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Carvana: IsBadBuy?

In the spring of 2017, Carvana Co. (Carvana), an e-commerce platform for buying used cars, was attempting to disrupt the $1 trillion-per-year US car market. With a presence in 24 US metropolitan areas, including Atlanta, Dallas, and Washington, DC, and significant growth in sales since its service launched in 2013, there was a strong argument for "the Amazon of cars" to go public. Ernie Garcia III, Carvana's 34-year-old cofounder and CEO, explained:

> We clearly got to a place in the business where we got to execution mode and we needed to open more markets and ramp up sales in markets we were already in. It became a much clearer story to tell the public markets. We think public capital is good for the brand.[1]

When the company held its IPO on the New York Stock Exchange on April 28, 2017, however, the results were surprising—the stock sputtered and closed down 16%.[2]

One of the key elements driving Carvana's ability to grow into new markets was its vertically integrated supply chain, a system that was critically linked to the company's "proprietary software systems and data."[3] In its IPO filings with the US Securities and Exchange Commission (SEC) on April 27, 2017, the company stated:[4]

> We acquire the majority of our used vehicle inventory from wholesale auctions. We also, to a lesser extent, acquire vehicles from consumers and directly from used vehicle suppliers, including franchise and independent dealers, leasing companies, and car rental companies. Using proprietary machine learning algorithms and data from a variety of internal and external sources, we evaluate tens of thousands of vehicles daily to determine their fit with consumer demand, internal profitability targets, and our existing inventory mix.

Years earlier, Carvana had turned to Kaggle, a crowdsourcing platform for data scientists, to develop these algorithms. In 2012, it hosted the Kaggle competition "Don't Get Kicked!" wherein 570 teams competed to predict if a car purchased at auction was a "kick" (or a bad buy)—a vehicle with a major defect.[5] At the time of the competition, data science was a burgeoning field, and industry watchers wondered if machine learning could help a company such as Carvana develop a competitive advantage.

[1] Kirsten Korosec, "Used Car Vending Machine IPO Sputters in First Day of Trading," *Fortune*, April 28, 2017, http://fortune.com/2017/04/28/carvana-ipo-debut/ (accessed Nov. 8, 2019).

[2] http://fortune.com/2017/04/28/carvana-ipo-debut/.

[3] Carvana Co. SEC Form 10-K, 2017.

[4] Carvana Co. annual report, 2017, https://investors.carvana.com/~/media/Files/C/Carvana-IR/reports-and-presentations/car-2017-annual-report.pdf (accessed Nov. 8, 2019).

[5] "Carvana: Don't Get Kicked!," Kaggle, https://www.kaggle.com/c/DontGetKicked (accessed Nov. 8, 2019).

Company Overview[6]

Carvana was founded in Phoenix in 2012 as a wholly owned subsidiary of DriveTime Automotive Group, Inc. (DriveTime). Its parent company was a chain of traditional used car dealerships focused on selling and financing cars to subprime borrowers in several US states. Formerly a rental car company called the Ugly Duckling Corporation, DriveTime was founded in 1992, when Ernie Garcia II bought the Ugly Duckling Corporation out of bankruptcy.

After graduating from Stanford University in 2005 with a bachelor's degree in management science and engineering, Garcia III joined DriveTime in 2007 as a financial analyst. Later serving as DriveTime's vice president and treasurer,[7] he cofounded Carvana with his father, the elder Garcia. Carvana's mission was "to change the way people buy cars." Garcia III was named Carvana's CEO at its founding, and he was described as having "brought a Silicon Valley swagger to the business."[8]

In a 2010 filing with the SEC, DriveTime described the size and scope of its business, which included 78 dealerships and 13 reconditioning facilities in 11 states. In 2009, it sold 49,500 vehicles and generated $946.3 million in revenue. That same year, DriveTime purchased 53,975 vehicles from 154 auctions nationwide.[9]

Carvana officially launched its service, selling its first car in January of 2013, and spun off from DriveTime the following year. Still, Carvana remained dependent on DriveTime for some of its operations, including vehicle inventory purchasing and inspection and reconditioning of used cars. This dependency on DriveTime was mentioned as a risk factor in Carvana's IPO filings. Bloomberg described the dependency as "piggybacking on DriveTime's facilities."[10]

Bloomberg raised other concerns after the IPO about the "spaghetti pile of ties between Carvana, DriveTime and other Garcia-controlled companies." First, DriveTime, which was principally owned by Garcia II, was considering a potential sale to a third party. And there were no guarantees that DriveTime under new ownership would enter into new agreements with Carvana.

Second, Garcia II, whose 71% stake in Carvana was valued in the offering at $1.5 billion, was a "notorious character." Listed as a resident of Trump Tower in 2016, occupying its 48th and 49th floors, he was a convicted felon.[11] He pled guilty to bank fraud in connection with the collapse of Charles Keating's Lincoln Savings and Loan in the 1990s. At the time of the IPO, Garcia II and his son held 97% of Carvana's voting shares, with control over matters like selecting directors.

Despite the "piggybacking," Carvana's business model was quite different from DriveTime's. From a desktop computer or mobile device, customers could inspect Carvana's huge inventory of over 7,300 vehicles "using interactive high-definition photography, obtain financing and warranty coverage,"[12] purchase the vehicle, and schedule delivery or pickup. All cars came with a seven-day money-back guarantee. If the customer chose the delivery option, the car was delivered the next day to the customer's home. Alternatively, the customer could pick up the car at one of Carvana's fully automated vending machines.

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[6] https://investors.carvana.com/~/media/Files/C/Carvana-IR/reports-and-presentations/car-2017-annual-report.pdf.

[7] "Ernie Garcia, III," Carvana Corporate Governance, Management and Directors, https://investors.carvana.com/corporate-governance/management-and-directors/management/ernie-garcia-iii (accessed Nov. 20, 2019).

[8] Neil Weinberg and Tom Metcalf, "Cars in Vending Machines, a Fading IPO and an Ex-Con Owner," *Bloomberg*, June 6, 2017, https://www.bloomberg.com/news/articles/2017-06-06/cars-in-vending-machines-a-fading-ipo-and-an-ex-con-behind-them (accessed Nov. 8, 2019).

[9] DriveTime Automotive, Inc., SEC Form S-1, March 19, 2010.

[10] https://www.bloomberg.com/news/articles/2017-06-06/cars-in-vending-machines-a-fading-ipo-and-an-ex-con-behind-them.

[11] Zoe Rosenberg, "Meet the Notorious Characters Who Call Trump Tower Home," Curbed New York, https://ny.curbed.com/2016/10/25/13405036/trump-tower-residents-list (accessed Nov. 8, 2019).

[12] Carvana Co. SEC Form S-1, 2017.

These vending machines were a major point of differentiation for Carvana. They helped distinguish the company from competitors such as Shift Technologies, Inc.; Vroom, Inc.; and Beepi Inc., three other web-based used-car sellers.[13] Carvana's vending machines were sleek glass-and-steel buildings that stood as high as eight stories tall. The machine in San Antonio held up to 30 cars and featured four delivery bays. Once the customer arrived, he or she inserted a giant coin into a custom slot, and the machine would vend the car.[14] The company would subsidize $200 in airfare, and arranged transportation for customers who lived more than 100 miles from a machine.[15]

By the end of 2016, Carvana employed about 1,000 people and had sold approximately 27,500 vehicles, generating $541.8 million in revenue since the launch of its service. In 2016 alone, the company generated $365.1 million in revenue, with a loss of $93.1 million.

Industry Overview[16]

The market Carvana competed in was very large and highly fragmented. In 2015, the US automotive industry made up roughly 20% of the US retail economy and generated approximately $1.1 trillion in sales. Automotive was "the largest consumer retail market in the United States," and used cars represented $710 billion of the annual sales, with 38 million used cars sold "at an average price of $18,552."

Of the 63,000 used-car dealerships in North America, the top 100 dealerships only held approximately 7% market share. Most of these dealerships ran brick-and-mortar operations customers could visit to inspect limited car inventories. These dealerships lacked "the scale and expertise to consistently purchase high-quality vehicles." Moreover, 81% of North American consumers did not enjoy their buying experience, and car salesmen were listed as one of the least-trusted professionals in a 2015 Gallup poll.

At the same time, Americans were becoming more comfortable shopping online. E-commerce sales had reached 8.4% of all US retail sales in the third quarter of 2016. Out of all US car buyers, 75% reported that they "would consider completing their entire car purchase online if given the opportunity."

Use of Data Science

Carvana hosted its first Kaggle competition before it even launched its service.[17] From September 30, 2011, to January 5, 2012, teams could submit predictions into the $10,000 "Don't Get Kicked!" Kaggle competition.

Kaggle offered the following description of the competition on its website.[18]

> One of the biggest challenges of an auto dealership purchasing a used car at an auto auction is the risk…that the vehicle might have serious issues that prevent it from being sold to customers. The auto community calls these unfortunate purchases "kicks."

[13] https://www.bloomberg.com/news/articles/2017-06-06/cars-in-vending-machines-a-fading-ipo-and-an-ex-con-behind-them.

[14] Andrew Hard, "Hate Car Dealerships? Try Carvana's 8-Story Tall Car Vending Machine," Digital Trends, March 15, 2017, https://www.digitaltrends.com/cars/carvana-launches-automated-car-vending-machine-in-texas/ (accessed Nov. 8, 2019).

[15] http://fortune.com/2017/02/07/carvana-vending-machine-austin/.

[16] Information and quotes in this section come from Carvana Co. SEC Form S-1, 2017.

[17] On July 26, 2017, Kaggle launched a second competition hosted by Carvana. See "Carvana Image Masking Challenge," Kaggle, September 27, 2019, https://www.kaggle.com/c/carvana-image-masking-challenge (accessed Nov. 8, 2019). The challenge was to develop an algorithm that removes a car photo's studio background.

[18] "Carvana: Don't Get Kicked!: Description," Kaggle, https://www.kaggle.com/c/DontGetKicked#description (accessed Nov. 8, 2019).

> Kicked cars often result when there are tampered odometers, mechanical issues the dealer is not able to address, issues with getting the vehicle title from the seller, or some other unforeseen problem. Kick cars can be very costly to dealers after transportation cost, throw-away repair work, and market losses in reselling the vehicle.
>
> Modelers who can figure out which cars have a higher risk of being kick can provide real value to dealerships trying to provide the best inventory selection possible to their customers.
>
> The challenge of this competition is to predict if the car purchased at the Auction is a Kick (bad buy).

To compete, teams downloaded the data from Kaggle's website.[19] The training dataset contained information on 72,983 cars purchased at auction during 2009–10.[20] Each car was classified as either a 1 (a bad buy) or a 0 (not a bad buy). The percentage of bad buys in the training dataset was 12.3%.

Additional information about each cars was available as well, including make, model, age, odometer, auction location, and buyer number. In total, each car was described by 34 factors. See **Exhibit 1** for the data dictionary—a list of these 34 factors and their definitions. The nicely laid out dataset begged the question: Which factors were most important in predicting bad buys?

In the testing dataset, there was similar information available for 48,707 cars. But unlike the training dataset, the testing dataset did not identify whether each car was a bad buy or not. The goal of the competition was to predict this missing column of data called "IsBadBuy." Teams were ranked on Kaggle's leaderboard[21] according to how accurately they predicted the bad buys in the testing set.

[19] "Carvana: Don't Get Kicked!: Data," Kaggle, https://www.kaggle.com/c/DontGetKicked/data (accessed Nov. 8, 2019).
[20] Presumably, these data came from DriveTime.
[21] "Carvana: Don't Get Kicked!: Leaderboard," Kaggle, https://www.kaggle.com/c/DontGetKicked/leaderboard (accessed Nov. 8, 2019).

Exhibit 1

Carvana: IsBadBuy?

Carvana Data Dictionary

Field Name	Definition
RefID	Unique (sequential) number assigned to vehicles
IsBadBuy	Identifies if the kicked vehicle was an avoidable purchase
PurchDate	The date the vehicle was purchased at auction
Auction	Auction provider at which the vehicle was purchased
VehYear	The manufacturer's year
VehicleAge	The years elapsed since the manufacturer's year
Make	Vehicle manufacturer
Model	Vehicle model
Trim	Vehicle trim level
SubModel	Vehicle submodel
Color	Vehicle color
Transmission	Vehicle's transmission type (manual or automatic)
WheelTypeID	The type ID of the vehicle's wheels
WheelType	The description of the vehicle's wheel tyle (alloy or covers)
VehOdo	The vehicle's odometer reading
Nationality	The manufacturer's country
Size	The size category of the vehicle (e.g., compact or SUV)
TopThreeAmericanName	Identifies whether the manufacturer is one of the top three American manufacturers
MMRAcquisitionAuctionAveragePrice	Acquisition price for this vehicle in average condition at time of purchase
MMRAcquisitionAuctionCleanPrice	Acquisition price for this vehicle in the above-average condition at time of purchase
MMRAcquisitionRetailAveragePrice	Acquisition price for this vehicle in the retail market in average condition at time of purchase
MMRAcquisitionRetailCleanPrice	Acquisition price for this vehicle in above-average condition at time of purchase
MMRCurrentAuctionAveragePrice	Acquisition price for this vehicle in average condition as of current day
MMRCurrentAuctionCleanPrice	Acquisition price for this vehicle in above-average condition as of current day
MMRCurrentRetailAveragePrice	Acquisition price for this vehicle in the retail market in average condition as of current day
MMRCurrentRetailCleanPrice	Acquisition price for this vehicle in the retail market above-average condition as of current day
PRIMEUNIT	Identifies if the vehicle would have a higher demand than a standard purchase
AUCGUART	The level of guarantee provided by the auction for the vehicle (Green light = guaranteed/arbitratable; yellow light = caution/issue; red light = sold as is)
BYRNO	Unique number assigned to the buyer who purchased the vehicle
VNZIP	Zip code where the car was purchased
VNST	State where the car was purchased
VehBCost	Acquisition cost paid for the vehicle at time of purchase
IsOnlineSale	Identifies whether the vehicle was originally purchased online
WarrantyCost	Warranty price (term = 36 months and mileage = 36,000)

Data source: "Carvana: Don't Get Kicked!: Data," Kaggle, https://www.kaggle.com/c/DontGetKicked/data (accessed Nov. 8, 2019).