Executive Summary

This executive summary provides an overview of a simulation exercise conducted for a consumer electronics company (CEC) aiming to configure an optimal supply chain for the production and shipping of LCD TV sets. The case study outlines the strategic considerations, constraints, and objectives faced by the company, including budget allocation, production subcontracting, transportation modes, and environmental impact.

When only focusing on minimizing the overall shipping cost (Option A), the CO_2 emission was 7425340.87 kg and the minimized cost was CNY 2,999,985,597.1. With a total budget of 3 billion CNY, the minimal emission after accounting for CO_2 (Option B) is 7401248.18 kg. However, since reducing CO2 emissions is thought likely to benefit from a tax incentive under government legislation, boost brand value, and finally result in a 10% increase in shipping budget, the team reran the model with a total budget of 3.3 billion CNY (Option C) and obtained a largely reduced CO_2 emission of 3469969.09 kg.

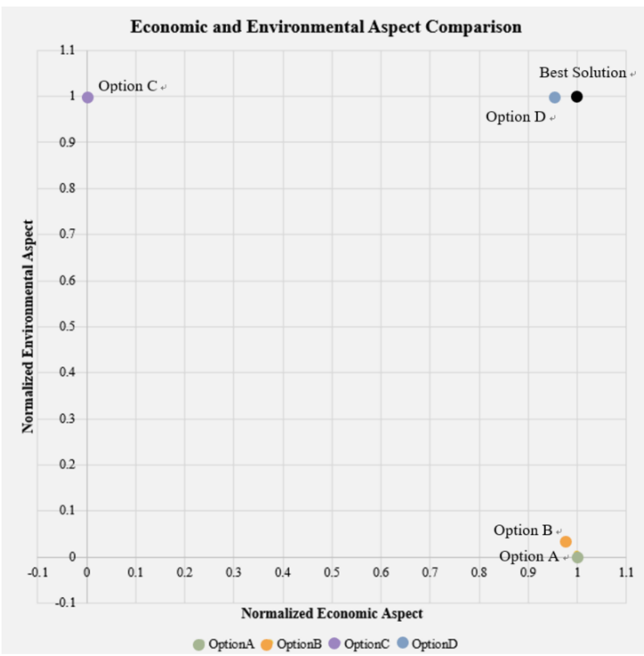

Figure 1

To decide which of the above strategies is the best, we modified the two-dimension diagram proposed by Hong *et. al.* (2014) and plotted the options on the diagram, with Normalized Economic Aspect (calculated by shipping cost) on the x-axis and Normalized Environmental Aspect (calculated by CO2 Emission) on the y-axis (Fig. 1). The best solution on the diagram would be on the point (1,1), where cost and CO_2 emission are at a minimum value, and the strategy closest to this point would be the optimal choice. By evaluating Options A, B, and C, it becomes evident that there is a clear trade-off between economic and environmental considerations. Option B is closer to the Best Solution (1,1), suggesting that Option B is a better strategy among the three. However, the benefit of CO2 emission reduction in Option C, accompanied by a 10% budget increase, means that the company's expenditure remains consistent with the original 3 billion CNY shipping cost. This implies that the company could achieve a substantially lower CO2 emission (more than 50% decrease) at the same expense under potential legislation, represented by Option D on the diagram (updated Option C). Given that Option D closely aligns with point (1,1), our team would recommend adopting a shipping plan that minimizes CO_2 emissions if such government legislation were implemented.

There were some assumptions and simplifications made in our optimization model. First, we used a continuous cost function rather than truckloads, as it allows for a more flexible and nuanced representation of the shipping cost. Also, costs were calculated linearly and economies of scale were ignored in the model; safety stock requirement, storage capacity, shipping times, and carrying cost were not considered. We also assumed that LCD demand is known and constant over time. Moreover, the shipping cost per metric ton is constant for each ODM-shipping mode combination and is proportional to product weight; CO_2 emission (kg) per ton-km shipped is constant for each shipping method, proportional to ODM-DC distance and product weight; and the unit production cost is constant for each ODM and proportional to unit produced only.

Impact of different transportation modes on safety stock

Transportation modes vary in capacity and timing for goods in transit, impacting safety stock levels differently. Relative to air, water modes have large capacity, and are less expensive, but with longer lead time. Safety stock levels are affected by customer service level requirements, demand variability, and lead time (Chopra and Meindl, 2016). As can be seen in formula (1), a high customer service level target, high demand variation, or high lead time contributes to a higher amount of safety stock required due to the increased uncertainty and potential for stockouts resulting from fluctuations in demand or delays in replenishing inventory. Safety stock requirements evolve across different stages of the product life cycle, with higher levels typically observed during the introduction and growth stages when demand variability is high; as products mature and demand stabilizes, safety stock levels can be optimized to balance inventory costs with customer service objectives.

$$\mathrm{ss} = \Phi^{-1}(CSL)\sigma\sqrt{L} \qquad (1)$$

Conclusion

This research looked at the supply chain architecture of a consumer electronics firm. He discovered a trade-off between cost reduction and greenhouse gas emissions. Option C, subject to future rules, delivers significant pollution reductions at comparable costs, while Option B favors balance. These findings suggest that in the presence of supportive legislation, businesses can prioritize environmental goals without going over budget. This investigation laid the groundwork for a future study combining safety stocks and economies of scale for a more complete picture.

References

Chopra, S. & Meindl, P. 2016. Supply chain management: strategy, planning, and operation. Sixth, Global edn, Pearson, Harlow, England.

Ji, C., Hong, T., & Park, H. S. 2014. 'Comparative analysis of decision-making methods for integrating cost and CO2 emission – focus on building structural design', *Energy and Buildings*, 72, pp. 186-194. doi: https://doi.org/10.1016/j.enbuild.2013.12.045

Appendix

A.1 Problem Formulation

Data:

- di: the distance between ODM i and the distribution center
- cxi: the production cost of LCD42 at ODM i
- cyi: the production cost of LCD32 at ODM i
- w: product weight in metric ton
- t: units of each product to be shipped
- sij: shipping cost from ODM i via transportation j

Decision Variables:

- xij : the amount of LCD42 produced by ODM i shipped via transportation j, for i in 1-7; for j in 1-7.
- yij : the amount of LCD32 produced by ODM i shipped via transportation j, for i in 1-7; for j in 1-7.
- ai / bi: whether ODM i is selected to produce LCD42 / LCD32

Objective function:

- Cost: minimize

$$\sum_{i=1}^{7} c_{xi} * xij + \sum_{i=1}^{2} c_{yi} * yij + \sum_{j=1}^{7}\sum_{i=1}^{7} w_{42} * sij * xij + \sum_{j=1}^{7}\sum_{i=1}^{2} w_{32} * sij * yij$$

- Emission: minimize

$$\sum_{i=1}^{7}\sum_{j=1}^{7} xij * Ej * di * w_{42} + \sum_{i=1}^{2}\sum_{j=1}^{7} yij * Ej * di * w_{32}$$

Constraints:

- Budget Constraint:

Objective function of cost <= 3 billion

- Shipping Targets:

$$\sum_{i=1}^{7}\sum_{j=1}^{7} xij \geq 920{,}000 \quad \sum_{i=1}^{2}\sum_{j=1}^{7} yij \geq 530{,}000$$

- Upper and Lower bound:

$$\sum_{j=1}^{7} xij \leq 600{,}000 * ai \quad \forall i = 1, \dots, 7 \qquad \sum_{j=1}^{7} yij \leq 600{,}000 * bi \quad \forall i = 1,2$$

$$\sum_{j=1}^{7} xij \geq 200{,}000 * ai \quad \forall i = 1, \dots, 7 \qquad \sum_{j=1}^{7} yij \geq 200{,}000 * bi \quad \forall i = 1,2$$

- Ship by air:

$$\sum_{i=1}^{7}\sum_{j=1}^{2} xij \ \geq 46{,}000 \quad \sum_{i=1}^{2}\sum_{j=1}^{2} yij \geq 53{,}000$$

- Ship by road:

$$\sum_{i=1}^{7}\sum_{j=3}^{5} xij \ \geq 92{,}000 \quad \sum_{i=1}^{2}\sum_{j=3}^{5} yij \geq 79{,}500$$

- Ship by rail:

$$\sum_{j=1}^{7} x_{i6} \geq 138{,}000 \quad \sum_{j=1}^{7} y_{i6} \geq 79{,}500$$

A.2 Option A result (minimizing cost with 3 billion CNY budget)

Product_ODM	Regular_Air	Air_Express	Road	Road_LTL	Road_Network	Rail	Water
LCD42_ODM1	0	0	0	0	92000	138000	90000
LCD42_ODM2	0	0	0	0	0	0	0
LCD42_ODM3	0	0	0	0	0	0	0
LCD42_ODM4	46000	0	0	0	0	0	554000
LCD42_ODM5	0	0	0	0	0	0	0
LCD42_ODM6	0	0	0	0	0	0	0
LCD42_ODM7	0	0	0	0	0	0	0
LCD32_ODM1	53000	0	0	0	79500	79500	318000
LCD32_ODM2	0	0	0	0	0	0	0

A.3 Option B result (minimizing CO_2 emission with 3 billion CNY budget)

Product_ODM	Regular_Air	Air_Express	Road	Road_LTL	Road_Network	Rail	Water
LCD42_ODM1	0	0	0	0	90306	0	229694
LCD42_ODM2	0	0	0	0	0	0	0
LCD42_ODM3	0	0	0	0	0	0	0
LCD42_ODM4	46000	0	0	0	1694	138000	414306
LCD42_ODM5	0	0	0	0	0	0	0
LCD42_ODM6	0	0	0	0	0	0	0
LCD42_ODM7	0	0	0	0	0	0	0
LCD32_ODM1	53000	0	0	0	79500	79500	318000
LCD32_ODM2	0	0	0	0	0	0	0

A.4 Option C result (minimizing CO_2 emission with 3.3 billion CNY budget)

Product_ODM	Regular_Air	Air_Express	Road	Road_LTL	Road_Network	Rail	Water
LCD42_ODM1	0	0	0	0	0	0	0
LCD42_ODM2	0	0	0	0	0	0	0
LCD42_ODM3	0	0	0	0	0	0	0
LCD42_ODM4	0	0	0	0	0	0	320000
LCD42_ODM5	0	0	0	0	0	0	0
LCD42_ODM6	0	0	0	0	0	0	0
LCD42_ODM7	0	46000	0	92000	0	138000	324000
LCD32_ODM1	0	0	0	0	0	0	0
LCD32_ODM2	0	53000	0	0	79500	79500	318000