

W20038

PREDICTING AUTOMOBILE PRICES USING NEURAL NETWORKS

Boya Zhang and Ahmed Ibrahim wrote this exercise under the supervision of Rasha Kashef solely to provide material for class discussion. The authors do not intend to illustrate either effective or ineffective handling of a managerial situation. The authors may have disguised certain names and other identifying information to protect confidentiality.

This publication may not be transmitted, photocopied, digitized, or otherwise reproduced in any form or by any means without the permission of the copyright holder. Reproduction of this material is not covered under authorization by any reproduction rights organization. To order copies or request permission to reproduce materials, contact Ivey Publishing, Ivey Business School, Western University, London, Ontario, Canada, N6G 0N1; (t) 519.661.3208; (e) cases @ivey.ca; www.iveycases.com. Our goal is to publish materials of the highest quality; submit any errata to publishcases @ivey.ca.

Copyright © 2020, Ivey Business School Foundation

Version: 2020-01-17

When purchasing a car, people often gravitated toward different features. Some popular features included functionalities like navigation systems, leather seats, seat heaters, and cruise control. For cars intended for private use, personal preferences such as favourite colour and the desired vehicle shape came into play. Therefore, the price of one particular car model could vary according to these features.

A car manufacturing plant had designed several new car models with different features and accessories. On June 11, 2018, Adam Ebraham, the chief marketing officer at an automobile agency, was looking at a list, which he had received from the manufacturing plant, of different car model features. After receiving the manufacturer's suggested retail price (MSRP), the dealerships would decide on a final price that included environmental fees, air conditioning fees, and other fees. The MSRP was the base price of a vehicle model, set nationally for every dealer, before environmental costs and fees were applied. A car's features and accessories affected the MSRP. Ebraham needed to provide the MSRPs to dealers next week, and he had to decide on the base prices. He did not know how to determine which features were essential or to what extent each feature contributed to the price.

He had heard of a prediction system called neural networks that could help him to accurately predict the price. Yusuf Farid, a data scientist with expertise in machine learning and prediction, had recently been hired at the company research lab. Ebraham stopped by Farid's office and provided Farid with the data collected for the previous batch of cars (see Exhibit 1).

There were 28 variables provided in the dataset—one dependent variable and 27 independent variables. The dependent variable was the price of each car model. Farid hoped to provide Ebraham with an accurate MSRP recommendation for the new cars before the deadline the following week.

THE DECISION

For predicting the prices, Farid decided that he would try various machine-learning methods, including linear regression. He also knew that neural networks excelled in predicting price, so he decided to use a feed-forward neural network to train data and accurately predict the price. He wondered how neural networks would compare to linear regression. What about other algorithms, like logistic regression? For long-term marketing, he wanted to decide on one particular computing system to determine prices.

EXHIBIT 1: CONFIGURATIONS OF THE PREVIOUS YEAR'S CARS

Pwi PStr Radio SpM M_Rim Tow_Bar	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
M_Rim	1	1	1	1	1	1	1	0	0	0	0	0	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Mqs	0	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1
Radio	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Str	1	1	1	1	1	1	1	1	1	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PW	1	1	1	1	1	1	П	1	1	1	1	1	1	1	П	1	1	1	1	П	0	1	1	1	1	1	1	1	1	0	0
Clock	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0
8	T	0	0	1	1	0	T	0	_	_	1	0	1	1	1	1	7	-	0	1	0	1	0	0	T	-	1	0	1	0	0
Comp	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
2AC	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Abag_2	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
Abag_1Abag	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ABS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mfr_G ABS	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
۵,	10	4	4	4	4	4	4	20	4	4	4	4	4	4	4	4	4	4	4	4	10	4	4	4	4	4	4	4	4	4	4
Wght G_P	1189 10	1189 4	1189 4	1189 4	1189 4	1189 4	1189 4	1109 20	1069 4	1109 4	1109 4	1174 4	1124 4	1124 4	1124 4	1124 4	1124 4	1124 4	1124 4	1124 4	1104 10	1104 4	1104 4	1104 4	1104 4	1104 4	1104 4	1104 4	1104 4	1104 4	1104 4
Grs Wght G_P																															5 1104 4
Cyl Grs Wght G_P	1189	1189	1189	1189	1189	1189	1189	1109	1069	1109	1109	1174	1124	1124	1124	1124	1124	1124	1124	1124	1104	1104	1104	1104	1104	1104	1104	1104	1104	1104	
Grs Wght G_P	3 3 6 1189	3 3 6 1189	3 3 6 1189	6 1189	3 3 6 1189	3 3 6 1189	3 3 5 1189	3 3 5 1109	3 3 5 1069	3 3 5 1109	3 3 5 1109	3 3 5 1174	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5
CC Drs Cyl Grs Wght G_P	3 6 1189	3 6 1189	3 6 1189	3 6 1189	3 6 1189	3 6 1189	3 5 1189	3 5 1109	3 5 1069	3 5 1109	3 5 1109	3 5 1174	3 5 1124	3 5 1124	3 5 1124	3 5 1124	3 5 1124	3 5 1124	3 5 1124	3 5 1124	3 5 1104	3 5 1104	3 5 1104	3 5 1104	3 5 1104	3 5 1104	3 5 1104	3 5 1104	3 5 1104	3 5 1104	2
CC Drs Cyl Grs Wght G_P	3 3 6 1189	3 3 6 1189	3 3 6 1189	3 3 6 1189	3 3 6 1189	3 3 6 1189	3 3 5 1189	3 3 5 1109	3 3 5 1069	3 3 5 1109	3 3 5 1109	3 3 5 1174	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1124	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5 1104	3 3 5
CC Drs Cyl Grs Wght G_P	0 1800 3 3 6 1189	1800 3 3 6 1189	1800 3 3 6 1189	1800 3 3 6 1189	1800 3 3 6 1189	1800 3 3 6 1189	1800 3 3 5 1189	1600 3 3 5 1109	1600 3 3 5 1069	1600 3 3 5 1109	1600 3 3 5 1109	1600 3 3 5 1174	1600 3 3 5 1124	1600 3 3 5 1124	1600 3 3 5 1124	1600 3 3 5 1124	1600 3 3 5 1124	0 1600 3 3 5 1124	1600 3 3 5 1124	1600 3 3 5 1124	0 1400 3 3 5 1104	1400 3 3 5 1104	1400 3 3 5 1104	1400 3 3 5 1104	1400 3 3 5 1104	1400 3 3 5 1104	1400 3 3 5 1104	1400 3 3 5 1104	0 1400 3 3 5 1104	1400 3 3 5 1104	1400 3 3 5
Colour Auto CC Drs Cyl Grs Wght G_P	1800 3 3 6 1189	0 1800 3 3 6 1189	0 1800 3 3 6 1189	0 1800 3 3 6 1189	0 1800 3 3 6 1189	0 1800 3 3 6 1189	0 1800 3 3 5 1189	0 1600 3 3 5 1109	0 1600 3 3 5 1069	0 1600 3 3 5 1109	0 1600 3 3 5 1109	1 1600 3 3 5 1174	0 1600 3 3 5 1124	0 1600 3 3 5 1124	0 1600 3 3 5 1124	0 1600 3 3 5 1124	0 1600 3 3 5 1124	1600 3 3 5 1124	0 1600 3 3 5 1124	0 1600 3 3 5 1124	1400 3 3 5 1104	0 1400 3 3 5 1104	0 1400 3 3 5 1104	0 1400 3 3 5 1104	0 1400 3 3 5 1104	0 1400 3 3 5 1104	0 1400 3 3 5 1104	0 1400 3 3 5 1104	1400 3 3 5 1104	0 1400 3 3 5 1104	0 1400 3 3 5
Colour Auto CC Drs Cyl Grs Wght G_P	0 Silver 0 1800 3 3 6 1189	0 Red 0 1800 3 3 6 1189	0 Red 0 1800 3 3 6 1189	1 Black 0 1800 3 3 6 1189	1 Grey 0 1800 3 3 6 1189	0 Grey 0 1800 3 3 6 1189	1 Grey 0 1800 3 3 5 1189	1 Blue 0 1600 3 3 5 1109	0 Grey 0 1600 3 3 5 1069	1 Grey 0 1600 3 3 5 1109	1 Blue 0 1600 3 3 5 1109	0 Grey 1 1600 3 3 5 1174	1 Black 0 1600 3 3 5 1124	1 Black 0 1600 3 3 5 1124	1 Grey 0 1600 3 3 5 1124	1 Blue 0 1600 3 3 5 1124	1 Blue 0 1600 3 3 5 1124	1 Black 0 1600 3 3 5 1124	0 Grey 0 1600 3 3 5 1124	1 Blue 0 1600 3 3 5 1124	1 Silver 0 1400 3 3 5 1104	1 Blue 0 1400 3 3 5 1104	1 Black 0 1400 3 3 5 1104	1 Grey 0 1400 3 3 5 1104	1 Grey 0 1400 3 3 5 1104	0 Grey 0 1400 3 3 5 1104	0 Grey 0 1400 3 3 5 1104	1 Blue 0 1400 3 3 5 1104	1 Green 0 1400 3 3 5 1104	0 Blue 0 1400 3 3 5 1104	0 Blue 0 1400 3 3 5
CC Drs Cyl Grs Wght G_P	0 Silver 0 1800 3 3 6 1189	0 Red 0 1800 3 3 6 1189	0 Red 0 1800 3 3 6 1189	1 Black 0 1800 3 3 6 1189	1 Grey 0 1800 3 3 6 1189	0 Grey 0 1800 3 3 6 1189	1 Grey 0 1800 3 3 5 1189	1 Blue 0 1600 3 3 5 1109	0 Grey 0 1600 3 3 5 1069	1 Grey 0 1600 3 3 5 1109	1 Blue 0 1600 3 3 5 1109	0 Grey 1 1600 3 3 5 1174	1 Black 0 1600 3 3 5 1124	1 Black 0 1600 3 3 5 1124	1 Grey 0 1600 3 3 5 1124	1 Blue 0 1600 3 3 5 1124	1 Blue 0 1600 3 3 5 1124	1 Black 0 1600 3 3 5 1124	0 Grey 0 1600 3 3 5 1124	1 Blue 0 1600 3 3 5 1124	1 Silver 0 1400 3 3 5 1104	1 Blue 0 1400 3 3 5 1104	1 Black 0 1400 3 3 5 1104	1 Grey 0 1400 3 3 5 1104	1 Grey 0 1400 3 3 5 1104	0 Grey 0 1400 3 3 5 1104	0 Grey 0 1400 3 3 5 1104	1 Blue 0 1400 3 3 5 1104	1 Green 0 1400 3 3 5 1104	0 Blue 0 1400 3 3 5 1104	0 Blue 0 1400 3 3 5
Colour Auto CC Drs Cyl Grs Wght G_P	Petrol 195 0 Silver 0 1800 3 3 6 1189	Petrol 195 0 Red 0 1800 3 3 6 1189	Petrol 195 0 Red 0 1800 3 3 6 1189	Petrol 195 1 Black 0 1800 3 3 6 1189	Petrol 195 1 Grey 0 1800 3 3 6 1189	Petrol 195 0 Grey 0 1800 3 3 6 1189	Petrol 195 1 Grey 0 1800 3 3 5 1189	Petrol 113 1 Blue 0 1600 3 3 5 1109	0 Grey 0 1600 3 3 5 1069	Petrol 113 1 Grey 0 1600 3 3 5 1109	1 Blue 0 1600 3 3 5 1109	0 Grey 1 1600 3 3 5 1174	Petrol 113 1 Black 0 1600 3 3 5 1124	Petrol 113 1 Black 0 1600 3 3 5 1124	1 Grey 0 1600 3 3 5 1124	Petrol 113 1 Blue 0 1600 3 3 5 1124	Petrol 113 1 Blue 0 1600 3 3 5 1124	1 Black 0 1600 3 3 5 1124	Petrol 113 0 Grey 0 1600 3 3 5 1124	Petrol 113 1 Blue 0 1600 3 3 5 1124	Petrol 100 1 Silver 0 1400 3 3 5 1104	Petrol 100 1 Blue 0 1400 3 3 5 1104	Petrol 100 1 Black 0 1400 3 3 5 1104	1 Grey 0 1400 3 3 5 1104	Petrol 100 1 Grey 0 1400 3 3 5 1104	Petrol 100 0 Grey 0 1400 3 3 5 1104	0 Grey 0 1400 3 3 5 1104	Petrol 100 1 Blue 0 1400 3 3 5 1104	Petrol 100 1 Green 0 1400 3 3 5 1104	0 Blue 0 1400 3 3 5 1104	0 Blue 0 1400 3 3 5
KM Fuel HP MC Colour Auto CC Drs Cyl Grs Wght G_P	31463 Petrol 195 0 Silver 0 1800 3 3 6 1189	43612 Petrol 195 0 Red 0 1800 3 3 6 1189	32191 Petrol 195 0 Red 0 1800 3 3 6 1189	23002 Petrol 195 1 Black 0 1800 3 3 6 1189	34133 Petrol 195 1 Grey 0 1800 3 3 6 1189	18741 Petrol 195 0 Grey 0 1800 3 3 6 1189	34002 Petrol 195 1 Grey 0 1800 3 3 5 1189	21718 Petrol 113 1 Blue 0 1600 3 3 5 1109	25565 Petrol 113 0 Grey 0 1600 3 3 5 1069	64361 Petrol 113 1 Grey 0 1600 3 3 5 1109	67662 Petrol 113 1 Blue 0 1600 3 3 5 1109	43907 Petrol 113 0 Grey 1 1600 3 3 5 1174	56351 Petrol 113 1 Black 0 1600 3 3 5 1124	32222 Petrol 113 1 Black 0 1600 3 3 5 1124	25815 Petrol 113 1 Grey 0 1600 3 3 5 1124	28452 Petrol 113 1 Blue 0 1600 3 3 5 1124	34547 Petrol 113 1 Blue 0 1600 3 3 5 1124	41417 Petrol 113 1 Black 0 1600 3 3 5 1124	44144 Petrol 113 0 Grey 0 1600 3 3 5 1124	11092 Petrol 113 1 Blue 0 1600 3 3 5 1124	9752 Petrol 100 1 Silver 0 1400 3 3 5 1104	35201 Petrol 100 1 Blue 0 1400 3 3 5 1104	29512 Petrol 100 1 Black 0 1400 3 3 5 1104	32694 Petrol 100 1 Grey 0 1400 3 3 5 1104	41002 Petrol 100 1 Grey 0 1400 3 3 5 1104	43002 Petrol 100 0 Grey 0 1400 3 3 5 1104	25002 Petrol 100 0 Grey 0 1400 3 3 5 1104	10002 Petrol 100 1 Blue 0 1400 3 3 5 1104	25331 Petrol 100 1 Green 0 1400 3 3 5 1104	27502 Petrol 100 0 Blue 0 1400 3 3 5 1104	49061 Petrol 100 0 Blue 0 1400 3 3 5
Fuel HP MC Colour Auto CC Drs Cyl Grs Wght G_P	Petrol 195 0 Silver 0 1800 3 3 6 1189	Petrol 195 0 Red 0 1800 3 3 6 1189	Petrol 195 0 Red 0 1800 3 3 6 1189	Petrol 195 1 Black 0 1800 3 3 6 1189	Petrol 195 1 Grey 0 1800 3 3 6 1189	Petrol 195 0 Grey 0 1800 3 3 6 1189	Petrol 195 1 Grey 0 1800 3 3 5 1189	Petrol 113 1 Blue 0 1600 3 3 5 1109	0 Grey 0 1600 3 3 5 1069	Petrol 113 1 Grey 0 1600 3 3 5 1109	1 Blue 0 1600 3 3 5 1109	0 Grey 1 1600 3 3 5 1174	Petrol 113 1 Black 0 1600 3 3 5 1124	Petrol 113 1 Black 0 1600 3 3 5 1124	1 Grey 0 1600 3 3 5 1124	Petrol 113 1 Blue 0 1600 3 3 5 1124	Petrol 113 1 Blue 0 1600 3 3 5 1124	1 Black 0 1600 3 3 5 1124	Petrol 113 0 Grey 0 1600 3 3 5 1124	Petrol 113 1 Blue 0 1600 3 3 5 1124	Petrol 100 1 Silver 0 1400 3 3 5 1104	Petrol 100 1 Blue 0 1400 3 3 5 1104	Petrol 100 1 Black 0 1400 3 3 5 1104	1 Grey 0 1400 3 3 5 1104	Petrol 100 1 Grey 0 1400 3 3 5 1104	Petrol 100 0 Grey 0 1400 3 3 5 1104	0 Grey 0 1400 3 3 5 1104	Petrol 100 1 Blue 0 1400 3 3 5 1104	Petrol 100 1 Green 0 1400 3 3 5 1104	0 Blue 0 1400 3 3 5 1104	0 Blue 0 1400 3 3 5

Page 3 9B20E002

EXHIBIT 1 CONTINUED

Configuration	Definition
Price	Offer price in CA\$
Age	Age in months
KM	Accumulated kilometers on odometer
Fuel	Fuel type (Petrol, Diesel, CNG)
HP	Horse power
MC	Metallic colour? (Yes=1, No=0)
Colour	Colour (blue, red, grey, silver, black, etc.)
Auto	Automatic (Yes=1, No=0)
CC	Cylinder volume in cubic centimeters
Drs	Number of doors
Cyl	Number of cylinders
Grs	Number of gear positions
Wght	Weight in kilograms
G_P	Guarantee period in months
Mfr_G	Within manufacturer's guarantee period (Yes=1, No=0)
ABS	Anti-lock brake system (Yes=1, No=0)
Abag_1	Driver airbag (Yes=1, No=0)
Abag_2	Passenger airbag (Yes=1, No=0)
AC	Automatic air conditioning (Yes=1, No=0)
Comp	Board computer (Yes=1, No=0)
CD	CD player (Yes=1, No=0)
Clock	Central lock (Yes=1, No=0)
Pwin	Powered windows (Yes=1, No=0)
PStr	Power steering (Yes=1, No=0)
Radio	Radio (Yes=1, No=0)
SpM	Sport model (Yes=1, No=0)
M_Rim	Metallic rim (Yes=1, No=0)
Tow_Bar	Tow bar (Yes=1, No=0)

Source: Created by the case author.