Art of Modelling Quiz 3 General Motors: Meeting State Ventilator Demands

Team 12

Executive Summary:

The purpose of this report is to provide a framework for crafting a distribution strategy for GM's Ventilator Project.

Allocation:

The first fundamental step in crafting a distribution strategy is to figure out the best way to allocate our ventilators. Based on our understanding of our factories' capacity, we can find the optimal solution that achieves our goals of meeting the demand of the most needy states while maximizing the proportion of other states' that receive ventilators. After satisfying the demand of the most needy states, we can cover almost 35% of every other state's ventilator demand, with an assumption that we can manufacture 13,300 (full capacity utilization) ventilators. It is important to note this assumption has limitations, as Phil has said he believes the factories will only reach 90% utilization (11970 ventilators) or will only be able to produce close to 10,000. As a result, the actual proportion of state's demand that will be covered when this plan is put into action will be lower. However, we felt it beneficial to perform our analysis with the 13,300 assumption, as we want to ensure we have a distribution plan in case we are able to reach 100% capacity utilization, or that GM's ventilator manufacturing process is more efficient than originally projected.

Costs and Pricing:

The second step of this distribution strategy is to figure out which factories should send supplies to which states in a way that minimizes overall transportation costs. Interestingly, the transportation costs are quite low overall, given the small volume of ventilators. When we found the optimal routes of distribution, transportation costs were only around $135,000 and the final generic price for all plants was almost $3280. As a result, if transportation costs remain low, they should be considered less important than other constraints like satisfying state demand. This is especially true if our products are still cheaper for hospitals. For example, hospital ventilators cost around $25,000-$50,000. If we were to send only 1 ventilator to a faraway state like Alaska, and make the hospital cover the whole cost of transport, the ventilator would have a price around $15,000, still 66.7% cheaper than the traditional hospital ventilator---and a small cost to save a life.

Conclusion:

If these two strategies are combined---maximizing the proportion of state's demand met while minimizing transportation costs---Project Ventilator will be able to not only save lives, but also save hospitals' money on ventilators.

Description of Modelling Approach

To meet the goals of GM's management, namely craft a distribution strategy and minimize costs, we have built two models. The first optimizes the proportion of ventilator demand per state, while the second minimizes the total cost of transportation. The model also allows GM to set a generic price with a 5% mark up to cover any unforeseen expenses.

Analysis – Model 1: Finding the Biggest Proportion

The first model determines the proportion of required demand that GM can satisfy with its four plants. First, the demand for the four states with factories - which are also the most needy - is met, and then the rest of the supply is distributed to the rest of the states proportionately. A solver model has been developed to maximize proportion. The decision variables were the demand proportion and all the cells in the allocation matrix (Exhibit 1) except for the rows for the four States with factories (since the allocation of the supply of ventilators for the four states is fixed). The primary constraints which were considered were the production capacities of the four GM plants at 100% capacity. Consequently, our allocation model relies on the assumption that the four factories will produce up to 13,300 ventilators. This level of production likely won't happen, but it is still most beneficial for GM to understand what it would look like if they are able to produce to this level. The optimized proportion determined by the solver was 34.9%. This means every state except for the four main states were supplied with at least 34.9% of their ventilator demand. Importantly, this proportion level decreases as production level decreases.

Analysis – Model 2: Finding the Cheapest Plan

Using the allocations derived from the first model, the cheapest course of action was determined by calculating the transportation, labor, and production costs of ventilators. Again, we ran a solver to minimize our distribution cost by changing cells in the allocation matrix (Exhibit 1) and production level in each plant. For each state, the manufacturing plant which had the lowest transportation cost per delivery and had excess supply was selected to meet their demand. Through this approach we were able to minimize transportation costs to $134,820, have labor costs of $14,816,000, and production costs of $26,574,814, for a total cost per ventilator of $3,281 including the 5% mark-up for unforeseen expenditures (Exhibit 2) which is our final generic price. In addition, we also calculated a final generic ventilator price such that the minimum cost of the most expensive plant, California, was covered by the set ventilator price (Exhibit 3). Under this model, we had a slightly higher ventilator price of $3,429 including the 5% mark-up and this price enabled our company to keep each plant manager satisfied as none of them would be doing worse than breaking even. Regardless of the pricing strategy chosen, $3,281 for General Motors' ventilator price, or $3,429 for covering the cost of the most expensive plant for General Motors, the hospital centers were getting ventilators at a steep discount compared to retail pricing. We could use the exact same models for the best and worst scenarios, but we have not included them here to save space.

Recommendations and Insight

The recommended allocation matrix for four States has been projected in Exhibit 1. General Motor is able to satisfy 34.99% of the ventilator demand in each state outside the four factory states (Michigan, Texas, California, New York) where demand is satisfied completely. The total transportation cost regarding this distribution strategy is $134,869.75.

Regarding this model, we recommend General Motors to set the price of ventilators at $3,281 per unit in general (Exhibit 2) or $3,429 per unit if GM wanted to at least meet the breakeven point for the most expensive factory - California (Exhibit 3). Yet, we discovered that the transportation cost was not the influencing factor, as it accounts for the lowest proportion (0.3%) of the ventilators total cost. This aligns with General Motor's distribution strategy of the Ventilator Project; instead of mitigating the transportation cost by meeting only the highest demand states while neglecting the lower projected demand states, it attempts to distribute to every state as the goal of this project isn't for profit, and GM even wants to invest any additional profit back into The Ventilator Project.

Strengths and Weaknesses of Model

A strength of this model is that it maximizes the supply of ventilators in each of our home production states. The demand in Michigan, Texas, and California is completely met by their home production plants, and New York is the only state where all their demand is not completely serviced by GM's home state plant. This means that we can minimize the cost of transportation by taking advantage of the government subsidy. In addition, another strength is that every state gets serviced in some capacity as GM is able to provide ventilators to meet at least 34.9% of a state's demand. Plus, by minimizing distribution costs, the price offered to the medical centers is kept minimal, which will help reduce the financial burden of expensive ventilators for the centers.

A weakness we can observe with this model is that we do not necessarily prioritize the states which have the highest need for ventilators. Since the company is trying to serve as many states as possible with the goal of achieving the highest proportion of ventilators in each state, all the states which do not have production within the state itself are treated as if they are on an equal plane. As a result, states like New Jersey which have an extremely high demand for ventilators still achieve the same proportion of ventilators given to them at 34.9% similar to a state with a lower need for ventilators such as Wyoming. As a result, some states will be left bereft of adequate ventilators. This situation can be remedied by other manufacturing companies across the nation stepping up like General Motors has done to provide ventilators at a low cost to needier states.

Another limitation is that our allocation model relies on the assumption that we will reach 13,300 units of production. If we are only able to produce the more moderate 10,000 level Phil described, or the 90% capacity level of 11,970, the proportion of states' demand satisfied will decrease. At the same time, it is possible that the factories are unable to even produce 10,000 units as they are shifting a car manufacturing plant into a ventilator one. In turn, our model does not necessarily address this uncertainty. However, it is important to note that no matter the production level---if it is 500 or 13,000---we can use our model to reoptimize the distribution strategy and find the new maximum proportion of state's demand we can satisfy.

Alternative Strategy

An alternative strategy GM could pursue is a 'proportion bucket' strategy. In this strategy, two models are required, an allocation model that optimizes the proportion of each state's demand, and a distribution model which optimizes which distribution center supplies each state. This model relies on the fact that distribution costs are quite low, no matter the state, and that there needs to be very few transports as there is not a high volume of ventilators. In turn, the difference between the distribution costs being 300,000 and 100,000, for example, are important, but matter less in the context of a global pandemic, especially when it is the goal of GM to 'do good'.

The first model has different 'buckets' of proportion—40-70%, in 10% buckets. In turn, the objective function is to maximize the overall proportion of each state's demand that is met. There are a few notable constraints, such as the overall supply allocated must be under 10,000, and that each state must receive at least 40% of their demanded ventilators. Through this model, we can optimize the proportion of each state covered at an average of 53.2%.

Once the demand allocations are set, we can craft a second model, using the first model as a basis. The second model optimizes which distribution center provides supplies to each state. This model is constrained by the 90% capacity level of our four production plants. In turn, the model shows which distribution is best to provide each state based on their allocation level. Interestingly, only California and Texas reach near their maximum capacity levels—3136 and 2817—in this model. This is because this model has a constraint that we will only produce a maximum of 10,000 ventilators.

Consequently, through these two models, it seems that GM can on average satisfy 53.2% of each state's demand. However, there are a few consequential limitations to this model. Notably, a constraint is that no state can have under 40% of their demand. In turn, this requirement creates a bias against large states, and a bias for small states, in terms of their proportion bucket. The smaller the state's demand, the more likely it is that the model allocates the state 70% proportion of their demand level. The model is also limited insofar as the 10% buckets are arbitrary. It is possible that the average proportion of each state's demand satisfied could be higher if the buckets were more granular, or larger in range. When we build a model that solely tries to maximize the overall proportion of states' demand covered, with no buckets or 40% floor, the solution avoids all the large, high-demand states and can satisfy the requirements of almost every other state except

Indiana, Georgia, and the 5 highest demand states. In turn, the average proportion of states covered is 82.5%, but the states with the highest need receive nothing. This is obviously not an effective strategy for distribution, but it highlights how Phil's objective of "meeting the greatest proportion of projected peak ventilator demands in each of the 50 states" is somewhat unattainable.

For this model, the distribution costs are much higher than in any other model, as it ships ventilators to all 50 of the states. In turn, the overall transportation cost is around $155,963 given the government distribution subsidy. This is only around $20,000 more in transportation cost in comparison with the cost-optimized model described earlier. In terms of cost per unit, this adds $15.59 per ventilator to cover the distribution cost. As a result, the overall cost per ventilator becomes $3672—still a fraction of the usual hospital ventilator cost. Consequently, as the distribution costs are not that high due to the subsidy, it is even more reason to pursue the 50 state strategy.

One of the biggest benefits of this model is that it ensures smaller states have a ventilator supply in case of future increases in demand. As we know it is somewhat of an inevitability that the other states will need ventilators, this strategy could be the optimal one when performed in conjunction with other firms. As many manufacturing firms are currently trying to produce ventilators and get them to high demand areas like New York City, it is possible GM can do the 'most good' by distributing ventilators to a larger proportion of people in every state. However, this does mean GM isn't focusing its resources on alleviating the hospital systems in the largest crisis—and that is where it is most likely lives will be lost. Moreover, as it drives up the distribution cost, it is possible that GM would prefer to mitigate its transportation costs rather than maximize the geography covered by the program.

Ultimately, this strategy — and its associated benefits and detriments—highlight how complicated the problem of ventilator distribution is. For Phil to reach the goals he has in terms of ventilator distribution, he needs to be clearer as to what those goals are, as maximizing the "proportion of projected peak ventilator demands in each of the 50 states met" requires not providing the states in most desperate need of supplies. Although Phil acknowledged that he would like to prioritize the highest demand states, as well as the states where the distribution centers reside, it conflicts with his final goal.

EXHIBIT 1: ALLOCATION MATRIX

Allocation Matrix

States	Michigan	Texas	California	New York
Alabama	-	104	-	-
Alaska	-	-	15	-
Arizona	-	-	152	-
Arkansas	-	62	-	-
California	-	-	1,238	-
Colorado	-	-	64	-
Connecticut	98	-	-	-
Delaware	21	-	-	-
Florida	-	157	-	-
Georgia	-	295	-	-
Hawaii	-	-	30	-
Idaho	-	-	34	-
Illinois	-	-	252	-
Indiana	66	-	232	-
Iowa	-	-	64	-
Kansas	-	-	58	-
Kentucky	-	33	-	-
Louisiana	-	270	-	-
Maine	31	-	-	-
Maryland	64	-	-	-
Massachusetts	291	-	-	-
Michigan	1,785	-	-	-
Minnesota	-	-	113	-
Mississippi	-	61	-	-
Missouri	-	-	302	-
Montana	-	-	23	-
Nebraska	-	-	38	-
Nevada	-	-	100	-
New Hampshire	29	-	-	-
New Jersey	510	-	-	-
New Mexico	-	-	45	-
New York	-	-	-	3,600
North Carolina	-	221	-	-
North Dakota	-	-	14	-
Ohio	248	-	-	-
Oklahoma	-	31	50	-
Oregon	-	-	41	-
Pennsylvania	277	-	-	-
Rhode Island	22	-	-	-
South Carolina	-	48	-	-
South Dakota	-	-	17	-
Tennessee	-	143	-	-
Texas	-	1,554	-	-
Utah	-	-	55	-
Vermont	58	-	-	-
Virginia	-	96	-	-
Washington	-	82	-	-
West Virginia	-	40	-	-
Wisconsin	-	-	38	-
Wyoming	-	-	12	-

EXHIBIT 2: CALCULATING PRICE FOR GM AS A WHOLE

Calculating Price for GM as a Whole		
Transportation Cost	$	134,870
Labour Cost	$	14,816,000
Production Cost	$	26,574,814
Total cost	$	41,525,684
Cost/Unit	$	3,125
Final Price (w/ 5% mark-up)	$	3,281

EXHIBIT 3: CALCULATING PRICE TO BREAKEVEN THE MOST EXPENSIVE FACTORY

calculating price								
	Michigan		Texas		California		New York	
transportation cost	$	22,596	$	34,742	$	77,531	$	-
labor cost	$	3,704,000	$	3,704,000	$	3,704,000	$	3,704,000
production cost	$	7,000,000	$	6,400,000	$	5,974,814	$	7,200,000
total cost	$	10,726,596	$	10,138,742	$	9,756,345	$	10,904,000
minimum price for each plant	$	3,065	$	3,168	$	3,266	$	3,029
one generic price	$	3,265.82						
markup	$	0.05						
final generic price	$	3,429.12						

EXHIBIT 4: ALLOCATING DEMAND WITH PROPORTION BUCKETS

Proportion Buckets

State	Peak Demand	40%	50%	60%	70%	Allocated	Decision	Proportion
Alabama	299	1	0	0	0	119.6	1	0.4
Alaska	42	0	0	0	1	29.4	1	0.7
Arizona	436	1	0	0	0	174.4	1	0.4
Arkansas	177	0	1	0	0	88.5	1	0.5
California	1238	1	0	0	0	495.2	1	0.4
Colorado	182	1	0	0	0	72.8	1	0.4
Connecticut	281	1	0	0	0	112.4	1	0.4
Delaware	59	0	0	0	1	41.3	1	0.7
Florida	451	1	0	0	0	180.4	1	0.4
Georgia	846	1	0	0	0	338.4	1	0.4
Hawaii	86	0	0	0	1	60.2	1	0.7
Idaho	98	0	0	0	1	68.6	1	0.7
Illinois	721	1	0	0	0	288.4	1	0.4
Indiana	854	1	0	0	0	341.6	1	0.4
Iowa	184	1	0	0	0	73.6	1	0.4
Kansas	167	0	0	0	1	116.9	1	0.7
Kentucky	95	0	0	0	1	66.5	1	0.7
Louisiana	775	1	0	0	0	310	1	0.4
Maine	88	0	0	0	1	61.6	1	0.7
Maryland	182	1	0	0	0	72.8	1	0.4
Massachuset	834	1	0	0	0	333.6	1	0.4
Michigan	1785	1	0	0	0	714	1	0.4
Minnesota	325	1	0	0	0	130	1	0.4
Mississippi	176	0	0	1	0	105.6	1	0.6
Missouri	866	1	0	0	0	346.4	1	0.4
Montana	65	0	0	0	1	45.5	1	0.7
Nebraska	108	0	0	0	1	75.6	1	0.7
Nevada	287	1	0	0	0	114.8	1	0.4
New Hampsh	84	0	0	0	1	58.8	1	0.7
New Jersey	1462	1	0	0	0	584.8	1	0.4
New Mexico	128	0	0	0	1	89.6	1	0.7
New York	4141	1	0	0	0	1656.4	1	0.4
North Caroli	633	1	0	0	0	253.2	1	0.4
North Dakot	41	0	0	0	1	28.7	1	0.7
Ohio	712	1	0	0	0	284.8	1	0.4
Oklahoma	234	1	0	0	0	93.6	1	0.4
Oregon	118	0	0	0	1	82.6	1	0.7
Pennsylvania	794	1	0	0	0	317.6	1	0.4
Rhode Island	63	0	0	0	1	44.1	1	0.7
South Caroli	138	0	0	0	1	96.6	1	0.7
South Dakot	49	0	0	0	1	34.3	1	0.7
Tennessee	411	1	0	0	0	164.4	1	0.4
Texas	1554	1	0	0	0	621.6	1	0.4
Utah	157	0	0	0	1	109.9	1	0.7
Vermont	165	0	0	0	1	115.5	1	0.7
Virginia	276	1	0	0	0	110.4	1	0.4
Washington	236	1	0	0	0	94.4	1	0.4
West Virgini	114	0	0	0	1	79.8	1	0.7
Wisconsin	109	0	0	0	1	76.3	1	0.7
Wyoming	35	0	0	0	1	24.5	1	0.7
						10000		0.532

EXHIBIT 5: TRANSPORTATION AND CAPACITY OPTIMIZATION (PROPORTION BUCKETS)

Transportation / Capacity Optimization									
State	Allocated	Proportion	**States**	Michigan	Texas	California	New York	Decision	Cost
Alabama	119.6	0.4	Alabama	0	1	0	0	1	1999.3
Alaska	29.4	0.7	Alaska	1	0	0	0	1	10279.51
Arizona	174.4	0.4	Arizona	1	0	0	0	1	4697.58
Arkansas	88.5	0.5	Arkansas	1	0	0	0	1	2070.18
California	495.2	0.4	California	0	0	1	0	1	0
Colorado	72.8	0.4	Colorado	1	0	0	0	1	3196.07
Connecticut	112.4	0.4	Connecticut	1	0	0	0	1	2066.02
Delaware	41.3	0.7	Delaware	1	0	0	0	1	2008.29
Florida	180.4	0.4	Florida	1	0	0	0	1	3340.18
Georgia	338.4	0.4	Georgia	1	0	0	0	1	2391.45
Hawaii	60.2	0.7	Hawaii	1	0	0	0	1	0
Idaho	68.6	0.7	Idaho	1	0	0	0	1	4684.21
Illinois	288.4	0.4	Illinois	1	0	0	0	1	997.66
Indiana	341.6	0.4	Indiana	0	0	1	0	1	5427.43
Iowa	73.6	0.4	Iowa	1	0	0	0	1	1418.26
Kansas	116.9	0.7	Kansas	1	0	0	0	1	2434.05
Kentucky	66.5	0.7	Kentucky	1	0	0	0	1	1299.78
Louisiana	310	0.4	Louisiana	1	0	0	0	1	2792.62
Maine	61.6	0.7	Maine	1	0	0	0	1	2667.5
Maryland	72.8	0.4	Maryland	1	0	0	0	1	1816.2
Massachuset	333.6	0.4	Massachuset	0	1	0	0	1	4807.48
Michigan	714	0.4	Michigan	0	1	0	0	1	3332.4
Minnesota	130	0.4	Minnesota	0	1	0	0	1	3098.71
Mississippi	105.6	0.6	Mississippi	1	0	0	0	1	2420.32
Missouri	346.4	0.4	Missouri	0	0	1	0	1	4394.04
Montana	45.5	0.7	Montana	1	0	0	0	1	3900.28
Nebraska	75.6	0.7	Nebraska	1	0	0	0	1	2396.34
Nevada	114.8	0.4	Nevada	1	0	0	0	1	5185.42
New Hampsh	58.8	0.7	New Hampsh	1	0	0	0	1	2207.61
New Jersey	584.8	0.4	New Jersey	0	1	0	0	1	4234.03
New Mexico	89.6	0.7	New Mexico	1	0	0	0	1	3566.83
New York	1656.4	0.4	New York	0	0	0	1	1	0
North Caroli	253.2	0.4	North Caroli	0	1	0	0	1	3326.57
North Dakot	28.7	0.7	North Dakot	1	0	0	0	1	2868.24
Ohio	284.8	0.4	Ohio	0	1	0	0	1	3096.98
Oklahoma	93.6	0.4	Oklahoma	1	0	0	0	1	2602.22
Oregon	82.6	0.7	Oregon	1	0	0	0	1	5232.77
Pennsylvania	317.6	0.4	Pennsylvania	0	1	0	0	1	3939.72
Rhode Island	44.1	0.7	Rhode Island	1	0	0	0	1	2254.86
South Caroli	96.6	0.7	South Caroli	1	0	0	0	1	2320.74
South Dakot	34.3	0.7	South Dakot	1	0	0	0	1	2453.55
Tennessee	164.4	0.4	Tennessee	0	0	0	1	1	2242.84
Texas	621.6	0.4	Texas	0	0	1	0	1	3460.39
Utah	109.9	0.7	Utah	1	0	0	0	1	4079.64
Vermont	115.5	0.7	Vermont	0	0	1	0	1	7435.08
Virginia	110.4	0.4	Virginia	0	0	1	0	1	6361.26
Washington	94.4	0.4	Washington	0	0	0	1	1	591.45
West Virgini	79.8	0.7	West Virgini	0	1	0	0	1	3279.07
Wisconsin	76.3	0.7	Wisconsin	0	0	0	1	1	2354.27
Wyoming	24.5	0.7	Wyoming	0	0	1	0	1	2934.06
		0.532		3135.9	2817.4	2055.2	1991.5	10000	155963.46