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 (CO_2) emission in the transportation of LCD TVs from their manufacturing bases to the Distribution Center (DC)

Supply Chain Sustainability

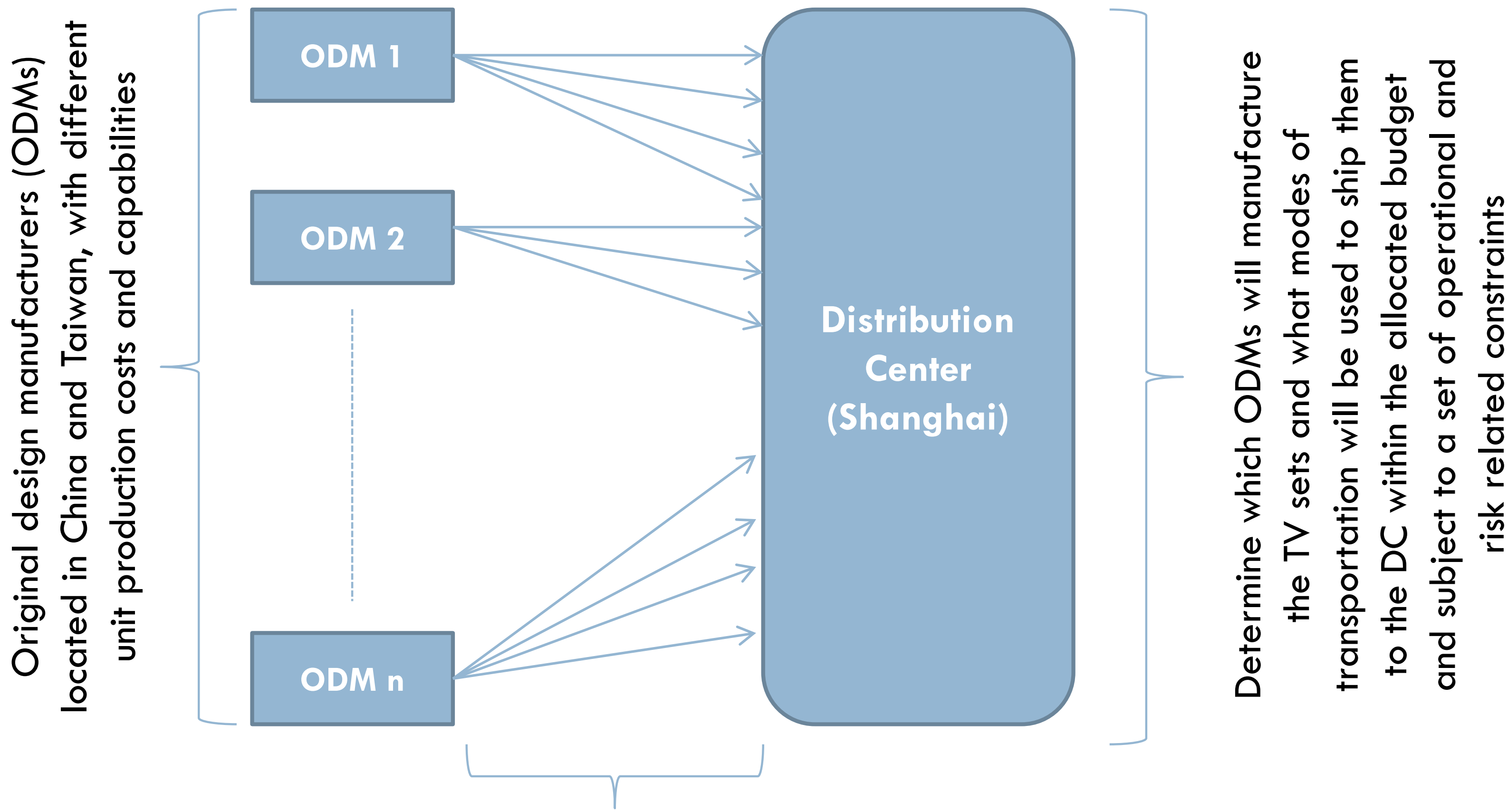
- Environmental consciousness and new regulations (especially in EU) constantly pressure companies towards the design and operation of Sustainable & Green Supply Chains

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



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), $o=1,\ldots,7$
- Production cost (p_{oi}) of each ODM $o=1,\ldots,7$ 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

- CO_2 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 CO_2

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

Mathematical Model

- Objective Function (CO2 emissions)

$$\min Z = \overbrace{(w_1 d_1 e_1) r_{111} + (w_1 d_2 e_1) r_{121} + \ldots + (w_1 d_7 e_7) r_{177}}^{\textbf{42” TV sets}} +$$

$$+ \overbrace{(w_2 d_1 e_1) r_{211} + (w_2 d_2 e_1) r_{221} + \ldots + (w_2 d_7 e_7) r_{277}}^{\textbf{32” TV sets}}$$

Mathematical Model

- Budget Restriction:

$$\overbrace{(p_{11}+s_{11}w_1)r_{111} + \ldots + (p_{17}+s_{77}w_1)r_{177}}^{\textbf{42'' TV sets - all (o,m) combinations}} +$$

$$+ \overbrace{(p_{21}+s_{11}w_1)r_{211} + \ldots + (p_{27}+s_{77}w_1)r_{277}}^{\textbf{32'' TV sets - all (o,m) combinations}}$$

$$\leq 3000000000$$

Mathematical Model

- Minimum Production Orders:

42″ TV sets

$r_{111}+\ldots+r_{117} \geq 200{,}000x_{11}$ (ODM 1 all trans modes)

…

$r_{171}+\ldots+r_{177} \geq 200{,}000x_{17}$ (ODM 7 all trans modes)

32″ TV sets

$r_{211}+\ldots+r_{217} \geq 200{,}000x_{21}$ (ODM 1 all trans modes)

…

$r_{271}+\ldots+r_{277} \geq 200{,}000x_{27}$ (ODM 7 all trans modes)

Mathematical Model

- Maximum Production Orders:

<u>42" TV sets</u>

$r_{111}+\ldots+r_{117} \leq 600{,}000x_{11}$ (ODM 1 all trans modes)

...

$r_{171}+\ldots+r_{177} \leq 600{,}000x_{17}$ (ODM 7 all trans modes)

<u>32" TV sets</u>

$r_{211}+\ldots+r_{217} \leq 600{,}000x_{21}$ (ODM 1 all trans modes)

...

$r_{271}+\ldots+r_{277} \leq 600{,}000x_{27}$ (ODM 7 all trans modes)

Mathematical Model

- Meeting supply with demand:

<u>42″ TV sets</u>

$r_{111}+\ldots+r_{117} + r_{121}+\ldots+r_{127}+\ldots+r_{171}+\ldots+r_{177} \geq$ 920000 (all flows among ODMs and the DC for every transportation mode)

<u>32″ TV sets</u>

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

Mathematical Model

- Supply risk and inventory requirements:

Air & Express Air – 42" TV sets

$$\underbrace{r_{111} + r_{121} + \ldots + r_{171}}_{\text{Air}} + \underbrace{r_{112} + r_{122} + \ldots + r_{172}}_{\text{Express Air}} \geq 46000$$

Air & Express Air – 32" TV sets

$$\underbrace{r_{211} + r_{221} + \ldots + r_{271}}_{\text{Air}} + \underbrace{r_{212} + r_{222} + \ldots + r_{272}}_{\text{Express Air}} \geq 53000$$

Mathematical Model

- Supply risk and inventory requirements (cont.):

Road, Road LTL & Road Network – 42" TV sets

$$\underbrace{r_{113}+\ldots+r_{173}}_{\textbf{Road}}+\underbrace{r_{114}+\ldots+r_{174}}_{\textbf{Road LTL}}+\underbrace{r_{115}+\ldots+r_{175}}_{\textbf{Road Network}} \geq 92000$$

Road, Road LTL & Road Network – 32" TV sets

$$\underbrace{r_{213}+\ldots+r_{273}}_{\textbf{Road}}+\underbrace{r_{214}+\ldots+r_{274}}_{\textbf{Road LTL}}+\underbrace{r_{215}+\ldots+r_{275}}_{\textbf{Road Network}} \geq 79500$$

Mathematical Model

- Supply risk and inventory requirements (cont.):

<u>Rail – 42" TV sets</u>

$$\underbrace{r_{116} + r_{126} + \ldots + r_{176}}_{\textbf{Rail}} \geq 138000$$

<u>Rail – 32" TV sets</u>

$$\underbrace{r_{216} + r_{226} + \ldots + r_{276}}_{\textbf{Rail}} \geq 79500$$

Mathematical Model

- Some variable are already fixed to 0:

<u>Not all transportation modes are available</u>

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>

$x_{23} = 0$; $x_{24} = 0$; $x_{25} = 0$; $x_{26} = 0$

Solution & Sensitivity Analysis

- How the supply chain can be optimized (minimize CO_2 emissions) if a budget of 3 billions is available?

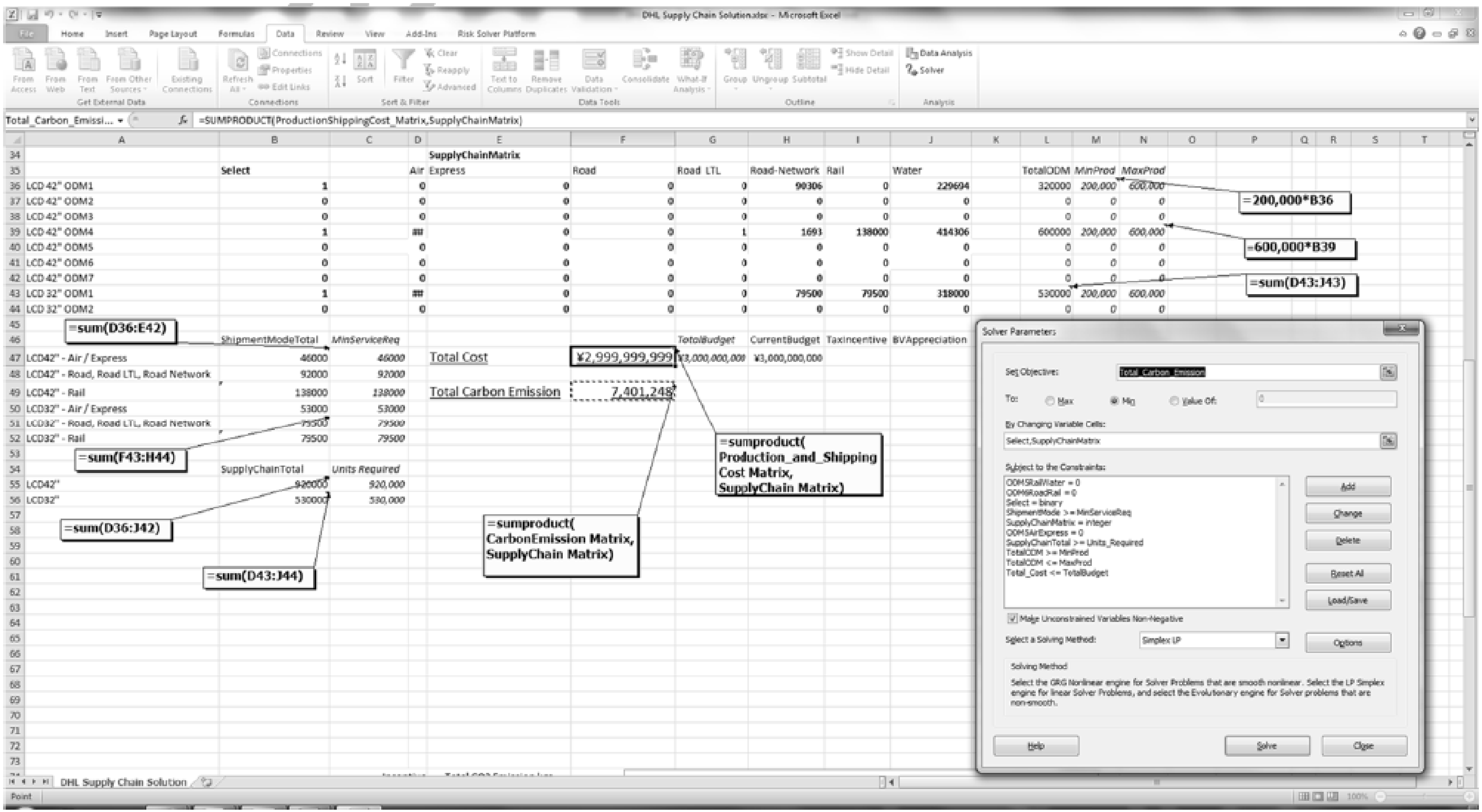
Note: All input data are provided in Excel for students.

Solution & Sensitivity Analysis

	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	¥2,076.91	¥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	¥2,709.91	¥2,707.08	¥2,709.91	¥2,654.66
LCD 42" ODM4	¥3,392.90	¥3,534.58	¥2,112.11	¥2,092.28	¥2,090.86	¥2,069.61	¥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	¥2,252.71	¥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.

Solution & Sensitivity Analysis



Solution & Sensitivity Analysis

				Supply Chain					
	Select		Air	Express	Road	Road LTL	Road-Network	Rail	Water
LCD 42" ODM1	1		0	0	0	0	90306	0	229694
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		46000	0	0	1	1693	138000	414306
LCD 42" ODM5	0				0	0	0		
LCD 42" ODM6	0		0	0					0
LCD 42" ODM7	0		0	0	0	0	0	0	0
LCD 32" ODM1	1		53000	0	0	0	79500	79500	318000
LCD 32" ODM2	0		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*							

Solution & Sensitivity Analysis

- How much the CO_2 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.

Solution & Sensitivity Analysis

				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*							

Solution & Sensitivity Analysis

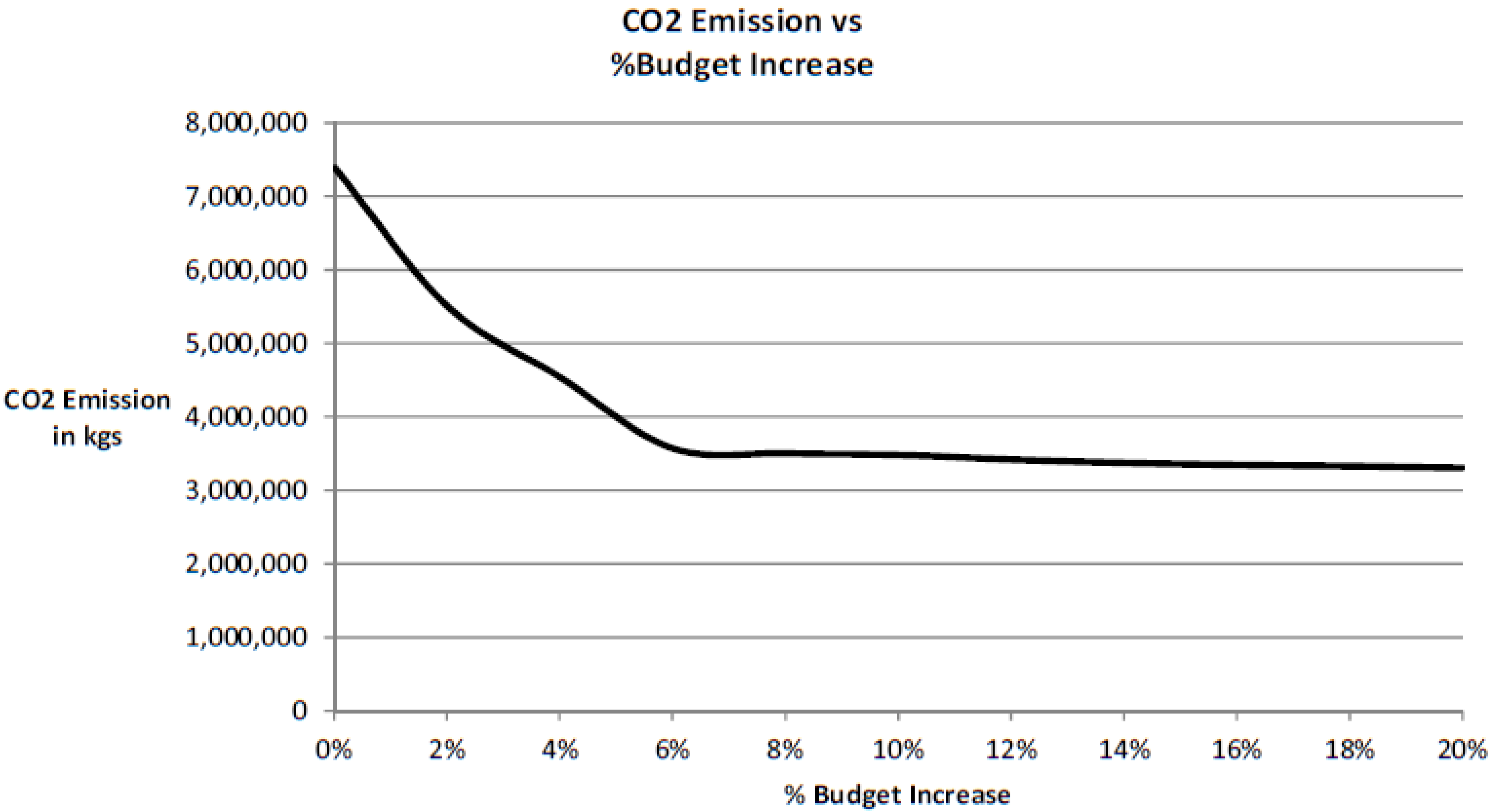
- What do we observe if we repeat this process for other possible percentage increases of the budget.

Solution & Sensitivity Analysis

- Sensitivity Analysis for different Scenarios:

%Budget Increase	0%	2%	3%	4%	6%	8%	10%	12%	14%	16%	18%
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%

Solution & Sensitivity Analysis



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

Solution & Sensitivity Analysis

- Summary - Key points:
  - A 2% increase in the budget reduces CO_2 emission by about 26%.
  - DHL's "Go Green" target of 30% reduction in CO_2 emission is achievable with an increase of about 3% in the budget.
  - At about a 6% increase in the budget, the reduction in CO_2 emission tails off at about 52%.
- The above findings are highly encouraging for sustainability in the supply chain and for environmental conservation.