SUPPLY CHAIN ANALYTICS ANALYSIS OF DHL SUPPLY CHAIN

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Outline

Case Study: DHL Supply Chain

- Problem Framing
- Input data
- Mathematical model
- Solution & sensitivity analysis

Introduction

- The degradation of the environment has led many governments and customers to pressure businesses to make their operations more environmentally friendly.
- This case illustrates how a small budget increase can drastically reduce carbon dioxide (CO2) emission in the transportation of LCD TVs from their manufacturing bases to the Distribution Center (DC)

Supply Chain Sustainability

 Environmental consciousness and new regulations (especially in EU) constantly pressure companies towards the design and operation of Sustainable & Green Supply Chains











Introduction

- Supply Chain Design Transshipment Problems:
 - Select suppliers and/or manufacturing plants (e.g. original equipment/design manufacturers OEMs/ODMs)
 - Determine production and/or procurement requirements and quantities (e.g. which ODMs will manufacture a product
 - Determine flows and select modes of transportation (e.g. air, road freight, ship freight and rail)

Problem Framing

Production & Shipment of 32" & 42" LCD TV sets



risk related constraints

Different modes of transportation are available (i.e., regular air, air express, road, road LTL, road network, rail or water) with varying shipping costs and CO2 emissions

Problem Framing - Specifications

- □ 1 DC, 2 products, 7 certified ODMs
- Production and shipment of 920,000 units of LCD42" and 530.000 units of LCD32".
- Budget: CNY 3 Billion
- What is the optimal configuration of the supply chain subject to economy of scale, production capacity and availability, supply risk management and service level requirements on the shipping front?

Problem Framing - Constraints

- A minimum production order of 200,000 units (either 32" or 42") to any selected ODM
- The maximum production order on any ODM is capped at 600,000 units (either 32" or 42")
- Minimum shipment orders (in units for 42" & 32") must be considered for different transportation modes to guarantee satisfactory inventory levels:
 - Regular air or express air: 46,000 (42") and 53,000 (32")
 - Road or Road LTL or Road Network: 92,000 (42") and 79,500 (32")
 - Rail: 138,000 (42") and 79,500 (32")

Problem Framing - Parameters

- □ Weight of each product (w_i) in metric tons, i=1,2
- Distance between each ODM and the DC in Kms (d_o), o=1,...,7
- Production cost (p_{oi}) of each ODM o=1,...,7 and for each product i=1,2

Problem Framing - Parameters

Shipment costs (s_{om}) per metric ton of each ODM o=1, ..., 7 for each mode (if available) of transportation m=1,...,7

- CO2 emissions (e_m) in Kg per Ton-Km shipped for each mode m=1,...,7
 - For example, a TV set weighting 20kgs and shipped road over 800Km will emit (20/1000) X 0.0613 X 800 = 0.98Kg of CO2

Problem Framing – Decision Variables

Determine how many units of each TV set will be shipped from each ODM across various modes of transportation (r_{iom}), i=1,2; m=1,...,7 and o=1,...,7
 Continuous non-negative variables

- Which ODMs we will select for each TV set (X_{io}), i=1,2 and o=1,...,7
 - Binary (0-1) variable

Objective Function (CO2 emissions)



32" TV sets

42" TV sets

+ $(w_2d_1e_1)r_{211}$ + $(w_2d_2e_1)r_{221}$ +... + $(w_2d_7e_7)r_{277}$

Budget Restriction:

42" TV sets - all (o,m) combinations

$$(p_{11}+s_{11}w_1)r_{111} + \dots + (p_{17}+s_{77}w_1)r_{177} +$$

32" TV sets - all (o,m) combinations

+ $(p_{21}+s_{11}w_1)r_{211}$ + ... + $(p_{27}+s_{77}w_1)r_{277}$ ≤ 3000000000

Minimum Production Orders: 42" TV sets $r_{111} + ... + r_{117} \ge 200,000 x_{11}$ (ODM 1 all trans modes) $r_{171} + ... + r_{177} \ge 200,000 x_{17}$ (ODM 7 all trans modes) 32" TV sets $r_{211} + ... + r_{217} \ge 200,000 x_{21}$ (ODM 1 all trans modes) ... $r_{271} + ... + r_{277} \ge 200,000 x_{27}$ (ODM 7 all trans modes)

Maximum Production Orders: 42" TV sets $r_{111} + ... + r_{117} \le 600,000 x_{11}$ (ODM 1 all trans modes) $r_{171} + ... + r_{177} \le 600,000 x_{17}$ (ODM 7 all trans modes) 32" TV sets $r_{211} + ... + r_{217} \le 600,000 x_{21}$ (ODM 1 all trans modes) ... $r_{271} + ... + r_{277} \le 600,000 x_{27}$ (ODM 7 all trans modes)

Meeting supply with demand:
<u>42" TV sets</u>

r₁₁₁+...+r₁₁₇ + r₁₂₁+...+r₁₂₇+...+r₁₇₁+...+r₁₇₇ ≥ 920000 (all flows among ODMs and the DC for every transportation mode) 32" TV sets

 $r_{211}+\ldots+r_{217}+r_{221}+\ldots+r_{227}+\ldots+r_{271}+\ldots+r_{277} \ge 530000$ (all flows among ODMs and the DC for every transportation mode)

Supply risk and inventory requirements: Air & Express Air – 42" TV sets $r_{111} + r_{121} + \dots + r_{171} + r_{112} + r_{122} + \dots + r_{172} \ge 46000$ **Express Air** Air Air & Express Air – 32" TV sets $r_{211} + r_{221} + \dots + r_{271} + r_{212} + r_{222} + \dots + r_{272} \ge 53000$ **Express Air** Air



Supply risk and inventory requirements (cont.): Rail -42'' TV sets $r_{116} + r_{126} + \ldots + r_{176} \ge 138000$ Rail Rail -32'' TV sets $r_{216} + r_{226} + \ldots + r_{276} \ge 79500$



Some variable are already fixed to 0:

Not all transportation modes are available
ODM 5:
$$r_{151} = 0$$
; $r_{152} = 0$; $r_{156} = 0$; $r_{157} = 0$;
ODM 6: $r_{163} = 0$; $r_{164} = 0$; $r_{165} = 0$; $r_{166} = 0$;

<u>Only ODM 1 and ODM 2 can produce 32" TV sets</u> x₂₃ =0; x₂₄ =0; x₂₅ =0; x₂₆ =0

How the supply chain can be optimized (minimize CO2 emissions) if a budget of 3 billions is available?

Note: All input data are provided in Excel for students.

	Production + Shipping Cost per Unit										
	Air	Express	Road	Road LTL	Road-Network	Rail	Water				
LCD 42" ODM1	¥3,400.20	¥3,541.88	¥2,119.41	¥2,098.16	¥2,089.66	¥2,076.9 1	¥2,051.41				
LCD 42" ODM2	¥4,804.24	¥5,059.26	¥2,409.85	¥2,381.51	¥2,378.68	¥2,381.51	¥2,313.51				
LCD 42" ODM3	¥4,849.28	¥5,075.97	¥2,738.25	¥2,709.9 1	¥2,707.08	¥2,709.9 1	¥2,654.66				
LCD 42" ODM4	¥3,392.90	¥3,534.58	¥2,112.11	¥2,092.28	¥2,090.86	¥2,069.6 1	¥2,044.11				
LCD 42" ODM5			¥2,923.82	¥2,909.65	¥2,902.57						
LCD 42" ODM6	¥5,680.08	¥5,963.44					¥2,779.89				
LCD 42" ODM7	¥4,392.08	¥4,604.60	¥2,281.05	¥2,252.7 1	¥2,247.04	¥2,254.13	¥2,186.12				
LCD 32" ODM1	¥2,880.60	¥2,986.86	¥1,920.01	¥1,904.07	¥1,897.70	¥1,888.13	¥1,869.00				
LCD 32" ODM2	¥3,909.08	¥4,100.35	¥2,113.29	¥2,092.03	¥2,089.91	¥2,092.03	¥2,041.03				

Note: All input data are provided in the Excel for students.

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LCD 42" ODM3	0		0		0	0	0	0	0
LCD 42" ODM4	1		46000		0	1	1693	138000	414306
LCD 42" ODM5	0				0	0	0		
LCD 42" ODM6	0		0						0
LCD 42" ODM7	0		0) 0	0	0	0	0
LCD 32" ODM1	1		53000) 0	0	79500	79500	318000
LCD 32" ODM2	0		0) 0	0	0	0	0
	ShipmentMode	MinServiceReq				TotalBudget	CurrentBudget	TaxIncentive	BVAppreciation
LCD42" - Air / Express	46000	46000		Total Cost	¥2,999,999,999	¥3,000,000,000	¥3,000,000,000		
LCD42" - Road, Road LTL, Road Network	92000	92000							
LCD42" - Rail	138000	138000		Total Carbon Emission	7,401,248				
LCD32" - Air / Express	53000	53000							
LCD32" - Road, Road LTL, Road Network	79500	79500							
LCD32" - Rail	79500	79500							
	SupplyChainTotal	Units Required							
LCD42"	920000	920,000							
LCD32"	530000	530,000							

How much the CO2 emissions will reduce if the budget increased by 10% to 3.3 billions.

Note: A 10% increase in the supply chain budget is possible by a combination of tax incentives and intangibles such as brand value appreciation engendered by customer goodwill and appreciation.

				Supply Chain					
	Select		Air	Express	Road	Road LTL	Road-Network	Rail	Water
LCD 42" ODM1	0		0	0	0	0	0	0	0
LCD 42" ODM2	0		0	0	0	0	0	0	0
LCD 42" ODM3	0		0	0	0	0	0	0	0
LCD 42" ODM4	1		0	0	0	0	0	0	320000
LCD 42" ODM5	0				0	0	0		
LCD 42" ODM6	0		0	0					0
LCD 42" ODM7	1		0	46000	92000	0	0	138000	324000
LCD 32" ODM1	0		0	0	0	0	0	0	0
LCD 32" ODM2	1		0	53000	79500	0	0	79500	318000
	ShipmentMode	MinServiceReq				TotalBudget	CurrentBudget	TaxIncentive	BVAppreciation
LCD42" - Air / Express	46000	46000		Total Cost	¥3,295,844,166	¥3,300,000,000	¥3,300,000,000		
LCD42" - Road, Road LTL, Road Network	92000	92000							
LCD42" - Rail	138000	138000		Total Carbon Emission	3,479,982				
LCD32" - Air / Express	53000	53000							
LCD32" - Road, Road LTL, Road Network	79500	79500							
LCD32" - Rail	79500	79500							
	SupplyChainTotal	Units Required							
LCD42"	920000	920,000							
LCD32"	530000	530,000							

What do we observe if we repeat this process for other possible percentage increases of the budget.

Sensitivity Analysis for different Scenarios:

%Budget Increase	0%	2%	30%	10%	6%	8%	10%	1.2%	1 4%	1.6%	18%
/0Douger increuse	070	∠ /0	J /0	4/0	070	0 /0	1070	1 Z /0	14/0	1070	10/0
CO2 Emission Kg	7401248	5513042	4907392	4542373	3572592	3502043	3479982	3416983	3373499	3346068	3330518
%Reduction	0%	26%	34%	39%	52%	53%	53%	54%	54%	55%	55%



The sensitivity analysis indicates that the bulk of the reduction in CO2 emission already occurs when the budget increases by 6%.

- Summary Key points:
 - A 2% increase in the budget reduces CO2 emission by about 26%.
 - DHL's "Go Green" target of 30% reduction in CO2 emission is achievable with an increase of about 3% in the budget.
 - At about a 6% increase in the budget, the reduction in CO2 emission tails off at about 52%.
- The above findings are highly encouraging for sustainability in the supply chain and for environmental conservation.