 32 625,00 |
| **Average** | € 24 762,40 | | | | | |

4) What is the cost of the component at the margin? In other words, how much does an additional ton of components cost BatKedge?

An additional ton of component would cost € 64,56 to BatKedge as it can be seen on the shadow price

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $J$5 | Env. Capacity LHS | 46550 | 3.375 | 0 | 1215 | 105 |
| $J$6 | Capacity LHS | 2450 | 64.5625 | 2450 | 190 | 70 |

5) Should BatKedge consider increasing its trucking capacity? If so, how much should it be prepared to spend?

Yes, it is a good to consider increasing trucking capacity because it will reduce cost, thanks to supplier B is cheaper, as it can be seen on the shadow price, for one unit more on trucking it will reduce 4,625

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $J$2 | Truck LHS | 1440 | -4,625 | 1440 | 35 | 190 |

6). Should BatKedge consider increasing its rail capacity? If so, how much should it be prepared to spend?

It would be a good option just only when supplier B will be at full capacity, because in this scenario, the supplier C becomes the less expensive, but for instance it is not neccesary to consider it

| Categories | Supplier A | Supplier B | Supplier C | Supplier D | Supplier E | Supplier F |
|---|---|---|---|---|---|---|
| Env Capacity | 15 | 16 | 18 | 20 | 21 | 23 |
| Transport | Rail | Truck | Rail | Truck | Truck | Rail |

7) Should BatKedge be willing to negotiate more components from suppliers B and F, even at a higher price? If so, how far should it be prepared to go?

It can be seen on the shadow price, in the case of supplier B, it does not have sense to negotiate more components, on the other hand in the case of F it could be profitable to negotiate more, because it will reduce general costs, and it could be at higher price until the total of shadow price of 5,37

| Supplier F |
|---|
| € 72,50 |

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $J$9 | B LHS | 573,75 | 0 | 600 | 1E+30 | 26,25 |
| $J$13 | F LHS | 450 | -5,375 | 450 | 21 | 243 |

This is the example increasing the price of F on 5,00

| Supplier F | |
|---|---|
| € | 77.50 |

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $J$9 | B LHS | 573.75 | 0 | 600 | 1,00E+30 | 26.25 |
| $J$13 | F LHS | 450 | -0.375 | 450 | 21 | 243 |

8). How should BatKedge evaluate a Kedge/Partner supplier on a cost basis? Should it be prepared to pay a premium for a Kedge supplier to reduce its commitment to the unions?

It was made two scenarios changing the balance Kedge/Partner suppliers

**Kedge 45% / Partner 55%**

| Categories | Supplier A | Supplier B | Supplier C | Supplier D | Supplier E | Supplier F |
|---|---|---|---|---|---|---|
| Price | € 49.50 | € 50.00 | € 61.00 | € 63.50 | € 66.50 | € 72.50 |
| Capacity | 300 | 600 | 510 | 655 | 575 | 450 |
| Env Capacity | 15 | 16 | 18 | 20 | 21 | 23 |
| Transport | Rail | Truck | Rail | Truck | Truck | Rail |
| Entity | Kedge | Kedge | Partner | Kedge | Partner | Partner |
| Quantities | 300 | 543.125 | 260 | 504.375 | 392.5 | 450 |
| Subtotal | € 14,850.00 | € 27,156.25 | € 15,860.00 | € 32,027.81 | € 26,101.25 | € 32,625.00 |
| **Average** | € 24,770.05 | | | | | |

2450

| **Min Cost** | € 148,620.31 |
|---|---|

**Kedge 45% / Partner 55%**

| Categories | Supplier A | Supplier B | Supplier C | Supplier D | Supplier E | Supplier F |
|---|---|---|---|---|---|---|
| Price | € 49.50 | € 50.00 | € 61.00 | € 63.50 | € 66.50 | € 72.50 |
| Capacity | 300 | 600 | 510 | 655 | 575 | 450 |
| Env Capacity | 15 | 16 | 18 | 20 | 21 | 23 |
| Transport | Rail | Truck | Rail | Truck | Truck | Rail |
| Entity | Kedge | Kedge | Partner | Kedge | Partner | Partner |
| Quantities | 266 | 600 | 322.5 | 236.5 | 575 | 450 |
| Subtotal | € 13,167.00 | € 30,000.00 | € 19,672.50 | € 15,017.75 | € 38,237.50 | € 32,625.00 |
| **Average** | € 24,786.63 | | | | | |

2450

| **Min Cost** | € 148,719.75 |
|---|---|

To evaluate it is necesary to compare between both cases and the original balance of 50%/50%

| Categories | Supplier A | Supplier B | Supplier C | Supplier D | Supplier E | Supplier F |
|---|---|---|---|---|---|---|
| Subtotal | € 14 850,00 | € 28 687,50 | € 15 860,00 | € 22 304,38 | € 34 247,50 | € 32 625,00 |

| | |
|---|---|
| **Total** | € 148 574,38 |

It can be seen than in both cases it is not something profitable