Executive Summary

The DHL supply chain is the thought leader on sustainability in the industry, as it was the first logistics company to set a quantified carbon efficiency goal: 30% off of its carbon dioxide emissions across global operations compared to its 2007 baseline. We, the DHL Solutions Team have come up with an optimization that can help the DHL supply chain reach this lofty goal. We ran a simulation exercise for a consumer electronic company, with the goal to see how much carbon dioxide emissions we can cut with a 10% increase in budget; we are anticipating a tax incentive from the government in the form of 10%. With this increased budget, we drastically reduced emissions and also reduced costs at the same time so these funds could be allocated elsewhere in the supply chain. At the same time, the brand value for the supply chain will increase because of DHL supply chain's leadership role in reducing emissions in the logistics industry. While this one operation does not represent the entire company, this simulation can be used as a blueprint for other operations in the supply chain to reduce total carbon dioxide emissions.

Background/ Introduction

DHL supply chain has been asked to subcontract and ship 32" and 42" LCD TV sets (LCD32" and LCD42") to a distribution center in Shanghai. The production of the LCD TV sets may be subcontracted to seven original design manufacturers (ODMs) based in both China and Taiwan. The consumer electronic company has allocated a budget of CNY 3 Billion to produce and ship 920,000 LCD42" and 530,000 LCD32". Of the seven ODMs that DHL may subcontract to, only two of which can produce both LCD32" and LCD42" (ODM 1 and ODM 2). The rest are only capable of producing the LCD42". Table 1 illustrates the TV unit production cost in CNY from the different ODMs as well as the distance from ODMs to the distribution center:

Orders given to any ODM must be more than 200,000 units. There is also a maximum order of 600,000 units for both the 32" and the 42" LCD TVs.

There are seven modes of transportation that can be used to ship the TVs from the ODMs to the Distribution Center: regular air, air express, road, road LTL (less than truckload), road network, rail, and water. The various shipping rates for each mode of transportation from each ODM for all products is listed in Table 1. ODM 5 is located near the distribution center which results in its modes of transportation being restricted to road, road LTL, and road network. ODM 6 is located in Taiwan which restricts their modes of shipping to air or water. The rate of carbon emissions varies amongst all modes of transportation. The following table (Table 2) displays the carbon emissions across all modes of transportation in kg per ton shipped per kilometer travelled.

CO2 Emission in Kg per Ton-Km shipped'	Regular Air	Air Express	Road	Road LTL	Road-Network	Rail	Water
	1.44	1.44	0.0613	0.0613	0.0613	0.0285	0.007

In order to keep sufficient inventory the electronics company has asked DHL to ship a minimum number of both 32” and 42” TVs through different modes of transportations. There must be at least 46,000 42” TVs and 53,000 32” TVs shipped via Air. There should be 92,000 42” TVs and 79,500 32” TVs shipped via Road. Lastly, there should be atleast 138,000 42” TVs and 79,500 32” TVs shipped via Rail. There was no minimum on shipments via water.

The DHL solutions team has worked out an optimal solution that fulfills all requirements. We feel confident that the government will be making efforts to reduce CO2 emissions through the use of tax incentive and anticipate that brand value will increase from customer awareness which could equate to a 10% increase in budget (totalling CNY 3.3 billion). Curious to discover how much carbon emissions can be reduced, we have gone taken it upon ourselves to find an optimal solution where this potential increase in budget is implemented.

Methodology

To run the simulation, we used Microsoft Excel with the Solver add-in to analyze the problem with linear programming. There are two parts to the problem: (1) optimize the supply chain with a budget of CNY 3 billion, and (2) optimize the supply chain with an increased budget of 10%

while minimizing CO2 emissions. We used linear programming to solve this problem because linear programming is an efficient method to optimize solutions for business research given the problem's constraints.

Initial Optimization

We used Microsoft Excel solver to find out which original design manufacturers (ODM) to order from and how many units of LCD TV sets to order from each ODM.

We used a total of 72 decision variables (DVs) (Appendix 1):

- 63 DVs representing each unique combination of the 7 transportation methods against the 7 ODMs capable of producing LCD42" and 2 ODMs capable of producing LCD32"
- 9 DVs representing decision to order from a specific ODM

The objective function for this optimization was to minimize the sum of production costs and transportation costs for each of the 63 decision variables that represent a ODM and transportation method combination.

In addition to the supply chain production and shipping constraints (Table 3), the problem had the following constraints:

- Total cost for production and shipping of all LCD42" and LCD32" units must be below the budget of CNY 3 billion
- The demand for both LCD42" and LCD32", 920,000 and 530,000 respectively, must be met
- For each ODM that we decide to order from, there is a minimum order of 200,000 units and a maximum order of 600,000 units

Table 3

Supply Chain Production and Shipping Constraints	
Minimum production of LCD42" (ditto for LCD32") at any manufacturing ODM	200,000 units
Maximum production of LCD42" at manufacturing OEM (ditto for LCD32") at manufacturing ODM	600,000 units
Minimum number of units of LCD42" (LCD32") to be shipped by Regular Air or Air Express	46,000 (53,000)
Minimum number of units of LCD42" (LCD32") to be shipped by Road or Road LTL or Road Network	92,000 (79,500)
Minimum number of units of LCD42" (LCD32") to be shipped by Rail	138,000 (79,500)

Proposed Optimization

For the proposed optimization of minimizing CO2 emissions, we had to make 3 changes to find a proper feasible solution:

1. CO2 emissions had to be considered for each unit shipped from a specific ODM to the distribution center
2. The budget constraint for production and shipping increased to CNY 3.3 billion,
3. An integer constraint on the decision variables was required to ensure that we are not shipping fractional units

The decision variables from the initial optimization do not change because we still need to know the total number of units shipped through each transportation method from each ODM

To minimize total CO2 emissions, we first had to calculate the emissions per single unit for both LCD42" and LCD32". We found this by multiplying the distance in kilometers from the specific ODM to the distribution center, by the CO2 emissions in kilogram per ton shipped per kilogram, and then multiplied that by the weight of each unit per metric ton (see appendix x). The total value of the CO2 emissions was found by finding the sum product of all the CO2 emissions per unit value for each shipping method to the corresponding 63 decision variables.

Analysis and Findings

Initial Budget without CO2 Emissions Consideration

After running the optimization with the initial budget of CY 3 billion without CO2 emissions being considered, we were able to determine which ODM to order from and how many units we should order from each one.

Feasible Solution	Constraints (if applicable)

LCD42” 320,000 units - ODM1 600,000 units - ODM4 920,000 units	LCD42” 920,000 units ✔
LCD32” 530,000 units - ODM1	LCD32” 530,000 units ✔
320,000 units LCD42” 530,000 units LCD32” - ODM1 600,000 units LCD42” - ODM4	Minimum Order 200,000 units per product per ODM ✔ Maximum Order 200,000 units per product per ODM ✔
LCD42” 46,000 units shipped by Regular Air LCD32” 53,000 units shipped by Regular Air	Minimum number of units shipped by Regular Air or Air Express LCD42” 46,000 units ✔ LCD32” 53,000 units ✔
LCD42” 92,000 units shipped by Road Network LCD32” 79,500 units shipped by Road Network	Minimum number of units shipped by Road or Road LTL or Road Network LCD42” 92,000 units ✔ LCD32” 79,500 units ✔
LCD42”	Minimum number of units shipped by Rail

138,000 units shipped by Rail LCD32” 79,500 units shipped by Rail	LCD42” 138,000 units ✔ LCD32” 79,500 units ✔
LCD42” 644,000 units shipped by Water LCD32” 318,000 units shipped by Water	No constraint

Budget	CNY 3,000,000,000
Total Cost	CNY 2,999,985,597.10
Over/Under	CNY 14,402.90
Total CO2 Emissions	7,425,340.87 kg.

Proposed Budget with CO2 Emissions Consideration

The second optimization was done with the proposed budget of CY 3.3 billion. The purpose of the new plan was to reduce CO2 emissions as much as possible given the new budget.

Feasible Solution	Constraints (if applicable)
LCD42” 200,000 units - ODM1	LCD42”

200,000 units - ODM4 520,000 units - ODM7 920,000 units	 920,000 units ✔
LCD32” 530,000 units - ODM2	LCD32” 530,000 units ✔
200,000 units LCD42” - ODM1 200,000 units LCD42” - ODM4 520,000 units LCD42” - ODM1 530,000 units LCD32” - ODM2	Minimum Order 200,000 units per product per ODM ✔ Maximum Order 200,000 units per product per ODM ✔
LCD42” 46,000 units shipped by Regular Air LCD32” 53,000 units shipped by Regular Air	Minimum number of units shipped by Regular Air or Air Express LCD42” 46,000 units ✔ LCD32” 53,000 units ✔
LCD42” 92,000 units shipped by Road LCD32” 79,500 units shipped by Road	Minimum number of units shipped by Road or Road LTL or Road Network LCD42” 92,000 units ✔ LCD32” 79,500 units ✔
LCD42” 138,000 units shipped by Rail	Minimum number of units shipped by Rail LCD42”

LCD32” 79,500 units shipped by Rail	138,000 units ✔ LCD32” 79,500 units ✔
LCD42” 644,000 units shipped by Water LCD32” 318,000 units shipped by Water	No constraint

Budget	CNY 3,300,000,000
Total Cost	CNY 3,266,029,761.60
Over/Under	CNY 33,970,238.40
Total CO2 Emissions	3,509,045.14 kg.

Conclusion

Based on our findings, it is in this specific consumer electronic company’s best interest to allocate more funding to the production and shipping budget. An increased budget will allow the company to ship more units using slower transportation methods with lower CO2 emissions. CO2 emissions of this specific consumer electronic company can be drastically cut by 52% with a 10% increase in budget. A 10% budget increase is easily justified through increased company brand value and awareness, as well as receiving tax incentives from government imposed CO2 emission reduction mandates. This plan will also cement Deutsche Post LLC as a thought leader on sustainability in the logistics industry. This type of analysis could be applied to Deutsche Post

LLC's global operations and could help them reach their goal of improving CO2 efficiency by 30%.

Appendices

Appendix 1: Data Sheet

Product	Weight in Metric Ton	Units to be shipped
LCD42"	0.022	920,000
LCD32"	0.0165	530,000

Table 1: This table shows the weight for each product and the demand for each product.

CO2 Emission in Kg per Ton-Km shipped[1]	Regular Air	Air Express	Road	Road LTL	Road-Network	Rail	Water
	1.44	1.44	0.0613	0.0613	0.0613	0.0285	0.007

Table 2: This table shows the CO2 emission for each Kg per Ton-Km shipped for each method of transportation.

			Shipping Cost per Metric Ton CNY						
Product - ODM	Distance to DC in Kms	TV Unit Production Cost CNY	Regular Air	Air Express	Road	Road LTL	Road-Network	Rail	Water
LCD42" ODM1	2508	1,983.40	64,400	70,840	6,182.40	5,216.40	4,830.00	4,250.40	3,091.20
LCD42" ODM2	1553	2,254.00	115,920	127,512	7,084.00	5,796.00	5,667.20	5,7960	2,704.80
LCD42" ODM3	1380	2,582.40	103,040	113,344	7,084.00	5,796.00	5,667.20	5,7960	3,284.40
LCD42" ODM4	2150	1,976.10	64,400	70,840	6,182.40	5,280.80	5,216.40	4,250.40	3,091.20
LCD42" ODM5	30	2,711.30	X	X	9,660.00	9,016.00	8,694.00	X	X
LCD42" ODM6	690	2,704.80	135,240	148,120	X	X	X	X	3,413.20
LCD42" ODM7	686	2,125.20	103,040	112,700	7,084	5,796	5,538.40	5,860.40	2,769.20
LCD32" ODM1	2508	1,818.00	64,400	70,840	6,182.40	5,216.40	4,830	4,250.40	3,091.20
LCD32" ODM2	1553	1,996.40	115,920	127,512	7,084	5,796	5,667.20	5,796	2,704.80

Table 3: This chart specifies the distances, production costs, and transportation costs for each specified decision variable.

Supply Chain Production and Shipping Constraints	
Minimum production of LCD42" (ditto for LCD32") at any manufacturing ODM	200,000 units
Maximum production of LCD42" at manufacturing OEM (ditto for LCD32") at manufacturing ODM	600,000 units
Minimum number of units of LCD42" (LCD32") to be shipped by Regular Air or Air Express	46,000 (53,000)
Minimum number of units of LCD42" (LCD32") to be shipped by Road or Road LTL or Road Network	92,000 (79,500)
Minimum number of units of LCD42" (LCD32") to be shipped by Rail	138,000 (79,500)

Table 4: This chart shows the constraints that were laid out in the problem and also transferred onto the Microsoft Excel spreadsheet.

Appendix 2: Excel Solver for Initial Optimization

		Ship Methods							
DV's		Reg Air	Air Express	Road	Road LTL	Road Network	Rail	Water	(1 = Open)
Manufacturers	ODM1 42	-	-	-	-	92,000	138,000	90,000	1
	ODM2 42	-	-	-	-	-	-	0	0
	ODM3	-	-	-	-	-	-	-	0
	ODM4	46,000	-	-	-	-	-	554,000	1
	ODM5	-	-	-	-	-	-	-	0
	ODM6	-	-	-	-	-	-	-	0
	ODM7	-	-	-	-	-	-	-	0
	ODM1 32	53,000	-	-	-	79,500	79,500	318,000	1
	ODM2 32	-	-	-	-	-	-	-	0

Table 1: Decision Variables; the last far right row indicates binary variables.

Objective Function:

Minimize ∑ of (unit production cost i * Xij + unit weight in metric tons * ship cost ij * Xij)

- where unit weight in metric tons: 0.022 for 42", 0.0165 for 32"

Constraints used:

Kh*Yi – ∑ Xij >= 0 Kh = max capacity, i = Each ODM, j = shipping method

Kl*Yi – ∑ Xij <= 0 Kl = min capacity, Xij = units produced at ODM i shipped using method j

∑ of all DVs for 42" >= 920,000

∑ of all DV's for 32" >= 530,000

Objective function <= 3 billion

∑ of DV's for Rail for 42" >= 138,000

∑ of DV's for Rail for 32" >= 79,500

∑ of DV's for Reg Air and Air Express for 42" >= 46,000

∑ of DV's for Reg Air and Air Express for 32" >= 53,000

∑ of DV's for Road, Road LTL, and Road Network for 42" >= 92,000

∑ of DV's for Road, Road LTL, and Road Network for 32" >= 79,500

(binary DV's are excluded from all å of DV's)

Appendix 3: Excel Solver for Proposed Budget

		Ship Methods							
DV's		Reg Air	Air Express	Road	Road LTL	Road Network	Rail	Water	(1 = Open)
Manufacturers	ODM1 42	-	-	-	-	-	-	200,000	1
	ODM2 42	-	-	-	-	-	-	-	0
	ODM3	-	-	-	-	-	-	-	0
	ODM4	-	-	-	-	-	-	200,000	1
	ODM5	-	-	-	-	-	-	-	0
	ODM6	-	-	-	-	-	-	-	0
	ODM7	46,000	-	92,000	-	-	138,000	244,000	1
	ODM1 32	-	-	-	-	-	-	-	0
	ODM2 32	53,000	-	79,500	-	-	79,500	318,000	1

Table 1: Decision variables; the last far right row indicates binary variables.

Objective Function:

∑ (distance i * emission j * unit weight in metric tons)

- Distance is in km, emissions are in kg per ton-km shipped

Constraints:

All of the constraints from the previous solver are in place again with the exception of two new constraints:

All the non binary decision variables are set to integer, so there wouldn't be fractional units.

∑ of (unit production cost i * Xij + unit weight in metric tons * ship cost ij * Xij) <= 3.3 billion

Appendix 4: Carbon dioxide emissions

	CO2 Emissio	1.44	1.44	0.0613	0.0613	0.0613	0.0285	0.007
Km to DC	Total CO2/U	Reg Air	Air Express	Road	Road LTL	Road Netwo	Rail	Water
2508	ODM1 42	79.453	79.453	3.382	3.382	3.382	1.573	0.386
1553	ODM2 42	49.199	49.199	2.094	2.094	2.094	0.974	0.239
1380	ODM3	43.718	43.718	1.861	1.861	1.861	0.865	0.213
2150	ODM4	68.112	68.112	2.899	2.899	2.899	1.348	0.331
30	ODM5	80.000	80.000	0.040	0.040	0.040	80.000	80.000
690	ODM6	21.859	21.859	80.000	80.000	80.000	80.000	0.106
686	ODM7	21.732	21.732	0.925	0.925	0.925	0.430	0.106
2508	ODM1 32	59.590	59.590	2.537	2.537	2.537	1.179	0.290
1553	ODM2 32	36.899	36.899	1.571	1.571	1.571	0.730	0.179
		-	-	-	-	92,000	138,000	90,000
		-	-	-	-	-	-	0
		-	-	-	-	-	-	-
		46,000	-	-	-	-	-	554,000
		-	-	-	-	-	-	-
		-	-	-	-	-	-	-
		-	-	-	-	-	-	-
		53,000	-	-	-	79,500	79,500	318,000
		-	-	-	-	-	-	-
		CO2 for initi	7,425,340.87					

Table 1: This table shows the total carbon dioxide emissions for the initial optimization

	CO2 Emissio	1.44	1.44	0.0613	0.0613	0.0613	0.0285	0.007
Km to DC	Total CO2/U	Reg Air	Air Express	Road	Road LTL	Road Netwo	Rail	Water
2508	ODM1 42	79.453	79.453	3.382	3.382	3.382	1.573	0.386
1553	ODM2 42	49.199	49.199	2.094	2.094	2.094	0.974	0.239
1380	ODM3	43.718	43.718	1.861	1.861	1.861	0.865	0.213
2150	ODM4	68.112	68.112	2.899	2.899	2.899	1.348	0.331
30	ODM5	80.000	80.000	0.040	0.040	0.040	80.000	80.000
690	ODM6	21.859	21.859	80.000	80.000	80.000	80.000	0.106
686	ODM7	21.732	21.732	0.925	0.925	0.925	0.430	0.106
2508	ODM1 32	59.590	59.590	2.537	2.537	2.537	1.179	0.290
1553	ODM2 32	36.899	36.899	1.571	1.571	1.571	0.730	0.179
		-	-	-	-	-	-	200,000
		-	-	-	-	-	-	-
		-	-	-	-	-	-	-
		-	-	-	-	-	-	200,000
		-	-	-	-	-	-	-
		-	-	-	-	-	-	-
		46,000	-	92,000	-	-	138,000	244,000
		-	-	-	-	-	-	-
		53,000	-	79,500	-	-	79,500	318,000
		OF: Minimiz	3,509,045.140					

Table 2: This table shows the carbon dioxide for the proposed optimization. The top table represents: distance i * emission j * unit weight in metric tons. For the values where it says 80, these are dummy values because there actually is no optim for this transportation method from that specific ODM. The number 80 was selected because that would be the most expensive option and solver would disregard that because this was a minimization problem.