CLIPBOARD HEALTH PRODUCT TEAM CASE STUDY #1

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We are launching Lyft's ride scheduling feature in Toledo, Ohio. Our objective is to develop a strategy that maximizes Lyft's net revenue over the next 12 months for scheduled rides on a particular route between Toledo's downtown and airport.

Since data is given in monthly figures, we will assume that time $t \in \{0, 1, 2, \ldots, 12\}$ is given in months, *e.g.*, $t = 0$ is the start of the first month, $t = 11$ is the start of the twelfth month, $t = 12$ is the end of the twelfth month, *etc*.

Assume that rider and driver acquisitions occur and costs are paid at the start of month, that is, at times $t = 0, 1, \ldots, 11$. Assume that net revenue is calculated at the end of each month, that is, at times $t = 1, 2, \ldots, 12$. Assume that rider and driver churn only occur at the end of each month immediately after calculating net revenue.

Let $0 \leq F \leq 25$ denote the fare per ride charged to the rider. Let $F_0 = \$25$ denote the prevailing fare.
Let $0 \leq W < F$ denote the wage per ride paid to the driver. Let $W_0 = \$19$ denote the prevailing wage.
Let R_t denote the post-acquisition number of riders at time t, $t \in \{0, 1, \ldots, 12\}$. Let R denote the initial pre-acquisition number of riders at time $t = 0$.
Let D_t denote the post-acquisition number of drivers at time t, $t \in \{0, 1, \ldots, 12\}$. Let D denote the initial pre-acquisition number of drivers at time $t = 0$.
Let $P_t^{(R)}$ denote the estimated number of potential new riders at time t, $t \in \{0, 1, \ldots, 11\}$.
Let $P_t^{(D)}$ denote the estimated number of potential new drivers at time t, $t \in \{0, 1, \ldots, 11\}$.
Let $E_t^{(R)}$ denote the number of people entering the potential new rider pool at time t, $t \in \{0, 1, \ldots, 11\}$.
Let $E_t^{(D)}$ denote the number of people entering the potential new driver pool at time t, $t \in \{0, 1, \ldots, 11\}$.
Let $T^{(R)} \subseteq \{0, 1, \ldots, 12\}$ denote the finite collection of times when a new rider is added.
Let $T^{(D)} \subseteq \{0, 1, \ldots, 12\}$ denote the finite collection of times when a new driver is added.
Let $A_t^{(R)}$ denote the number of new riders acquired at time t, $t \in \{0, 1, \ldots, 11\}$.
Let $A_t^{(D)}$ denote the number of new drivers acquired at time t, $t \in \{0, 1, \ldots, 11\}$.
Suppose that $P_t^{(R)} = P_{t-1}^{(R)} - A_{t-1}^{(R)} + E_t^{(R)}$ and $P_t^{(D)} = P_{t-1}^{(D)} - A_{t-1}^{(D)} + E_t^{(D)}$, $t \in \{1, \ldots, 11\}$. That is, $P_t^{(R)}, P_t^{(D)}$ are post-entry, pre-acquisition values. For $t = 0$, assign values $P_0^{(R)} := P_0^{(R)} + E_0^{(R)}$ and $P_0^{(D)} := P_0^{(D)} + E_0^{(D)}$.
Let $\$10 \leq Q_t^{(R,n)} \leq \$20$ denote the customer acquisition cost (CAC) of the n^{th} new rider at time t, $t \in \{0, 1, \ldots, 11\}$, $n = 1, \ldots, A_t^{(R)}$.
Let $\$400 \leq Q_t^{(D,n)} \leq \$600$ denote the CAC of the n^{th} new driver at time t, $t \in \{0, 1, \ldots, 11\}$, $n = 1, \ldots, A_t^{(D)}$.
Let $\$0 \leq Q_t^{(R)} \leq \$20A_t^{(R)}$ denote the total CAC of new riders at time t, $t \in \{0, 1, \ldots, 11\}$.
Let $\$0 \leq Q_t^{(D)} \leq \$600A_t^{(D)}$ denote the total CAC of new drivers at time t, $t \in \{0, 1, \ldots, 11\}$.

Since, under prevailing initial conditions, each rider requests 1 ride per month, each driver completes 100 rides per month, and the ride request fulfillment rate (RRFR) is approximately 60%, then the initial ratio of riders to drivers is approximately 167:1. We will assume that $R = 167D$. Since we need a reasonable upper limit, and lacking additional information, let us assume that 167 is the maximum number of rides that a driver can complete per month. For similar reasons and simplicity, assume that RRFR is uniform across the driver population and that ride request rates are uniform across the rider population. Then each driver fulfills $\mathtt{min}(\mathtt{min}(RRFR\left(\frac{R_t}{D_t}\right), 167), R_t)$ rides in month $t + 1$, where the outer `min` is the limit on D_t imposed by rider existence.

Absent labor statistics to the contrary, assume that potential rider and driver acquisition pools, that is, $P_t^{(R)}$ and $P_t^{(D)}$, only decrease due to acquisitions, not a shrinking labor market. For these reasons and since it is unlikely that the ride

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scheduling feature is sufficiently appealing to significantly expand the potential rider or driver pools, we assume that the number of people entering the pools is uniform across the 12 months, that is, $E_t^{(R)}$ and $E_t^{(D)}$ are constant for all t. Seasonal fluctuations may exist but we refrain from speculating in the absence of data. Note that significant economic disruption in Toledo could also impact the accuracy of our assumptions.

We will disregard opportunity cost. Therefore, we will acquire riders or drivers at all times t when we have sufficient time $12-t$ remaining to recoup acquisition costs. We must determine the revenue maximizing ratio of riders to drivers for each acquisition time $t = 0, \ldots, 11$, subject to limits $P_t^{(R)}$ and $P_t^{(D)}$. First we must know the CACs $Q_t^{(R,n)}$ and $Q_t^{(D,n)}$. (Observe that CAC depends on t since an expansion of the acquisition pool at time t will drive down CAC. That is, $Q_t^{(R,n)}$ ($Q_t^{(D,n)}$) and $P_t^{(R)}$ ($P_t^{(D)}$) are inversely related.) We propose an exponential pricing model for $Q_t^{(R,n)}$ ($Q_t^{(D,n)}$) dependent on acquisition pool size $P_t^{(R)}$ ($P_t^{(D)}$) for each month t.

Arbitrarily fix $P_0^{(R)}$ and $P_0^{(D)}$. Since driver acquisition and rider marketing channels are only so deep then $P_t^{(R)}$ and $P_t^{(D)}$ are finite for all t. For each month t we will assume that CACs $Q_t^{(R,n)}$ and $Q_t^{(D,n)}$ increase exponentially with respect to $P_t^{(R)}$ and $P_t^{(D)}$. Specifically, in the rider case, given $P_t^{(R)}$ we have a CAC growth rate r such that

$$10e^{rP_t^{(R)}} = 20.$$

Then

$$r = \frac{ln(2)}{P_t^{(R)}}.$$

It follows that the cost to acquire the n^{th} rider at time t is

$$\begin{aligned} Q_t^{(R,n)} &= 10e^{rn} \\ &= 10e^{\frac{ln(2)}{P_t^{(R)}}n} \\ &= 10(2)^{\frac{n}{P_t^{(R)}}}. \end{aligned}$$

Similarly, in the driver case, given $P_t^{(D)}$ we have a CAC growth rate s such that

$$400e^{sP_t^{(D)}} = 600.$$

Then

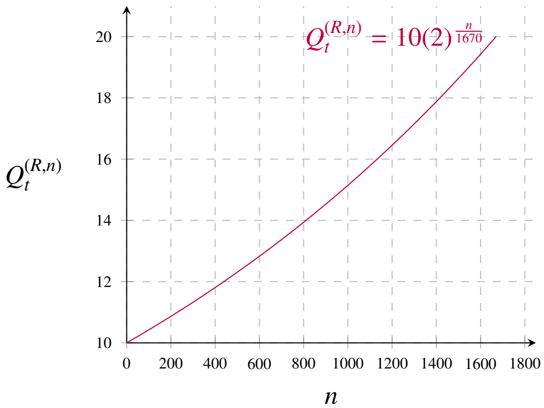
$$s = \frac{ln\left(\frac{3}{2}\right)}{P_t^{(D)}}.$$

It follows that the cost to acquire the n^{th} driver at time t is

$$\begin{aligned} Q_t^{(D,n)} &= 400e^{sn} \\ &= 400e^{\frac{ln\left(\frac{3}{2}\right)}{P_t^{(D)}}n} \\ &= 400\left(\frac{3}{2}\right)^{\frac{n}{P_t^{(D)}}}. \end{aligned}$$

Thus we have the following exponential cost models: $Q_t^{(R,n)} = 10(2)^{\frac{n}{P_t^{(R)}}}$ and $Q_t^{(D,n)} = 400\left(\frac{3}{2}\right)^{\frac{n}{P_t^{(D)}}}$.

Figure i illustrates the cost $Q_t^{(R,n)}$ ($Q_t^{(D,n)}$) to acquire the n^{th} rider (driver) at time t given $P_t^{(R)}$=1670 ($P_t^{(D)}$=10). Such a graph exists for each time $t = 1, \ldots, 12$ and depends only on $P_t^{(R)} = P_{t-1}^{(R)} - A_{t-1}^{(R)} + E_t^{(R)}$ ($P_t^{(D)} = P_{t-1}^{(D)} - A_{t-1}^{(D)} + E_t^{(D)}$). In particular, it is independent of the initial fixed number of riders R (drivers D).



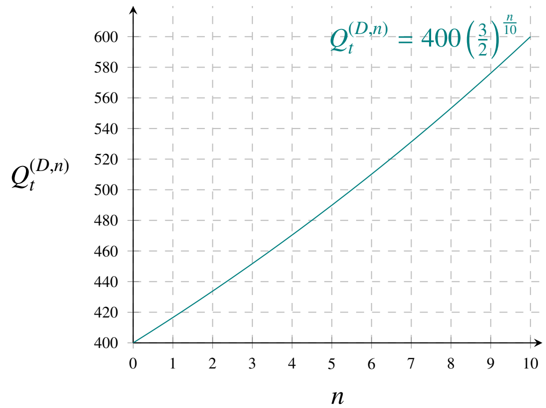


Figure i: the left hand side depicts the cost $Q_t^{(R,n)}$ to acquire the n^{th} rider for $P_t^{(R)} = 1670$. Similarly, the right hand side depicts the cost $Q_t^{(D,n)}$ to acquire the n^{th} driver for $P_t^{(D)} = 10$. Note that although we chose $P_t^{(R)}$ and $P_t^{(D)}$ to reflect the prevailing initial ratio of riders to drivers given by $R = 167D$, we certainly need not have $P_t^{(R)} = 167P_t^{(D)}$ as depicted here.

To simplify spreadsheet calculations we estimate sums with integrals, so the total rider acquisition cost at time t is

$$\begin{aligned}\int_{n=0}^{A_t^{(R)}} Q_t^{(R,n)} dn &= \int_{n=0}^{A_t^{(R)}} 10(2)^{\frac{n}{P_t^{(R)}}} dn \\ &= \frac{10P_t^{(R)}}{ln2}\left(2^{\frac{A_t^{(R)}}{P_t^{(R)}}} - 1\right).\end{aligned}$$

Similarly, the total driver acquisition cost at time t is

$$\begin{aligned}\int_{n=0}^{A_t^{(D)}} Q_t^{(D,n)} dn &= \int_{n=0}^{A_t^{(D)}} 400\left(\frac{3}{2}\right)^{\frac{n}{P_t^{(D)}}} dn \\ &= 400P_t^{(D)}\left(\frac{3^{\frac{A_t^{(D)}}{P_t^{(D)}}}}{2^{\frac{A_t^{(D)}}{P_t^{(D)}}} ln\frac{3}{2}} - \frac{1}{ln\frac{3}{2}}\right).\end{aligned}$$

We implemented functions RIDER_INTEGRAL($P_t^{(R)}, A_t^{(R)}$) and DRIVER_INTEGRAL($P_t^{(D)}, A_t^{(D)}$) in the spreadsheet to evaluate costs for each time t.

Since the given data does not indicate the effect of fare variation on rider metrics (*e.g.*, average rider requests per month or rider churn), assume that the fare F remains constant at \$25. We further justify fixing the fare at the maximum by noting that the route endpoints (downtown and airport) suggest that the ride may be essential and therefore ride demand may be rather price inelastic. We suggest that further research into revenue dependence on fare measure churn rates and average monthly ride requests at varying fare rates, as well as identify the alternative ride options for unfulfilled riders. In particular, we should identify whether unfulfilled riders use Lyft's unscheduled ride service or an external party service, and what fares are paid in each case. Perhaps unfulfilled riders exhibit a tendency to use Lyft's unscheduled service at a higher fare or drivers are amenable to a lower wage on unscheduled rides. Such possibilities indicate that maximizing scheduled-ride net revenue could preclude company-wide net revenue maximization. Further research is needed. Although neither the Department of Transportation nor Ohio mandate fare maximums, it would be prudent to remain cognizant of rideshare legislation.

Extrapolate from the prevailing $RRFR = 60\%$ at $W = \$19$ and the experimental $RRFR = 93\%$ at $W = \$22$ to suppose that $RRFR$ is linear with respect to W such that $RRFR = .11W - 1.49$ when $.60 \leq RRFR \leq .93$ and $\$19 \leq W \leq \$22$. We will restrict $RRFR$ and W to these ranges. Moreover, we will assume that W is constant for all 12 months.

Given the assumptions thus far, we now propose a net revenue maximizing algorithm. The sheet "Algorithm Template" contains a blank template to implement the algorithm. We implement an example in the sheet "Algorithm". Cells that require user input are highlighted yellow. Although all parameters other than dollars are nonnegative integers in the real world, we do not round until the final net revenue calculation.

§i.) Fix the initial number of drivers D in cell Q4. We choose $D = 10$ for our example in "Algorithm".

§ii.) Fix wage W in cell C6.
If neither rider nor driver acquisitions are made during the 12 months, then wage $W = \$20.94$ maximizes net revenue at $\$325,250.96$. Sheet "No Acquisitions" exhibits this scenario.

§iii.) Fix $P_0^{(R)}$ in cell L4 and $P_0^{(D)}$ in cell R4. We choose $P_0^{(R)} = 10000$ and $P_0^{(D)} = 1000$ for our example in "Algorithm".

§iv.) Fix $E_t^{(R)}$ in cell M6 and $E_t^{(D)}$ in cell S6. We choose $E_t^{(R)} = 2100$ and $E_t^{(D)} = 10$ for our example in "Algorithm".

§v.) Start with $A_t^{(R)} = 0 = A_t^{(D)}$ for all t.

§vi.) Let $t = 0$.

§vii.) We want 167 in col AA row time $t + 1$ (so that each driver is operating at maximal capacity 167 rides per month) and values < 167 for all col AA rows time $> t + 1$ (so that we do not hire drivers earlier than necessary when we do not have sufficient ride demand and drivers churn at 5%). We want Real RRFR in col AD to equal RRFR in col W (otherwise we do not have sufficient drivers to fulfill existing ride demand). Observe that these conditions will be satisfied when we have the optimal ratio of acquired riders to drivers given by $\frac{R_t}{D_t} = \frac{167}{RRFR}$ (col AE). Thus we obtain these conditions by adjusting $A_t^{(R)}$ in col N row time t and $A_t^{(D)}$ in col T row time t. Adjust $A_t^{(R)}$ and $A_t^{(D)}$ as necessary by using the following two steps in any order:

  i.) If col AA row time $t + 1$ is < 167 then increase $A_t^{(R)}$ or decrease $A_t^{(D)}$ such that col AA row time $t + 1$ equals 167 and col AA is < 167 for all row times $> t + 1$ and col AD row time $t + 1$ equals RRFR.

  ii.) If col AD row time $t + 1$ is $<$RRFR then increase $A_t^{(D)}$ to the minimum value such that col AD row time $t + 1$ equals RRFR.
  The maximum 12 month net revenue generated with an initial 10 drivers and 1670 riders, each subject to limited acquisition channels, is approximately $\$115,000$. Note that the optimal ratio of riders to drivers in our example is approximately 205 (col AE), with a decrease in the last 3 months when it is impossible to recoup acquisition costs given expected values of riders and drivers.

§viii.) If $t = 11$ then this completes the maximization of 12 month net revenue (cell AB20). Otherwise iterate through steps §vii - §viii for $t := t + 1$.

We note that the use of sums rather than integrals may be the main source of error in this case study. Other identified improvements to this case study solution would be to replace the spreadsheet and this file with a more concise and user-friendly file, to contain implementation in a separate more powerful program, and to allow for non-uniform wage W at each time t.