The Military and Real Estate: A Monocentric Study of the Effect of City Business District Distance on Housing Prices Near Military Installations

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Abstract: Due to mission requirements, active duty service members transition between duty stations multiple times during their service. During the transition, known as a permanent change of station, service members must decide whether to live in on-post housing at their new duty station or to live in the surrounding area. In this study, the factors that affect the pricing of a house were analyzed to provide insight on real estate markets around military installations. This study specifically focused on the relationship between the driving travel time to the installation and the home price. Web scraping was used to collect real estate information within the proximity of preselected military facilities, a Google Maps application programming interface was utilized to collect drive times, and statistical models were built to synthesize the data. House prices were found to have an inverse relationship with drive time to nearby military installations.

Keywords: Central Business District, Monocentric City Model, Real Estate, Statistical Analysis

1. Introduction

1.1 Background

Personnel in the United States' Armed Forces experience constant geographical change over their careers that require them to adapt to new areas on the nation. Service members most likely will be required to move more frequently than civilian counterparts. Along with the administrative work needed to obtain processing orders, getting assigned a new position with a new unit, moving personal belongings and gear, finding new school districts for children (if applicable), and potentially adjusting to a new climate, servicemembers must find a new place of residence. In the process of finding a new place to live, there are many considerations to be made to include proximity to work, distance from the commercial business district, and the affordability of the desired neighborhood.

One of these important considerations for choosing where to live is the duration of the commute to work. The amount of time it takes to drive from an individual's place of residence to their place of work and back can affect the attractiveness of a house. Drive time is especially important for servicemembers due to early morning physical training and military training exercises that go late into the night. A longer drive would mean leaving for work earlier and getting home later. Servicemembers also consider the school district for their children and the price they can afford based on the Basic Allowance Housing (BAH) they receive. Each time a member of the armed forces moves, the decision on where to live is a decision left to the individual soldier or family to figure out without any knowledge of the neighborhood, city, or state. Therefore, analysis of housing markets around military installations could better inform service members in the housing decision experienced every two to three years.

1.2 Literature Review

Many economic studies have analyzed the concept of the central business district (CBD), the location where the majority of jobs and economic activity occurs. Distance to the CBD is commonly chosen as the independent variable in

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studies and are found to have a significant effect on property prices (De Bruyne and Van Hove, 213; Yiu and Tam, 2004). In his study on real estate price indexes, Palmquist noted the benefit to studying housing markets is the vast amount of data available on "…structural and neighborhood characteristics that can be expected to have significant effects on the price of a house" that can be easily accessed using online databases such as Zillow (1980). When analyzing these characteristics' effects on a house's price, the time required to drive that physical distance may have a more significant effect than straight line distance (Osland et al., 2007; Söderberg and Janssen, 2013). A combination of low travel times and distance from unattractive sources of noise pollution have both been found to increase housing prices (De Bruyne and Van Hove, 2013; Waddell et al., 1993). The trend of housing prices decreasing with an increased distance from the CBD is present in foreign housing markets as well (Chen and Hao, 2008). However, in large metropolises, CBD distance has been found to be statistically insignificant when a polycentric city concept occurs, where multiple influential economic centers exist (Heikkila et al., 1989). Finally, additional geographical factors such as distance to railroad stations, landfills, airports, and wetlands have been found to have significant effects on housing prices (Hess and Almeida, 2007; Nelson et al., 1992; Espey and Lopez, 2000; Doss and Taff, 1996).

1.3 Assumptions

The baseline assumption for this study is that housing prices increase as distance to the CBD, specifically a nearby military installation, decreases with all other factors held equal. This assumption is being made and tested for accuracy because it is believed that military personnel living off post will want to live as close as possible to the military installation where they are stationed and that they value the shortest possible drive time to work. Proximity to one's assigned military installation matters because military personnel need to get to work frequently, consistently, and often quickly.

Another assumption being made in this study is that housing prices can be modeled linearly if enough variables and characteristics, both linear and categorical, associated with a house are included. Later, the selection of such variables and characteristics will be further explained. Finally, this study will compare models to see if these trends hold constant for both training installations and installations that contain operational units. An anti-thesis case study location will also provide insight to more complex locations as later discussed.

1.4 Location Selection

In selecting locations to serve as case studies for this study, many considerations were made to conduct accurate statistical analysis and representative conclusions. The first consideration and decision made was to select multiple locations to provide not only many observations, in this case many houses, but also to have multiple locations that are geographically spread across the United States. In doing so, conclusions made from this study may be applied more broadly. To test if the presence and proximity of the selected military installation influenced housing prices in the immediate area, those isolated from large cities, tourist destinations, large airport, local attractions, and other sources of economic development were selected.

In accordance with these specifications: Fort Rucker, Alabama; Fort Drum, New York; and Fort Hood, Texas were selected. Forts Rucker, Drum, and Hood all satisfy these constraints and therefore qualify for evaluation. Fort Carson was also included as an anti-thesis case study as it is co-located with a major airport, large tourist attractions such as skiing and other outdoor activities, the Air Force Academy, and a large city that is a major source of economic development in the area. The expected trend for the Fort Carson case study is that the anticipated trend, increased housing prices when closer to a military installation, will not be present because many other highly influential and difficult to model variables affect an individual's attraction to the area and valuation of a home based on location.

One additional consideration taken when selecting the military installations was the type of unit present. Fort Carson is home to the 4th Infantry Division, Fort Drum is home to the 10th Mountain Division, and Fort Hood is home to the 1st Calvary Division, all large operational units that are on regular garrison/deployment cycles. Fort Rucker, on the contrary, is exclusively home to a training unit, the 1st Aviation Brigade, that oversees training new Army pilots and advancing the technical expertise of personnel at various stages of their career. The demographics including age, rank, and socioeconomic status, of the population of military personnel that are assigned to a training unit are different than those assigned to a large operational unit. This distinction is important to understand and will be considered later in analysis of the housing markets of the locations due to its potential effect on what types and sizes of houses are valued higher in these different locations. In summary, this study analyzes the housing markets surrounding the military installation for one isolated training unit, two isolated operational units, and one non-isolated operational unit. These varied locations provide a large dataset for analysis and contain a diverse set of housing markets to investigate.

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1.5 Variable Selection

Once the locations were selected for this study, housing characteristics were selected for appropriate and representative statistical analysis. For this study, the online real estate database Zillow was used to collect information about the real estate markets around the selected military installations. In selecting housing characteristics for this study, a few considerations were made. First, the characteristics used had to be consistent across all listings and locations. To increase the consistency of listings studied, only listings labeled as 'For Sale' by Zillow were considered because they contained all the characteristics chosen in this study. Finally, characteristics that are known to have a major influence on an individual's choice to purchase a house, such as size and amenities, were considered.

Table 1 shows a summary of the variables selected for analysis and the case study location data sets. For each variable, the minimum, maximum, and mean values are provided for reference. This information shows some baseline trends in the variation between locations for average house prices, consistency in number of beds, and a lower average drive time for the Fort Rucker case study.

Table 1. Variable Data Summary

Summary Statistics	Fort Carson (N = 869)	Fort Drum (N = 293)	Fort Hood (N = 1,005)	Fort Rucker (N = 447)
Price				
Minimum	59900	6900	22000	17900
Maximum	986500	599600	1920000	725000
Mean	403191.2	128818.3	228896.9	174122.5
Beds				
Minimum	2	2	2	2
Maximum	5	5	5	5
Mean	3.636364	3.481229	3.569154	3.257271
Baths				
Minimum	1	1	1	1
Maximum	5	5	5	5
Mean	2.992520	1.914676	2.374129	2.341163
Size_SqFt				
Minimum	730	700	624	772
Maximum	7494	6451	6151	6421
Mean	2687.604	1786.294	2086.171	1958.776
Time_min				
Minimum	8.683333	5.833333	8.683333	7.533333
Maximum	41.11667	41.18333	59.85000	32.55000
Mean	25.36419	22.14170	29.76731	17.66984

In addition to the housing variables scraped from Zillow, a geographical characteristic was collected for each observation of the location's datasets, the time to drive to the corresponding military installation. These characteristics were used as further dependent variables in the statistical analysis described later to understand the relationship between the price of a house and the distance to its closest military installation.

2. Methodology

2.1 Statistical Computation Program

To conduct the statistical analysis of the aforementioned variables, the R programming language and software environment was used. R was used because it efficiently takes advantage of open source packages, aids the troubleshooting process, and can be programmed to interact with many programs such as the suite of Google applications. R, in addition to processing data scraped from internet sources, was used to create statistical models and corresponding analysis as well as to create graphics for a visual representation of trends found in the data. R packages used in this study include: *tidyverse, rvest, rebus, lubridate, svDialogs, gmapsdistance,* and *gpplot2*.

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2.2 Model Formulation

In formulating a linear model for future statistical analysis, the independent variable was the price of a house and the dependent variables were the number of bedrooms and bathrooms, the total square footage of the house, the distance from the house to the corresponding military installation, the drive time from the house to the corresponding military installation, and the city in which the house is located (to be used as a categorical variable, addressed later in this study). Equation 1 shows the general form of this linear model.

House Price = Drive Time (min.) + Number of Bedrooms + Number of Bathrooms + House Size (Sq. Ft.) + City(factor)*   (1)
    * = City where House is located (0 or 1) for each city in the case study location)

The next step in the model formulation process was to determine a city that would be used as the baseline factor. This city baseline factor would be used as the point of comparison for each of the cities' categorical variable. The city used as the baseline factor for each case study location was the main city outside of and the city that has a large presence in supporting the military installation. These baseline locations include Enterprise, AL for Fort Rucker, Watertown, NY for Fort Drum, Killeen, TX for Fort Hood, and Colorado Springs, CO for Fort Carson.

Table 2. Model Summaries

Predictors	Fort Rucker Estimates	p	Fort Hood Estimates	p	Fort Drum Estimates	p	Fort Carson Estimates	p
(Intercept)	-4235.85	0.782	-143237.87	<0.001	-83170.53	0.019	132821.03	<0.001
Time min	1404.98	0.047	3837.28	0.001	6444.14	<0.001	-1826.79	<0.001
Beds 2	-8331.64	0.393	-3762.99	0.874	-4922.98	0.769	5755.99	0.608
Beds 4	31800.55	<0.001	-16449.64	0.070	-8306.14	0.333	10196.29	0.227
Beds 5	-605.40	0.975	-30809.99	0.105	-24976.26	0.169	3929.22	0.721
Baths 1	-20147.41	0.097	-12950.52	0.505	-12261.48	0.213	20967.33	0.203
Baths 1.5	-2949.18	0.876	-52852.30	0.288	-4370.95	0.728		
Baths 2.5	6826.77	0.634	-8088.26	0.665	81892.90	<0.001	-857.22	0.985
Baths 3	18020.87	0.018	12168.05	0.263	57434.61	<0.001	12431.36	0.174
Baths 3.5	29112.15	0.188	18657.78	0.544			65097.45	0.091
Baths 4	54381.32	0.002	6881.17	0.761	-5390.67	0.820	39510.33	0.001
Baths 5	84979.19	0.004	123225.17	0.018	32390.52	0.501	133801.84	<0.001
Size Sq Ft	78.03	<0.001	130.63	<0.001	45.41	<0.001	108.39	<0.001
Daleville	-27949.76	0.011						
New Brockton	-17873.42	0.334						
Newton	4544.79	0.696						
Ozark	-49068.95	<0.001						
Baths 4.5			30977.98	0.797			22818.50	0.530
Belton			67731.90	<0.001				
Copperas Cove			-5183.49	0.730				
Gatesville			-36296.39	0.309				
Harker Heights			-37149.03	0.240				
Lampasas			13260.93	0.650				
Temple			-50068.12	0.043				
Carthage					27206.68	0.045		
Gouverneur					-130851.89	<0.001		
Observations	447		1005		293		869	
R^2 / adjusted R^2	0.711 / 0.700		0.461 / 0.451		0.423 / 0.397		0.681 / 0.676	

When reading the output of the linear model summaries in Table 2, the estimates show the strength of the city's effect on the price of the house. For example, if the estimate for the coefficient in the model for Belton, TX was listed as 10,000 and had a statistically significant p-value (less than 0.05), it would be interpreted that a house located in Belton, TX would be estimated as costing $10,000 more than a house with equivalent characteristics in Killeen, TX (the case study

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location's baseline location factor). The trend of price differences among cities may be attributed to the attraction level or popularity of such cities.

The best fit models in this case study have the highest R Squared value. Increasing a model's R Squared value means the model can explain a larger percentage of the data with statistical significance. Transformations were also performed on each of the variables to test for an increased coefficient of determination (or, R Squared value). The transformations that increased the models' coefficient of determination in this study were logarithmic and square root transformations.

2.3 Analysis Considerations

For the analysis in this study, there were a few select factors taken into consideration before making statistical conclusions from the modeling and calculations done. The biggest consideration was how to interpret the results of the statistical modeling and how they supported or negated the hypothesis that housing price increases as distance from the house to the CBD, specifically a nearby military installation, decreases with all other factors held equal. The first consideration was to include the aforementioned major variables. If these important variables were not considered, conclusions made on trends and on the hypothesis of this study would hold less statistical and practical significance.

The next consideration before making conclusions in the study was the determination of statistical significance of the drive time from a house to the corresponding military installation. If the p-value correlating to the drive time variable was found to be less than 0.05, then that variable was considered statistically significant. If significant, a negative coefficient for either variable would be interpreted as a decrease in house price as distance from the military installation increased, which supports this study's hypothesis and assumption.

The final two considerations for this study's analysis were to interpret results on an all things held equal basis and to analyze the effect of the city categorical variable on the hypothesis. In interpreting the linear models' statistical calculations, conclusions must consider that any statistically significant variables' coefficients effect the price of a house when all other factors are equal between two locations. Additionally, analyzing the effect of the city categorical may provide some beneficial insight as to the accuracy of the hypothesis. If the drive time variable is found to be statistically significant, the city factor allows the impact of the drive time variable to be analyzed while accounting for unique factors of various cities/neighborhoods such as city specific crime, school districts, and age of the city. The city factor essentially removes these unique and hard to model variables from the effect of drive time.

3. Conclusion and Future Work

3.1 Model Conclusions

Conclusions from the models created in this study have a variety of applications and impact for military personnel looking for a new home at their next duty station as well as for the Army as an organization in how it selects locations and determines the layout of new military installations. The original hypothesis for this study was the house price would increase as drive time from a house to the associated military installation decreased. While this trend was not found to be true, the significance of drive time's relationship to a house price was found to exist and be significant. This may be caused by unattractive factors such as noise pollution, traffic, or light pollution caused by a closer proximity to a military installation that may drive nearby house prices down, which was not considered during the creation of this study. Additionally, unattractive businesses such as tattoo parlors, pawn shops, and saloons may negatively affect the prices of houses closest to military installations due to their close proximity to military installations. Of note, this trend was not present in the Fort Carson case study location. The model for Fort Carson was the only model to have a negative slope that describes the decrease in house prices as drive time to the military installation increases. This opposing trend was expected as Fort Carson's surrounding area, the city of Colorado Springs has many factors that affect the attractiveness of houses. The military installation is most likely not the CBD for the area surrounding Fort Carson. Finally, as seen in Figure 1, when plotted against drive time, the residuals of the data (not including drive time) for each of the case study locations is randomly and evenly distributed around a horizontal trend line. This means that the data can be accurately and appropriately represented by a linear model moving forward with analysis.

When analyzing the model summaries found in Table 2, there are a few interesting trends. In the models created in this study, the baseline number of bedrooms and bathrooms were three and two, respectively, because they were the most common arrangements in the data collected. Out of the basic housing characteristics, the number of bedrooms was found to be statistically insignificant in affecting the price of a house except in one location. In the Fort Rucker case study, the

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increase from three to four bedrooms was found to increase the price of a house, with statistical significance. In comparison, the number of bathrooms in all four case study locations (as denoted in Table 2 by bold formatted p values for corresponding bathroom count factors) were found to have a statistically significant effect on the price of a house at varying levels. One might expect that more weight is put toward the number of bedrooms in a house during the decision-making process because the house needs to fit the servicemember's family in a certain number of rooms which is less flexible of an arrangement compared to sharing bathrooms. But, the number of bathrooms was found to also have a statistically significant effect on a house's price with a higher coefficient, therefore having a greater effect on a house's price. Another interesting trend resulting from the model summaries is the city factors found to be significant (their associated p-values are bolded in the middle of the table presented in Table 2). Certain cities (such as Daleville, Ozark, and Gouverneur) were found to have a negative effect on a house's price compared to the associated baseline city just outside the military installation whereas other cities (such as Belton and Carthage) were found to increase the price of a house in comparison.
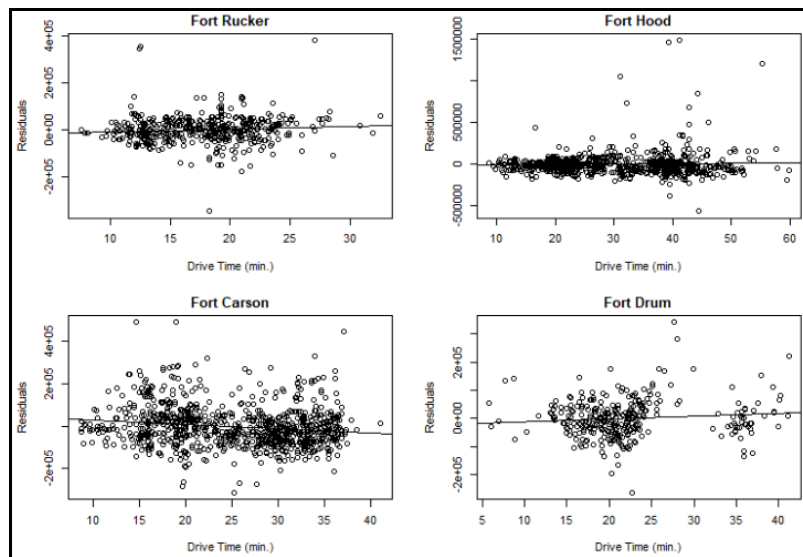

Figure 1. Residuals vs. Drive Time for Each Location

Finally, when looking at the coefficients of determination, or R^2 values, the only two locations to have coefficients of determination higher than 50% were Fort Rucker and Fort Carson. The two isolated operational unit case study location, Fort Hood and Fort Drum, had much lower coefficients of determination. While none of these models had high enough coefficients of determination to be used for predictive purposes, the models did a better job accounting for variation in the housing markets around Fort Rucker and Fort Carson. Fort Hood and Fort Drum were more difficult to model and account for the majority of variables that effect house prices, missing over half of the factors at the Fort Hood and Fort Drum locations that affect a house's price. It is difficult to conclude what other variables may be affecting the house prices at those locations, but that could be the subject of future work.

In conclusion, for a servicemember experiencing the PCS process and moving to a new military installation, there are many factors to consider when buying or renting a new house and finding one that best suits the needs and desires of their family. Based on the findings of this study, a house that is farther away from an individual's assigned military installation can be expected, with statistical significance, to be more expensive. While this is the inverse of the trend in the hypothesis of this study, it is important to consider when searching for a suitable new home. It is recommended that servicemembers weigh the benefits of living farther away or closer to a military installation with their housing allowance and budget for a new house. Another important factor taken from the results of this study that should be considered by members of the armed forces when moving is the neighborhood and town they are moving into. Some towns are more attractive and thus may have more highly valued properties.

Another perspective and takeaway from this study is for the United States Army as an organization. When creating new military installations, the lack or presence of nearby large economic centers near the base, the selection of how many entry points and where they are located, and the selection of training area or weapon range locations could all affect a city's attractiveness to new servicemembers or civilians due to drive time or relative location and therefore have a large impact on

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the real estate market in that city. Sometimes the city where a house is located does not have a statistically significant impact on that house's price, reflecting a neutral attractiveness toward that city. But, other times, as seen in this study, the city can have a significantly large effect on a house's valuation which should be considered by both servicemembers and those who decide where new military installations will be located.

3.2 Future Work

To improve this study in the future, the modeling and statistical analysis would benefit from a greater number of case study locations. An increase in observations and different locations across the nation would make the statistical conclusions more accurate and applicable across the United States. Additionally, added variables such as corresponding school districts' national rank, distance to the nearest airport, and distance to the next largest city with a population of over 200,000 people would be beneficial variables to add to the modeling process for geographical characteristics and considerations. These variables might produce statistically significant insights that would improve the understanding of housing markets surrounding military installations, specifically the United States Army installations. Adding variables for drive times at three or more times in the day would create a more accurate understanding of drive time's effect on housing price given commuting trends occurring at different times of the day with associated traffic. Finally, the ability to break down large cities such as Colorado Springs into neighborhoods would allow applicable conclusions to be made from models of case study locations that have large cities in the immediate surrounding area as with Fort Carson, CO. As for housing characteristics, adding variables for the year a house was built, the number of floors, and the size of the house's lot would allow for more control variables to be included in the study and provide a model that accounts for a greater amount of the variation in housing data.

When looking at plots of house prices versus drive time to the corresponding military installation for each case study location, depicted in Figure 2, a few patterns can be seen that lead to possible future analysis. In each of the plots in Figure 2, each house listing in the datasets collected are plotted as semi-translucent black points. Where there are concentrations of listings, a more opaque shade of black occurs. Firstly, in the plot of the Fort Carson case study area, there aren't any major patterns in the data set. The house prices and corresponding drive times are quite varied. As previously stated, this case study location is the anti-thesis for this study and thus a correlation and patterns in the data were not expected. For the next two plots in Figure 2, corresponding to the Fort Drum and Fort Hood case study locations, there are two concentrations of listings around twenty and forty minutes in drive time. While the listings at both drive times are concentrated around the same price, this split in listings may correspond to two levels of attraction to houses close and farther away from each military installation. Future analysis might find that a certain demographic, based on age, years of service, or enlisted versus commissioned officers, prefers one of the distances, twenty or forty minutes of drive time, from the nearby military installation. Finally, in the plot corresponding to the Fort Rucker case study location, there is a general concentration of listings without a division or apparent pattern. This may be explained, by future analysis, by the unique populations stationed at Fort Rucker and their effect on the local housing market. Since the majority of military personnel stationed at Fort Rucker are lieutenants assigned to Flight School or captains assigned to the Aviation Captain's Career Course (CCC). Because both populations of military personnel are only assigned to Fort Rucker for short periods of time, around a year long, compared to other duty stations, they may prefer to be located closer to the military installation. This is seen in the majority of listings located around twenty minutes in drive time. The patterns depicted in Figure 2 and discussed in this section could exist as the basis for future studies to create more accurate deterministic models for the real estate markets around military installations.

The creation of a tool built for both servicemembers and realtors to understand housing markets in the areas surrounding military installations would greatly benefit those populations. An easy to use tool that encompasses all the data and modeling in this study as well as the suggestion for expansion mentioned previously would provide insight and allow for more educated and informed decisions regarding the purchase or rental of houses across the nation. Doing a comparison of what variables are found to have a statistically significant effect on a house's price that is rented versus for sale could provide additional insight. Expanding the breadth and depth of this study through added observations and variables would make it a more applicable and usable real estate tool to help guide expectations for a population of Americans that moves many more times than their civilian counterparts.
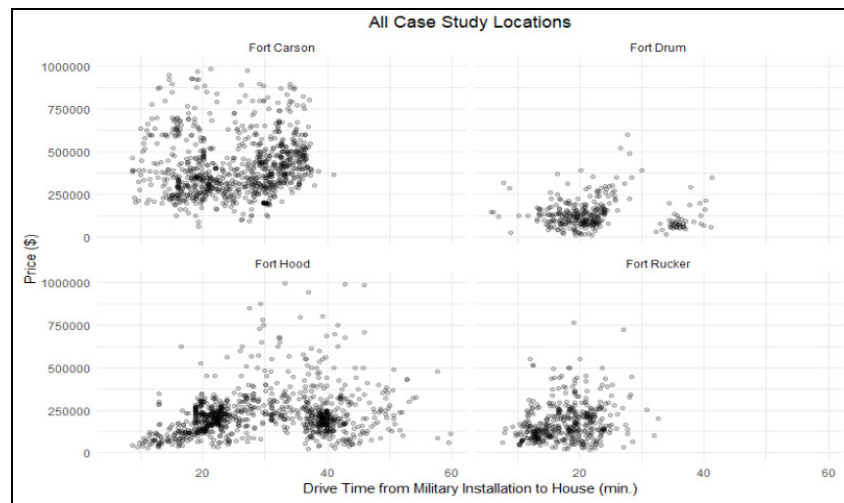
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Figure 2. House Price vs. Drive Time for Each Installation

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