Does Price Buy Performance or Satisfaction in an HF Transceiver?

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The Beatles made the phrase “Money can’t buy me love!” famous as did the Rolling Stones with “I can’t get no satisfaction!” And there is the ever-popular, “You get what you pay for!”. But does this logic apply to buying an HF transceiver in amateur radio? Making a purchase decision for a new rig captures the consciousness of hams right up there with what antenna should I use but usually comes in first place.

The ARRL does not recommend specific rigs as a policy but it has a web page devoted to the question. Some years ago, it published a two-page article, “Lab Notes: What Rig Should I Buy?” and listed several technical aspects common to transceivers that a prospective buyer should examine before making a purchase decision. Any ham fest, club meeting, or online forum group are sources of a wide variation in HF rig recommendations. Just don’t expect them to be either consistent or reconcilable with one another. So how does a ham in the market for a new HF rig combine all of these suggestions? Perhaps this article can help narrow down a smaller set of rigs to fit your personal taste.

In this article, I use a unique dataset compiled from three known sources. This allows me to compare a list of popular HF transceivers and receivers covering the past 50 years by their retail price, measured receive performance by Rob Sherwood NC0B and overall satisfaction by hams who reported their experiences using a consistent rating scale.[2] While there are both transceivers and receivers in the Sherwood Tables, I use the term *rig* to cover both of them to make the double wording less cumbersome. You will find these results to be both expected, as in “*Aha,* I knew it,” as well as very surprising. They put a far more precise point on using any of these three sets of data on HF rigs alone or by mentally juggling them all by oneself. My goal is to assist readers in their thinking about HF transceivers past and present and what to generally expect from the outlay of funds in purchasing one of them on the Sherwood list, whether new or used. In addition, the results illustrate the typical receive performance one might experience for the price point as released to the market. Nonetheless, the ham operator in the market should always use his or her preferences for an HF rig in addition to bench measurements of receive performance and how others say they feel about the rig being considered.

The sources used here are already well-known to and used by most amateurs. The League has been testing new products in it’s Laboratory for decades.[3] The *QST* Product Review archive is a source of these reviews based upon published measurement standards. In 1976, Rob Sherwood NC0B began

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1 My sincere thanks are expressed for the numerous communications I’ve had with Rob Sherwood NC0B on his bench test tables document and RF testing in general. None of this work should carry his endorsement and any errors are my own. I appreciate the communications with Mark Wilson K1RO at ARRL on the QST Product Reviews and how they have sourced pricing of rigs for their reviews. Discussions with Bob Allison WB1GCM at the ARRL Lab are also much appreciated. No endorsements by any of these three should be inferred by the reader.

2 A more modest but worthwhile attempt to compile current “discounted” retail prices and the Sherwood Table was published by Rick DJ0IP. See https://www.dj0ip.de/sherwood-forest/performance-cost/. His analysis is worth reading. It does not contain retail price circa year introduced into the marketplace but instead traces the fluctuation of retail prices after release.

3 These tests are detailed in the ARRL Test Procedures Manual at http://www.arrl.org/files/file/Technology/Procedure%20Manual%202011%20with%20page%20breaks.pdf.

testing HF transceivers and receivers to compare notes on what he read in *QST* regarding the Drake R-4C receiver he was using in CW contests. He began publishing his bench test results in print for those who wanted them.

Since that time, the Sherwood Tables have become an equally prominent and trusted source of information about the receive performance of both receivers and transceivers used in amateur radio. They are certainly results that manufacturers watch and use to make changes to their equipment as they do with the ARRL's Laboratory staff.[4] As the ARRL's two page guide says,

"*You've finally got some cash to spend on Amateur Radio equipment, but you want to make the right choice. Ask any veteran ham and he or she will tell you about that #%&$@ radio they purchased. No one wants to throw away money, but how do you know which rig is best?*"[5]

Indeed, that fundamental question beguiles most hams, whatever their experience, as they consider the purchase of a rig. It's safe to say that the vast majority of licensed amateurs are not experimenters or have the skills and equipment to conduct similar tests themselves. It's fortunate for them to have these sources of objective bench tests on most rigs available on the market for the past several decades.

There is also a crowd-sourced set of reviews published by eHam.net. They are voluntary and do not reflect all consumers of a given product, only those who submit their assessments. It's important to keep that in mind. They go back a number of years for various products and services in the ham radio marketplace. They offer the reviewer an opportunity to respond to a consistent 1-5 rating scheme with a headline and text narrative explaining their experiences and opinions. But these "reviews" are essentially consumer satisfaction reviews, not workbench tests. One definition of consumer satisfaction is "It is a measure of how products and services supplied by a company meet or surpass customer expectation."[6] The crowd-sourced (voluntary) eHam.net statements and ratings are typical for online product and service reviews but less sophisticated than one industry standard of three questions rated 1-10 by consumers (the American Customer Satisfaction Index).[7] But the eHam.net Product Reviews web page is our *only* consistent source of such consumer satisfaction measures across a wide array of ham radio products, including HF rigs.

These two approaches to evaluating rigs should not be confused or assumed to match precisely. In fact, we do not know how the receive performance of transceivers on a workbench contributes to the satisfaction held by purchasers of them. At least, until this study. In addition, the retail price of a transceiver is also *not* known to be a clear and demonstrable predictor of superior-performing rigs or the consumer satisfaction with them. This flies in the face of the oft-heard wisdom: *you get what you pay for.* Addressing these questions is the focus of this article. *Does retail price paid for an HF rig yield bench measured (receive) performance or typical customer satisfaction?* I approach this by describing a unique dataset I have assembled from the Sherwood Tables, eHam.net website Product Review ratings, and *QST* pricing information supplemented with various other sources for the year the rig was introduced to the market. I've also added the number of reviews of each rig on eHam and the

4 Hear my interviews with Rob Sherwood NC0B and Bob Allison WB1GCM on the ICQ Podcast in episodes 305 and 312 respectively for many details. They can be found at icqpodcast.com.

5 Steve Ford, "Lab Notes: What Rig Should I Buy?" American Radio Relay League, located at http://www.arrl.org/files/file/Technology/tis/info/pdf/29379.pdf.

6 https://en.wikipedia.org/wiki/Customer_satisfaction.

7 https://en.wikipedia.org/wiki/American_Customer_Satisfaction_Index.

year of the *QST* (and other) review used for retail price.[8] This price-at-introduction is the only consistent means of comparing the price of a rig as no researcher could track down all sales prices over all sellers over all years during the sales life of a rig. If s/he could, the question becomes *which* price would be consistently applied for comparison to performance or consumer satisfaction? This is why I took the time to compile the MSRP-value or subsequent approximation after MSRP was used less by manufacturers for rigs in the Sherwood Tables.

Data Details and Analytical Methods

The *retail price* data are largely from *QST* reviews but, especially for vintage gear, from manufacturer's catalogs and advertisements in magazines (e.g., *CQ*, *Ham Radio Magazine*, *Monitoring Times*, etc.). They are in U.S. dollars. But due to the 50-year time period for the rigs tested in the Sherwood Tables (1950-2019), inflation changes the value of the dollar. So the price variable was converted to constant 2019 dollars using the Consumer Price Index adjustments frequently used by economists for income or price data.[9]

The *customer satisfaction* data is the average eHam rating from 1-5, taken from the Product Reviews portion of the website. This is a *cumulative* average evaluation over time for the life of the set of reviews on eHam.net. It reflects the *total experience* by the reviewer.[10] Note that this site averages all reviews for a product but does not show the *variation* across individual consumers who publish ratings. This is unfortunate in some ways because the individual variation in reviews would be revealing as to how uniformly the ham radio marketplace evaluates a given product or service. It is our only long-term, consistent measurement of consumer satisfaction with amateur radio products and services. Any cursory reading of popular ham radio blogs, websites, and listening on the ham bands reveals that the eHam ratings have currency of opinion in the amateur radio marketplace. Clearly, it is a source that many hams use to guide their purchases. Thus, it is the only effective option for measuring overall *satisfaction* with HF transceivers.

The Sherwood Tables contain several columns reporting the *bench test performance* conducted by Sherwood. He gives a technical description of them in his "Terms Explained" document.[11] He sorts his table based upon a single "favorite" column, close-in dynamic range at 2-kHz spacing. That is his

8 Mark Wilson, Contributing Editor to QST, told me that "*The pricing information is shown in the last paragraph of each QST review. That's not MSRP, but rather the approximate selling price at the time the review was edited. I generally look at a few of the resellers' websites (HRO, DX Engineering, Universal Radio) for that information. The websites generally do show MSRP for current equipment if that helps.*" (personal communication, November 26, 2019). For some vintage gear, I checked pricing information when the rig was released to the market in magazines like CQ, for example, around the month the rig was release for advertised pricing. Often, these were listed in the ads as well as in some manufacturer catalogs as "manufacturer's suggested retail price" (MSRP) or also called "list price". So the "retail" price used here is usually higher than the many discounted sales price points for transceivers or receivers but, I believe, reflects the market value placed upon the rig by the manufacturer. It is thus a reasonable measurement of the *intended* retail price point for the rig itself. Moreover, *is it not why QST and other publication outlets include the manufacturer's price or a reseller's price circa the year of release?* It reflects a signal to the marketplace on the "value" of the rig, regardless of how retail outlets eventually and continually as the rig ages, scale their "for sale" price points for a given rig. For further details, see this link:https://ecommerce-platforms.com/glossary/manufacturers-suggested-retail-price-msrp.

9 See www.bls.gov/cpi/ for details on the CPI and this source for the inflation adjustment procedures: www.bls.gov/cpi/factsheets/escalation.htm.

10 This includes the feature set, aesthetics, ergonomics, price, manufacturer/reseller communication, brand loyalty, and so forth. This is an important aspect of this measure so the reader should bear this in mind in the interpretation of my results.

subjective criterion of an objective measurement, based upon his years of experience both as a bench engineer as well as an active contesting ham operator. Not all hams would necessarily evaluate a rig's performance on that one criterion and, indeed, that is why multiple bench tests are performed.[12] However, for the CW contest operator, this single column might be the sole source for receive evaluation.

A given rig has engineering, design and production results embodied in an entire rig, not various measured "parts" of the rig. A few rigs have no eHam consumer satisfaction reviews and were omitted from the analysis.[13] A few more had multiple entries with an alternate hardware change or something to distinguish the hardware enough to warrant an additional set of measurements. More importantly, the eHam ratings and price cannot reflect separate rigs like this so I used the stock rig tests from the Sherwood, omitting the additional rig versions to keep these measurements consistent. A final count of 126 rigs from the Sherwood Tables which have eHam satisfaction ratings and price data are used in this study. They do not reflect *all* HF rigs manufactured during the period covered but they do contain most all of the major ones over the past few decades. Nonetheless, this should be kept in mind in evaluating the generalization of the results to rigs not in the Sherwood Tables.

It was important to create a *summary* measurement of the rig's measured bench test results. This is because of several issues. One is that buying an HF transceiver (or a receiver) is not at all like *a la carte* ordering in a restaurant. Engineering design by manufacturers combines their corporate priorities for performance and features to meet a target price point, resulting in a mostly fixed "menu choice" among rigs that yield a relatively fixed set of RF characteristics. A buyer, for instance, doesn't specify the RF sensitivity for a rig purchase; the rig chosen simply has a measurable sensitivity rating. Another is the complexity of using all of the bench measurements contained in the Sherwood suite of tests. They will overlap one another such that a given rig that has very good sensitivity is likely to have other superior characteristics but this, too, can vary across rigs. The key question is whether the relevant data in the Sherwood Tables can be effectively summarized into a single composite index measuring the bench performance in receiving HF signals?

After communicating with Rob NC0B about this project, a set of measurements contained in the Sherwood Tables were used for this study. So as to capture all of the tests into a *single* index, I used a statistical procedure (principal components) to take into account how the various tests correlate across the set of rigs in his Tables.[14] This is the first time to my knowledge that anyone has attempted to synthesize all of these measurements of HF receivers by Sherwood into a single index score. As the

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11 See this link: http://www.sherweng.com/documents/TermsExplainedSherwoodTableofReceiverPerformance-RevF.pdf. Sherwood clearly states his understandable preference for the ranking by the "close-in" dynamic range for CW contest operators as he is an active one himself.

12 Rick DJ0IPE also makes this argument at https://www.dj0ip.de/sherwood-forest/performance-cost/.

13 Omitted rigs because of a lack of eHam ratings include these as listed in the Sherwood Tables: Aerial-51 ALT-512, Ten-Tec Omni-B, Collins 75-S3B, Signal/One CX-11A,Lowe HF-235,KWZ-30. An entry for the Flex 6300 noted as "2nd sample" was also omitted because there are no separate consumer satisfaction ratings or pricing information it. Another double entry was for the Kenwood 590SG. Trying to combine the bench tests were intractable because of not knowing which eHam reviews might have covered which sample. So I decided to use the first set of tests by Sherwood for this study. In addition, Sherwood does not have table entries on a few tests for a few rigs, resulting in slightly incomplete data. This issue is handled in the statistical procedure used to summarize the tests through principal component indexes.

14 Covered in most multivariate statistics texts, accessible overviews can be found at: https://en.wikipedia.org/wiki/Principal_component_analysis or https://www.itl.nist.gov/div898/handbook/pmc/section5/pmc55.htm. PCA has frequently been used in RF studies, such as in propagation, for over a half century. See, for instance, W.C. Hoffman (ed.), *Statistical Methods in Radio Wave Propagation.* 1960. New York: Pergamon Press.

results will show, the *Sherwood Performance Index* (SPI) I've created does effectively distinguish HF rigs largely consistent with the single-column Sherwood rankings themselves.

[Figure 1 about here]

A summary of this principal components analysis is shown in Figure 1. I used the measurements under the Sherwood Measurement column (i.e. noise floor, AGC threshold, etc.). The first component accounts for 40.8 percent of what the Sherwood bench tests have in common (see top right panel). The second component pales by comparison in reflecting only16.3 percent of the remaining variation in these measurements after the first component is extracted from the data. This procedure is inductive so judgment in the optimal interpretation is part of the analysis. Examining the dominance of the first component and the *scree plot* of all components extracted (see graph in Figure 1) led to my use of just the first component to create a receive performance index. The *loadings* shown in the Pattern Matrix indicates the relationship that each bench measurement in the Sherwood Tables has to the composite index while the communality puts this in a different metric of the "shared variance" between the bench test and the composite index. The KMO and Bartlett's Test (lower left panel) is statistically significant, demonstrating that this set of measurements does have something in common (versus just a set of unrelated random variables). The resulting linear component has no real world metric so it's expressed as a standardized z-score with a mean of 0 and a standard deviation of 1.0.[15] This was transformed into a T-score (much like the metric of IQ tests) with a mean of 100 and standard deviation of 15. Thus, the average performing rig on all of the Sherwood measurements shown in Figure 1 would have a score of 100 on this Sherwood Performance Index.

[Figure 2 about here]

It is important to first observe how the key indicators of price, performance and satisfaction are distributed before getting to an analysis of how they might be related. In Figure 2, the distributions of these three key variables are displayed using histograms.[16] The rig retail price as presented to the marketplace circa year of introduction is shown in the left panel. The median price of these rigs in 2019 dollar values is $3,145 with an average of $4,297. This is usually the case for a right-skewed distribution. Half of the rigs cost less than about $3,100 but some cost a *lot* more. We will identify those specific rigs below but the standard deviation of $3,914 suggests a wide variation in rig prices over these past few decades even where inflation is held constant. The Sherwood Performance Index has an average of 100. Some rigs perform at about 70 on this index while the best ones score at about 140. This index is similar in shape to a normal curve (see super-imposed line). The eHam satisfaction ratings tend to have a "halo effect" in that they bunch near the top rating of 4.7 (which is also the median score). This measurement has a left-skew with some rigs being rated below 4 out of 5. These three indicators have meaningful variation across the 126 rigs used from the Sherwood Tables, representing many of the most popular ones from a fifty-year period. These descriptive statistics give the reader a basis for better understanding the remaining analyses of how they connect with one another.

Results for Whether Price Buys Performance and Satisfaction with HF Rigs

15 See this for an overview of standardized z-scores and their use: https://en.wikipedia.org/wiki/Standard_score. For T-score transformations, see the same source.

16 See this source for a description of histogram graphics: https://en.wikipedia.org/wiki/Histogram.

Here are some descriptive illustrations of individual rigs on these three factors so that the reader is familiar with the basic data. A summary of the top and bottom ten rigs on retail price at market entry, performance and satisfaction is contained in Figure 3. Here we get insight into the skewed distribution of rig price as the release prices for certain Hilberling, Collins, Racal, JRC, and Icom products were well over $10,000 in 2019 dollar values! The inflation price for the Collins rigs especially illustrates that they were expensive back then but their same dollar value today is much higher than most rigs (whose average is just over $3,000). Many of these "expensive" rigs also receive the highest average eHam satisfaction scores as well, along with some much less expensive rigs. Note that while the Hilberling PT-8000A had the most expensive release price and second when adjusted for inflation, it fell into the *bottom* ten rigs on satisfaction. But it *was* in the top ten on receive performance.

So just throwing money at buying a rig *might* buy performance but *not necessarily*. It won't ensure getting the highest overall receive performance. But, in contrast, the Anan -200D rig was in the top group on satisfaction but in the large middle range on both price and performance. The top-performing Flex 6000 Series and the new Yaesu FTdx101D only had the Yaesu rig in the top most satisfying rigs, although the Flex 6700 placed in the most expensive list. We will continue to see such a particular pattern in overall rig satisfaction throughout the analysis when price and performance are linked to the eHam scores. But this pattern will be more clearly resolved below.

[Figure 3 about here]

One aspect of these puzzling results is that the dates of the rig's release vary over several decades. The venerable Collins rigs were pricey when they were released but would be wallet-busting for the typical ham in today's dollars. So how have these three metrics of price, performance and satisfaction varied over the years? I've compared each using graphs in Figure 4. Here is where some very clear patterns in HF rigs emerge. Bear in mind that the Sherwood Tables do not contain *all* HF rigs, only his selected set. In the left panel, median rig prices have fluctuated in nominal and real terms since the 1950s but have mostly remained below the $4,000 mark. The inflationary period of the 1980s impacted these rig prices as the clear spike during that period shows. Since 2000, the premium rig introductions have made their mark as periodic spikes to the $6,000 to $8,000 median levels were reached, all in constant 2019 dollar values.

[Figure 4 about here]

Did measured performance follow these price trends? In the middle panel, the median Sherwood Performance Index levels bobbed up and down below the overall median of 100 *until the year 2000* when we observed the "premium" rigs being introduced. Since 2000, median receive performance began a clear upward trend. This reaches over the 130 median performance level, some two standard deviations (SD=15) above the average of 100![17] Clearly, within the scope of rigs in the Sherwood Table, the technical design and implementation of rigs is the best it has been to this point. So, a general answer is that, yes, performance *in the aggregate* has clearly jumped about the time that median prices did.

17 Referring back to Figure 2, the Sherwood Performance Index is symmetrical very much like a normal distribution. Under such a distribution, we would expect fully two-thirds (68.2%) of all observations to be within two standard deviations of the mean (and median), in this case, fifteen points. Thus, a two standard deviation rise is considerable from a statistical view point.

How have rig satisfaction ratings changed over this period? The hobby is replete with love stories about vintage gear. But how have hams collectively rated rigs released over this time span? Due to difference in year-to-year versus decade-to-decade patterns, I've superimposed a line graph of *yearly* averages in eHam scores with boxplots of *decade* averages and their variation over those years in this rightmost panel. This right panel suggests that, simply, they *haven't changed much* on average among the rigs that the Sherwood Tables review from decade to decade, although there are two obvious downward spikes toward the lower end of the 1-5 rating. The median eHam average rating-per-rig has fluctuated up and down relative to the median score of 4.7 out of 5 over this lengthy time horizon. At times, they have fluctuated wildly. But the boxplots show that there is simply a lot of variation *within* each decade in the satisfaction ratings.[18] I emphasize that this is the *cumulative* rating to date of rigs regardless of the year they were released to the market and that they vary from year-to-year but *not on average* over the long 50-year period.

But these aggregate trends, something that hams often talk about regarding prices and the ritual of taking note of which rig tops the Sherwood Tables or has the highest eHam rating, does not inform us about the *individual rig connection* among these three metrics. Figure 5 begins to do this. The scatterplot of average eHam satisfaction score by Sherwood Performance Index puts each rig on this graph with their respective data values. I've added a reference line for the median score on satisfaction (blue) and performance (red).[19] Additionally, I've added color and shape markers for rigs based upon the quartile distribution of rig prices in 2019 dollars (e.g., lowest 25%, 25-50%, 50-75%, and 75% and higher prices). This scatterplot identifies *high*-satisfaction, *high*-performing rigs at various price categories. Such symbology is similar to a quadrant analysis used frequently in business.[20] I have annotated several individual rigs to illustrate these connections among satisfaction, performance and price level.

[Figure 5 about here]

For instance, the Yaesu Ftdx-101D is at the top of the eHam ratings, along with the Icom IC-7851, both current flagship transceivers for their respective manufacturers. The Icom is in the highest price quartile while the Yaesu is in the third (and lower) price group. They are both at the 130 or so Performance Index level. The Apache ANAN-7000DLE, also a highest performer, is a less expensive rig yet is also at the top of the satisfaction rating scale. The Kenwood TS-890 comes in at 4.9 on the eHam average rating, is in the same price group as the Yaesu Ftdx-101D and also at the 130 Performance Index level. The Elecraft K3S and KX2 are both highly rated on eHam, perform similarly around 130, but are in different price groups with the KX2 being a less expensive (and portable QRP) transceiver. Finally, I've highlighted two rigs that are less appealing to their reviewers on eHam (about

18 Sherwood and I discussed the two dramatic "dips" in this line graph which led to my addition of the boxplots in this panel of the graph. There were indeed some low *numbers* of reviews for a few *low-rated* rigs appearing in his table. Those being rated less than 4.0 on average occurred in the 1970s, 1980s, and 1990s and are the Atlas 350 XL, Yaesu FRG-8800, and Icom R-72. Two of these are receivers while the Atlas is a transceiver. Further analysis shows that these rigs received 9, 13 and 6 reviews, respectively. However, many high-rated rigs had similarly small numbers of reviews, too. The overall relationship between the average eHam rating and the number of reviews is nearly zero. This leads me to conclude that it is not the unreliability that might be introduced by "small" numbers of reviews that yielded lower or higher averages but merely the subjective experiences of those submitting their reviews. This bodes well for the reliability of what the eHam ratings represent as consumer satisfaction ratings.

19 For the median, approximately one half of all rigs are above this value with the other half below it so it makes a good reference point for such a graph.

20 See, as an example, http://meetingsift.com/quadrant-analysis/.

average at 4.7) but are at high performers. The Flex 6400 and 6600M SDR rigs are in the second quartile on price but perform exceptionally well on Sherwood's tests. They just have lower satisfaction scores, on average, than the others noted above. But the Elecraft KX3 also falls into the average eHam range as does the Flex 6700, their flagship rig, but the KX3 fares about 20 points higher on the Sherwood Performance Index.[21] In short, the rigs in this upper quadrant of the scatterplot are among the best performers using the Sherwood Table measurements, have among the highest consumer satisfaction ratings but vary in terms of price point as they have been presented to the marketplace by their manufacturers. Note that *few* of the highest priced rigs shown in Figure 3 are listed in this quadrant (exceptions include the Icom 7851 among limited others).

It's clear that the relationships among price, performance and satisfaction are somewhat complex. This may help explain some of the vigorous debates heard on the air or read in website forums! The results in Figure 5 do clarify the upper ends somewhat but often is the case that advocacy for a new rig lies in what it does "for the money." A clear reading of the websites discussing rigs and the eHam narratives will easily show that.

To examine this nuance of how hams evaluate HF rigs, I've created a ratio of the Sherwood Performance Index to the retail price in 2019 dollar values, a measure of performance-to-price or "bang for the buck." Using the same method as for the Sherwood Index, I converted the raw CPI-adjusted price to a z-score and then a T-score transformation to a mean of 100 and standard deviation of 15. The resulting Performance-to-Price Ratio is 1.0 if the Sherwood Index is 100 and the price is 100. A higher performance for the price results in ratios over 1.0 while the converse yields ratios less than 1.0. Figure 6 is a similar scatterplot of this Performance-to-Price Ratio by eHam satisfaction score. To aid interpretation, I used a similar color and shape classification for the absolute price quartiles to complement the Performance-to-Price Ratio. It helps identify those "bang for the buck" rigs that are frequently discussed by purchasing amateur operators and are within the actual price quartile range.

[Figure 6 about here]

As before, I've labeled some specific rigs to illustrate their combined characteristics on these two factors. *There is a clear set of rigs that give a very high "bang for the buck" in performance and are above average in satisfaction.* When one recalls that the eHam 1-5 ratings are skewed toward the high end, this emphasizes the attractiveness of this subset of "hot" rigs for hams in which price *is* a consideration!

The Flex 6000 Series has two rigs, the 6400 and the 6600M that are at the top of the performance-for-the-price metric and are in the lowest two price quartiles. So is the Elecraft KX3. Two additional Elecraft rigs, the KX2 and K3 also fall into this group. The new Yaesu Ftdx-101D is also a member here. Close behind are the Icom IC-7300 and the Kenwood TS-590SG. There are competitors which have similar scores on the Ratio but have less than the average eHam satisfaction rating. These include the Icom 7610, the Kenwood TS-590S and the venerable Perseus SDR receiver. It's worth noting how the Kenwood 590S moved upward in customer satisfaction yet stayed about the same in terms of the performance per dollar. It also amplifies what the annual trends in measurement performance through the Sherwood Tables hinted at: receiver performance since 2000, and especially 2010, has progressed immensely. I do not think that these rigs are a surprise to those who have studied reviews carefully. But

21 In a personal communication, Rob Sherwood NC0B told me that the Flex 6700 measurement tests are a bit of an anomaly that "may never be fully understood." I report this as a qualification to this reported result.

these results put them into a clearer perspective on balancing the price of a rig with its measured performance *and* what fellow hams think of them.

Because readers will want more detail than a graphic like a scatterplot, which is used to show relationships between two or more variables rather than a listing of the data themselves, I've included in Figure 7 the set of rigs that fell into the top quartile (top 25%) of the Performance-to-Price Ratio. In addition, the year that the rig was introduced to the market, the Sherwood Performance Index, the eHam average satisfaction rating (and quartile) and both the nominal introductory retail price and the CPI-adjusted price in 2019 buying power (and quartile) are included. While mildly subjective, I've coded some rigs according to how they fit into the characteristics of actual price, performance-to-price, and customer satisfaction. While all are in the top group of performance relative to the price point, they differ in terms of satisfaction and retail price point.

[Figure 7 about here]

These categories include the **Sweet Spot**, **Hot Rod**, and **Contender** groups of rigs. Those in the *Sweet Spot* have high performance index scores and are in the top group on eHam satisfaction and fall into the lowest or second quartile for absolute price. These are the ones where buyers get the most for the least and like them very much, according to these data. The *Hot Rod* rigs have the very top receive performance but hams collectively express less satisfaction with them. They are below average in price point. The *Contender* rigs have moderate-to-highest performance with the highest quartile of eHam satisfaction scores. They just cost more than the median price in 2019 dollar values. All of the other unclassified rigs also have the highest performance-to-price ratios but are less distinguishable in terms of collective satisfaction or lower price. This labeling and rationale are my evaluation of these results. Individual readers may view them alternatively to suit their own purchase interests.

Sweet Spot rigs include the Elecraft KX2 and K3S, the Kenwood TS-590SG, the Icom IC-R8600 (receiver) and the venerable Drake R-4C (receiver).

Hot Rods include the Flex 6600M and 6400 and the Elecraft KX3. They perform at the top of this performance-to-price group. They are not given the overall satisfaction level as do those in the **Sweet Spot** category.

Contenders are the new Yaesu Ftdx-101D, a very top performer, as well as the Kenwood TS-890 and the Apache ANAN-7000DLE.

Many hams identify their operating on HF with one of the major manufacturers, almost as much as they do with mode of operation. Saying "I'm an Icom guy" (or substitute Yaesu, Kenwood, Elecraft or Flex) is a status badge worn by many ham operators, frequently symbolized in apparel worn to clubs and ham fests. In addition, the clear improvement in measured rig performance during the 2000s may be related to improvements by the major manufacturers who typically have larger R&D teams. To examine how much these major manufacturer status symbols as well as how yearly trends might be linked to performance and satisfaction, I've used a linear modeling procedure (multiple regression) to evaluate this question.[22] Multiple regression attempts to separate out the associations of each predictor variable to the dependent variable such as performance or satisfaction. The results typically tell us the

22 For a summary of multiple linear regression, see this link: https://en.wikipedia.org/wiki/Linear_regression. These equations were estimated by Ordinary Least Squares (OLS).

relative effect of each predictor while all the other predictors are held constant or controlled for in the equation. This is the *net effect* of the predictor.

Figure 8 contains a summary of the multiple regression models for performance and satisfaction as dependent variables. They are predicted by retail price in 2019 dollar values and binary variables indicating whether the rig is made respectively by Yaesu, Kenwood, Icom, Flex or Elecraft as opposed to any other manufacturer and the decade in which is was released to the marketplace.[23] The decades are represented by binary variables for the pre-1970s, 1970s, 1980s, 1990s, or 2000s. The 2010 decade is the reference category. The regression coefficient for these binary predictor variables is the difference in the dependent variable between the group scored 1 (e.g., 1970s) and the omitted reference category (2010 decade), *net* of all other variables in the equation. These results tell us about performance or satisfaction differences for a given decade as compared to the 2010 years, for instance, or the same differences for a given major manufacturer versus the "other" brands. These possible differences are independent of the introductory price to the marketplace put in 2019 dollars. Because the number of reviews per rig vary on eHam, sometimes widely, I included the number of eHam reviews that contributed to the average satisfaction rating in that model so as to control for this possibility.

[Figure 8 about here]

For the Sherwood Performance Index, about two-thirds of *all* the differences in receive performance are associated with these predictors. The R^2 coefficient is .688 which means that about 69 percent of the rig-to-rig performance is linked to the set of predictors, a significant equation as the F-ratio of 30.3 indicates. Now, *which* factors influence receive performance? Is it price? Is it the secular upward trend in performance over time? Do the major manufacturers just produce better performing rigs using Sherwood's measurements?

Retail price as the rig entered the market does moderately increase performance as the Beta coefficient indicates (Beta = .341). It can range in the usual case from 0 to 1.0 in either a positive or negative direction (e.g., price could be linked to worse performance or better performance). This coefficient is interpreted as for a one standard deviation difference in price, the Sherwood Performance Index changes by 0.341 of a standard deviation (about 5 points). This is not surprising. *What is surprising is that it is not larger.* According to these results, the "you get what you pay for" mantra just does not hold up regarding Sherwood's receive measurements.

The consistent negative coefficients for the decade-of-release indicator variables follow the upward trend shown in Figure 4 but confirm that they are independent of price. Let me explain this pattern. The fact that the regression coefficients are largest for the pre-1970s period and continually get smaller through the 2000s confirms that *regardless* of price or *who* made the rig, receive performance continued to get better during the 2010 decade. Putting a finer point to this generality, pre-1970s rigs were measured by Sherwood to be almost two standard deviations *poorer* than 2010 era rigs in receive performance (b = -27.901 points, net of price or manufacturer). This continues to decline with each successive decade (-25.473, -24.800, -20.555 and -13.715). The jump of almost one standard deviation (b = -13.715) from the 2000 era rigs to the 2010 rigs is simply dramatic when price itself is controlled.

23 For retail price in 2019 dollars, I used the natural log. It is skewed to the right as shown in Figure 2 although this is very typical with both price and income data so the natural log regains symmetry so as to not distort the regression estimates. This is a common procedure used in regression models.

RF technology, design, and manufacturing as they shape receiving just got better after 2010. I will illuminate this further below.

In terms of the Sherwood Performance Index, there are two clear and significant major manufacturer effects. Elecraft rigs have a 17-point advantage in performance (b = 17.022), net of price, decade or other major manufacturer performance. Flex Radio Systems has a similar 12-point net advantage (b = 12.085). These are, respectively, just over (Elecraft) and under (Flex) one standard deviation difference on the Performance Index. In comparison to other manufacturers, Icom, Kenwood and Yaesu have non-significant net differences in performance. That is, they are not different from the "other" non-major manufacturers with these variables controlled. These results show that only two of the major manufacturers have statistically significant higher performing transceivers, net of price and their competitors: Elecraft and Flex Radio Systems. Given that these two companies emerged in the last two decades, these "late comers" to the marketplace vis-a-vis Icom, Kenwood and Yaesu have made a demonstrable impact on received performance as measured by Sherwood's tests.

Average satisfaction with a rig, however, has a far smaller relationship with price, decade of manufacture, or being made by a major name brand per se. While the overall regression model is significantly different from a zero association (F=2.15), the R^2 coefficient is only .199 or linked to about 20 percent of the differences in average satisfaction from rig-to-rig. This is only one-third the size of the association that performance has with this set of factors. Retail price has a positive and significant effect on satisfaction (Beta = .289), modestly lower than the effect on performance (Beta = .341). None of the other predictors are distinguishable from zero on a statistical basis, although being a Flex product or being released during the 1970s or 2000-2009 decades have positive coefficients. The number of reviews on eHam, included only in this model for customer satisfaction, has no effect, net of other predictors. That is a gratifying result which supports the reliability of the average ratings whether it's in the hundreds or tens of reviews.

However, the absolute Performance Index number, even with a control for the entry retail price in the equation, does not fully reveal the performance-for-price investment. Figure 9 addresses this more directly using the Performance-to-Price Ratio along with these major manufacturer and decade differences. This is a comparison of mean scores on the Sherwood Performance Index using a two-way analysis-of-variance (ANOVA)[24] which jointly estimates the average performance scores for the two groups of major manufacturers simultaneously. The statistical tests for whether the average performance scores differ by decade or major manufacturer, or have different time trends for major manufacturers, are shown in the top panel of Figure 9. A graphic plot of mean scores on the "bang for the buck" Ratio for each decade by major manufacturer is in the bottom panel.

[Figure 9 about here]

These results show that the clear up-tick in performance around the year 2000 (see Figure 4) also holds for the performance made proportional to the entry retail price. These trends do significantly differ by major manufacturer. As the regression model results for the Sherwood Performance Index

24 See this link for an overview of ANOVA: https://en.wikipedia.org/wiki/Analysis_of_variance. ANOVA compares mean scores on a dependent variable across categories of one or more independent variables (i.e., decade and major manufacturer). These comparisons are tested for significant *differences* and whether the differences in one set of categories (e.g., manufacturer) varies *within* the categories of another independent variable (e.g., decade). In this case, whether the differences by major manufacturer and not the same across decades.

suggested, there are significantly *higher* Performance-to-Price Ratios for both Elecraft and Flex Radio Systems rigs. That is, the "bang for the buck" is higher for these two manufacturers. However, Kenwood also made great strides on this metric as did Yaesu. Icom had a similar improvement but their Ratios were simply lower in value for 2000 and 2010. All five of the major manufacturers *improved* on this Ratio so these distinctions are for the relative *starting* and *ending* points on the Ratio scale as illustrated in the graph. The non-major manufacturer group ("Other") also made strides in their performance value scores between 1990 to 2000 but remained somewhat flat while the major manufacturers demonstrably jumped in measured performance during 2000 to 2010.

[Figure 10 about here]

The same analysis is shown in Figure 10 for the eHam satisfaction rating. While the means appear to be jumping around somewhat wildly in the plots, the test results indicate that *none* of these differences reach statistical significance. So the observed distinctions among the averages are fairly random. This is due to the greater variation in eHam scores *within* each decade, illustrated by the wild annual fluctuations. So whether ham buyers of a particular rig as a whole are highly satisfied (most are) or they just "can't get no satisfaction," these results demonstrate that it does not appear to be associated with the decade of the rig's release or the major manufacturer who offered it.

Conclusions on Price, Performance and Satisfaction

In preparing this research, I could not find anyone who had published an assembled price and satisfaction measurements with either Sherwood or ARRL Lab bench tests for HF transceivers. Consequently, this study is a unique opportunity to gain insight into how these financial investments and outcomes of perhaps the primary purchase that hams make are related to the measured receive performance of the rig itself. Do you get (only) what you pay for? And, will you be satisfied with your purchase?

The findings are somewhat expected from usual discussions over HF rigs in amateur radio in many ways but surprising in terms of the magnitude of the relationships among price, performance and satisfaction. Price ***is*** positively related to better receive performance and the consumer's satisfaction with this set of well-known rigs included in the Sherwood Tables. The relationship is just smaller than our conventional logic would expect. Moreover, our collective satisfaction with these HF rigs is only moderately related to the price point or how well it receives signals. So price does modestly get better receive performance as well as general satisfaction among your peer hams who state their views in the eHam ratings. But using the results expressed in the charts and tables I've included here will help you narrow down the HF rigs that you might be considering.

This underscores a key empirically supported fact that we should recall in considering an HF rig purchase. Overall satisfaction with a transceiver depends on a number of things, receive performance only being *one* of them. However, what is relatively important to one ham *may not* be to another. From reading the eHam narratives extensively, the set of features in a rig is often mentioned as a stated reason for a positive or negative rating. The "bang for the buck" assessment by purchasers is important to some but price may be far less of a purchase issue for others. Only obtaining the individual review scores from eHam and studying them can begin to unravel these varying motives.[25] Major name-brands

25 This work is underway and will be reported on in the future.

do not seem to have much broad or long-term sway with overall average satisfaction. This empirical result does fly in the face of a significant number of comments in the eHam narratives themselves and what many hams tell one another. But when *all* of the reviews are tallied and averaged, the mean rating on eHam for a given rig just does not appear to universally follow major manufacturer labels or the objective, measured receive performance. Perhaps the jury is still out on this but I can only ascertain from the results I've presented that they are minimal in magnitude.

Rig receive performance significantly and dramatically improved for rigs released to the market during the 2000 and 2010 decades, especially in the latter. The receive performance as measured through a composite index of the key metrics published in the Sherwood Tables is *better in recent years than it has ever been and it isn't even close.*[26] While the major manufacturers all shared in this dramatic improvement in this aspect of rig performance, as did the others, two recent ones entered at the top quartile of the Sherwood Performance Index and continued to improve, even more than their competitors. These were Elecraft and Flex Radio Systems. The rigs tested by Sherwood from these two manufacturers in the amateur radio marketplace captured the highest composite level of receive performance during the 2010 decade using the SPI.

The results I've presented do help readers juggle these three sources of information in an objective way. While the statistical analysis may not be every reader's cup of tea, the results themselves do identify a number of rigs that appear to have the "most for the least" investment and that many other hams evaluate it very highly in terms of the overall experience with the rig.[27] While it is is important for any consumer to carefully evaluate specific aspects of a product in terms of their own preferences and priorities, and this is clearly the case for a new HF rig, my results help the reader hone in to a smaller subset and their desired price point. This subset will be with a high measured receive performance, and with the knowledge that other hams have rated them very highly. But it's always *caveat emptor*!

As Sherwood himself has recently said, it's time to widely test and improve transmission as has been the case with reception.[28] Unfortunately, we will likely never have parallel tests on the transmission performance of the rigs currently in the Sherwood Tables so as to combine more facets of what each rig offers ham operators. The only potential set of results are transmitter bench tests from the ARRL Lab, the only existing compilation of which I am aware is that compiled by PA0Q.[29] They are potentially controversial as per the critique by DJ0IP.[30] I may endeavor to compile the transmitter test results from the ARRL Lab as published in *QST* should time permit for as many of the rigs contained in the Sherwood Tables. Those combined data and results may yield a more complete performance index in the future.

There are limitations to these data. I've verbally waved my arms in this article about the fact that the consumer satisfaction as measured in the eHam ratings are for the entire rig "experience," not just just, say, receive performance as the bench tests by Sherwood reflect. While it would add some validity to the breadth of the concept of transceiver performance to also include metrics of the "feature set," that

26 Rob Sherwood NC0B says he has reached this conclusion using his preferred single test in my interview with him on the ICQ Podcast, Episode 305, at icqpodcast.com. My results expand his conclusion to reflect his entire set of tests.

27 Not every reader of *QST* enjoys poring through the meticulous bench tests prepared by the ARRL Lab, I'm told. However, most do generally accept the results even if they do not fully understand them or could replicate them in their own shack.

28 See Rob Sherwood NC0B. "It's Time to Clean Up our Transmitters." *QST* November 2019, pages 39-41.

29 See this link: https://www.remeeus.eu/hamradio/pa1hr/productreview.pdf.

30 See https://www.dj0ip.de/transceivers/performance/performance-lists/.

could be most challenging and confusing if not done reliably and validly across *all* rigs in the dataset. As technology has continued to improve over the past 50 years, especially in the past decade, technical features have expanded such that it might be impossible to compile a complete list of the classes of features, which rig explicitly has what, the quality of performance of each one, and so forth. But perhaps this article will spur other amateur radio operators on to do such compilation.

Author Bio

Life Member Frank M. Howell PhD holds a General Class license. He is Professor Emeritus at Mississippi State University and Adjunct Professor at Emory University. Frank taught statistics, survey research methods, and GIS/Remote Sensing over four decades, served on the Chancellor's staff at the University System of Georgia, and retired as Editor-in-Chief at Springer Media, a large scientific publishing company in the Netherlands. Before becoming a college professor, Frank led the building two radio stations in Milledgeville GA, holding a 3rd Class Radiotelephone License. He is ARRL Assistant Director in the Delta Division and a Presenter on the ICQ Podcast where he frequently conducts feature interviews. He blogs about amateur radio at k4fmh.com, syndicated at AmateurRadio.com. Frank is Vice President for Programs at the Central Mississippi ARA and President of the Magnolia Intertie Inc. He lives in Ridgeland MS. You can contact him at k4fmh@arrl.net.

Figures

Pattern Matrix

Sherwood Measurement:	*Loading:*	*Communality:*
Noise Floor (dBm)	.278	.077
AGC Threshold (uV)	.411	.169
100kHz Blocking (dB)	.451	.203
Sensitivity (uV)	.518	.268
LO Noise Spacing	-.817	.668
FE Selectivity Ranking	.578	.334
Filter: Ultimate dB	.843	.710
Dynamic Range: Wide (dB)	.747	.558
Dynamic Range: Narrow (dB)	.830	.689

Initial Eigenvalues

Component:	*Total*	*% of Variance*	*Cumulative %*
1	3.676	40.849	40.849
2	1.468	16.307	57.156
3	.978	10.868	68.023
4	.938	10.417	78.440
5	.662	7.353	85.793
6	.485	5.385	91.178
7	.388	4.310	95.488
8	.248	2.757	98.245
9	.158	1.755	100.000

KMO and Bartlett's Test

KMO Measure of Sampling Adequacy		.690
Bartlett's Test of Sphericity	Approx. Chi-Square	421.500
	df	36
	Sig.	.000

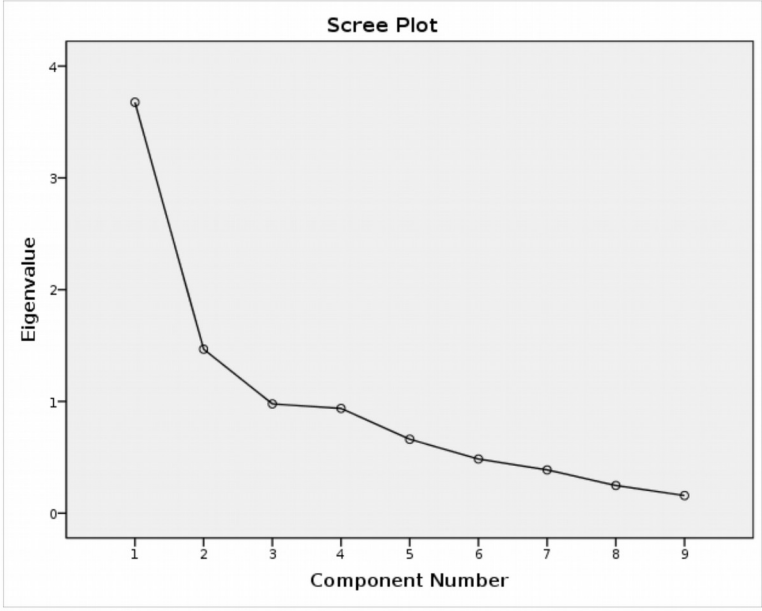

Figure 1. Summary of Principal Components Analysis Results of Sherwood Table Measurements

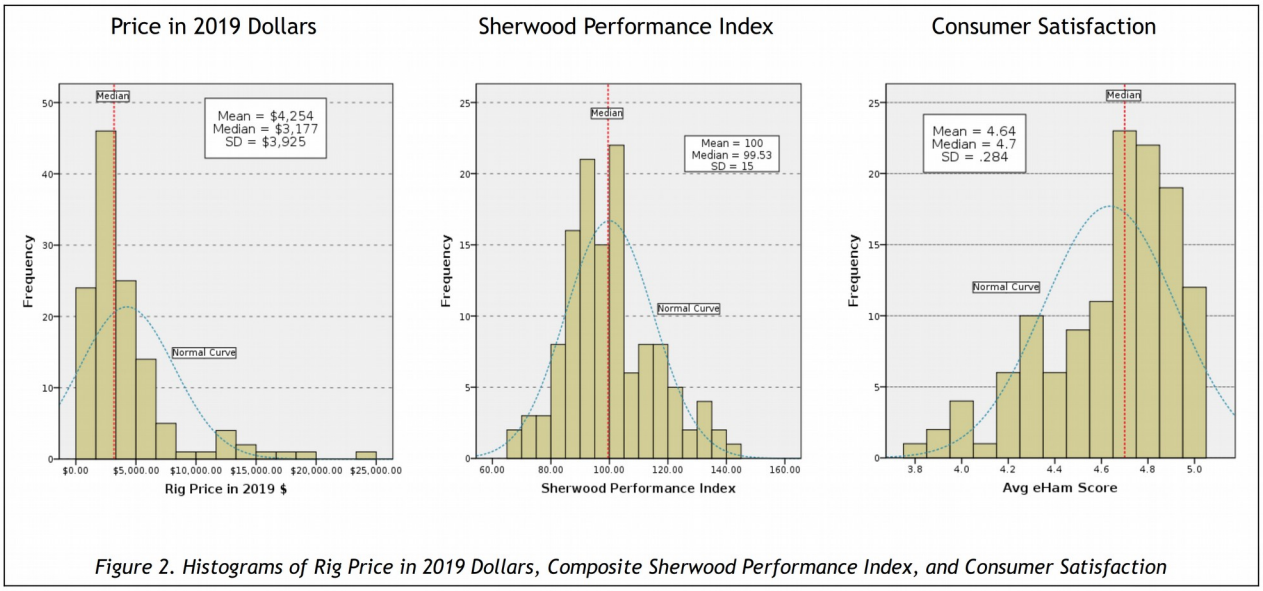

Figure 2. Histograms of Rig Price in 2019 Dollars, Composite Sherwood Performance Index, and Consumer Satisfaction

Retail Price on Market Entry					
Year of Review	Release Price $	*Top 10 Rigs*	*Year of Review*	Price in 2019 $	*Top 10 Rigs*
2014	$17,500.00	Hilberling PT-8000A	1954	$23,763.94	Collins R-390A
2008	$13,500.00	Icom R9500	2014	$18,904.73	Hilberling PT-8000A
2016	$13,499.95	Icom IC-7851	1979	$17,610.19	Racal 6790 GM
2007	$10,600.00	Icom IC-7800	2008	$16,033.21	Icom R9500
2014	$7,999.00	Kenwood TS-990S	2016	$14,383.07	Icom IC-7851
2008	$7,000.00	Icom IC-7700	1966	$14,382.14	Collins 51S1
2015	$6,999.00	Flex Radio Systems 6700	2007	$13,074.87	Icom IC-7800
1991	$6,850.00	JRC NRD-93	1991	$12,860.10	JRC NRD-93
2007	$6,000.00	Icom IC-781	1982	$11,923.83	Collins KWM-380
2010	$5,500.00	Yaesu Ftdx-5000D	1990	$11,738.33	Icom IC-781
		Bottom 10 Rigs			*Bottom 10 Rigs*
1981	$550.00	Yaesu FRG-7700	2003	$1,091.94	Ten-Tec Argonaut VI
2000	$549.00	Elecraft K2	1994	$1,042.26	Icom IC-703+
1974	$500.00	Drake R-4C Stock	1994	$1,028.23	Drake SW8
1980	$500.00	Kenwood R-1000	1984	$984.29	Kenwood R-600
1973	$499.95	Drake R-4C/CF-600/6	2000	$815.21	Elecraft K2
1999	$499.00	Lowe HF-150	2017	$782.44	Elecraft KX2
2002	$495.00	Palstar R-30	1999	$765.87	Lowe HF-150
1976	$490.00	Heath SB-104	2011	$737.88	Flex Radio Systems FLEX-1500
1984	$399.95	Kenwood R-600	2017	$729.23	Yaesu FT-891
1971	$320.00	Heath SB-303	2002	$703.57	Palstar R-30

Consumer Satisfaction			Performance		
Year of Review	*Avg eHam Score*	*Top 10 Rigs*	*Year of Review*	*Performance Index*	*Top 10 Rigs*
1973	5.00	Drake R-4C/CF-600/6	2019	143.83	FlexRadio 6600M
1996	5.00	AOR 5000	2019	137.57	Yaesu Ftdx-101D
1979	5.00	Kenwood R-820S	2019	137.52	FlexRadio 6400
2019	5.00	Apache ANAN-200D	2016	133.73	Icom IC-7851
2019	5.00	Yaesu Ftdx-101D	2019	131.76	Kenwood TS-890S
2018	5.00	Apache ANAN-7000DLE	2012	131.46	Elecraft KX3
1962	5.00	Collins 75-S3 Wing	2015	130.52	Flex Radio Systems 6700
2001	5.00	Ten-Tec 340	2014	127.42	Hilberling PT-8000A
1991	5.00	JRC NRD-93	2016	126.04	Elecraft K3S
2016	5.00	Icom IC-7851	2017	124.49	Elecraft KX2
		Bottom 10 Rigs			*Bottom 10 Rigs*
1971	4.20	Heath SB-303	1999	80.57	Lowe HF-150
1984	4.20	Yaesu FT-757	1984	80.25	Kenwood TS-430S
1981	4.10	Yaesu FRG-7700	1974	79.22	Kenwood TS-520
2015	4.00	Yaesu FT-991	1971	76.98	Heath SB-303
1982	4.00	Icom IC-720A	1980	75.38	Kenwood R-1000
1979	4.00	Icom IC-701	1981	74.97	Yaesu FRG-7700
2014	4.00	Hilberling PT-8000A	1976	74.93	Yaesu FT-101E
1985	3.90	Yaesu FRG-8800	1984	71.15	Kenwood R-600
1977	3.90	Atlas 350-XL	1984	68.09	Kenwood R-2000
1993	3.80	Icom IC-R72	1996	67.39	AOR 5000

Figure 3. Top Ten and Bottom Ten Rigs on Price, Sherwood Table Index Performance and eHam Satisfaction Score

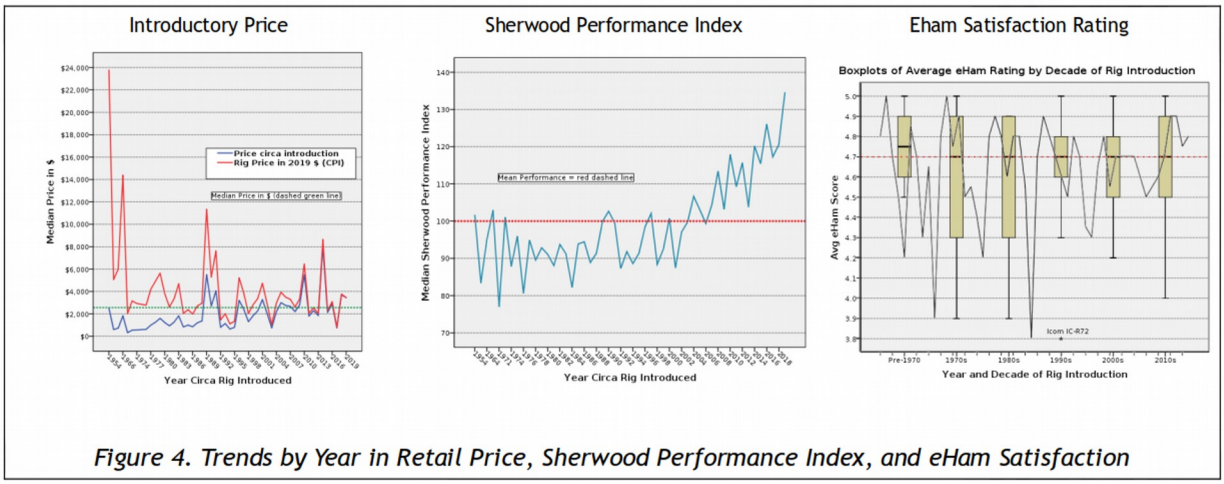

Figure 4. Trends by Year in Retail Price, Sherwood Performance Index, and eHam Satisfaction

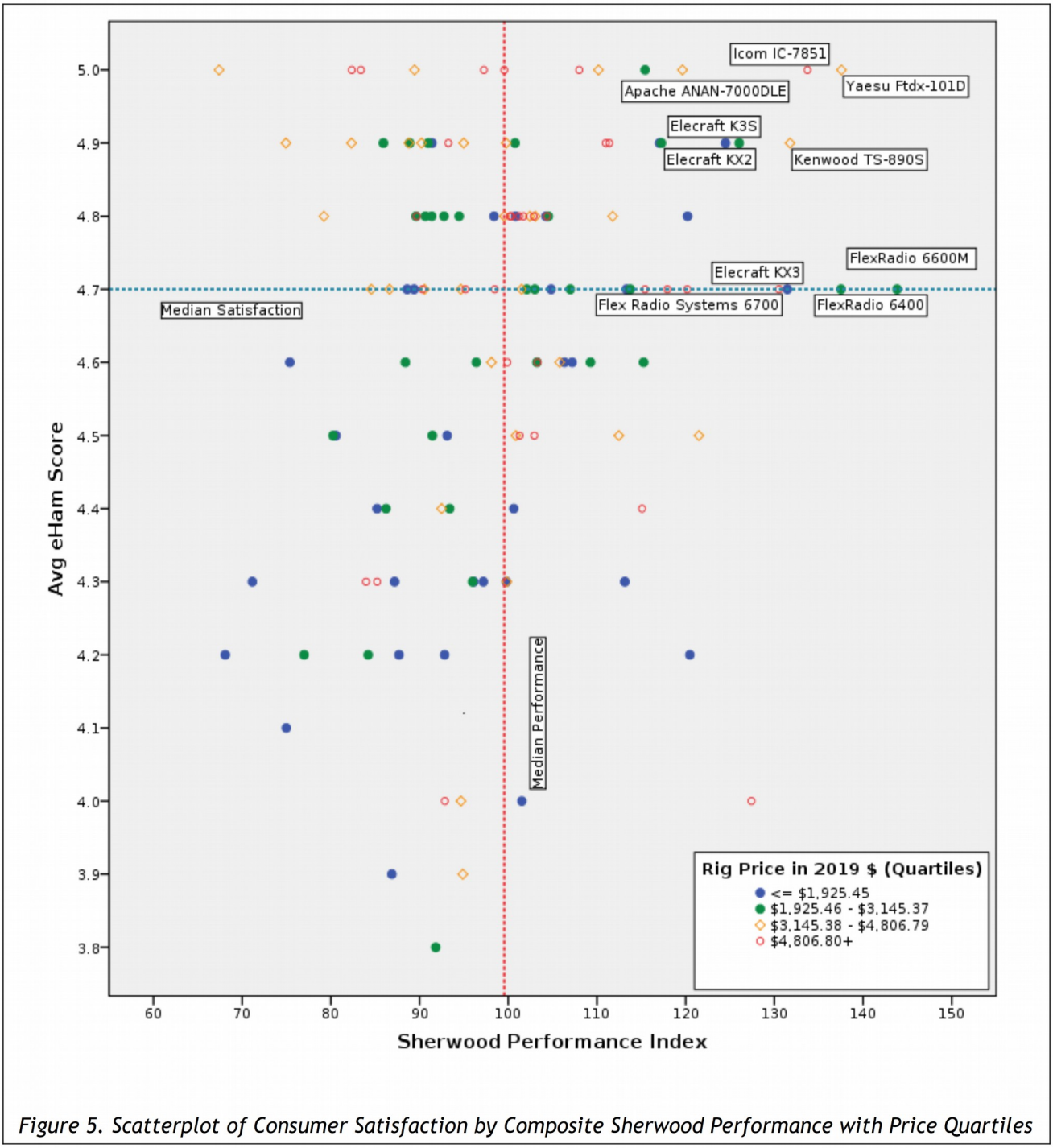

Figure 5. Scatterplot of Consumer Satisfaction by Composite Sherwood Performance with Price Quartiles

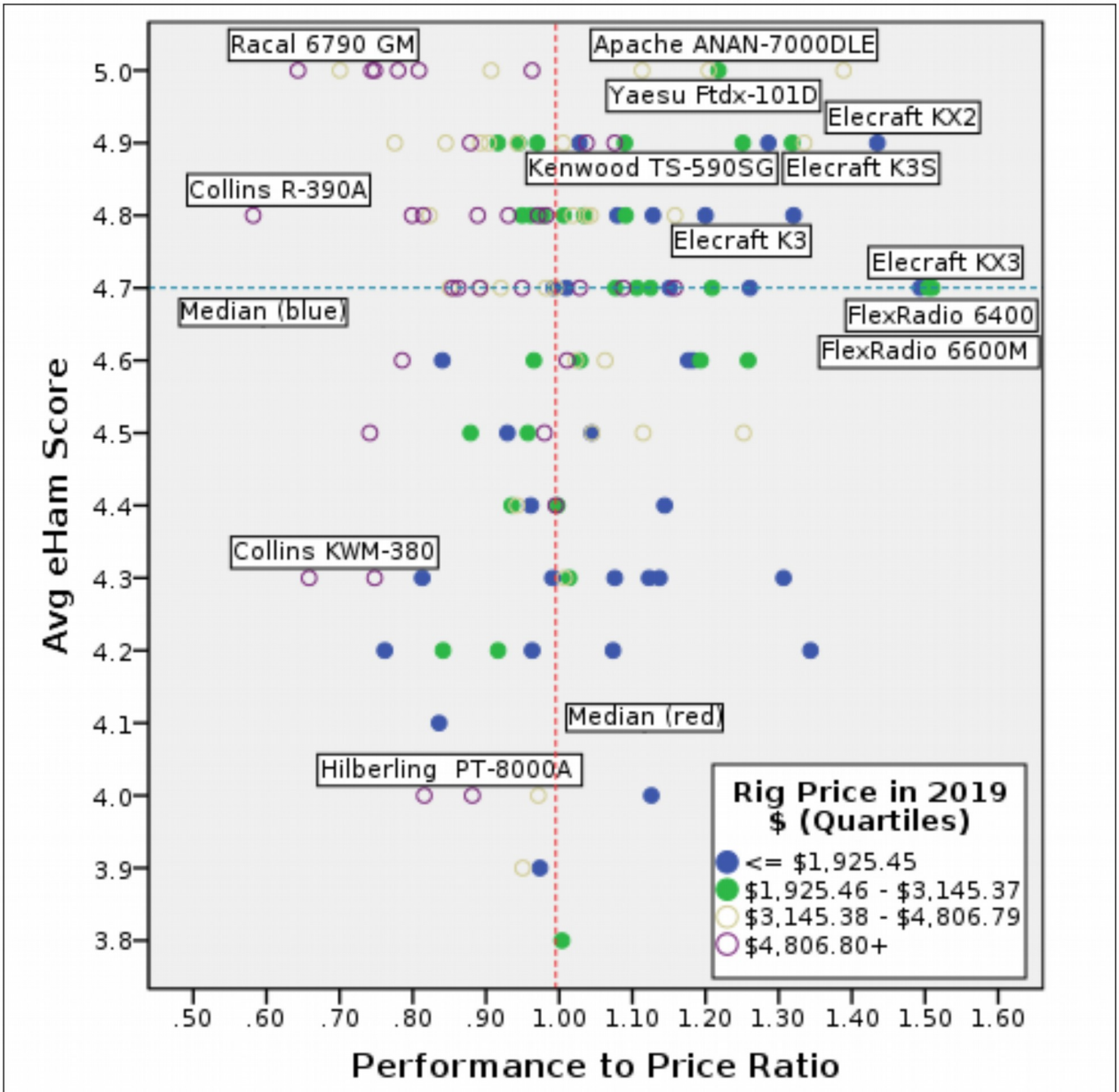

Figure 6. Scatterplot of Performance-to-Price Ratio by Satisfaction with Price Quartiles.

No.	Rig Name	Introduction Year	Performance-to-Price Ratio (Top Quartile)	Sherwood Performance Index	eham Average	Introduction Price	Price in 2019 $	eHam Quartile	Price in 2019 $ Quartile
1	Flex 6600M	2019	1.51	143.83	4.7	$2,999.00	$2,999.00	2nd	2nd
2	Flex 6400	2019	1.50	137.52	4.7	$1,999.00	$1,999.00	2nd	2nd
3	Elecraft KX3	2012	1.49	131.46	4.7	$999.95	$1,113.62	2nd	1st
4	Elecraft KX2	2017	1.43	124.49	4.9	$750.00	$782.44	4th	1st
5	Yaesu Ftdx-101D	2019	1.39	137.57	5.0	$3,995.00	$3,995.00	4th	3rd
6	Perseus	2008	1.34	120.47	4.2	$1,299.00	$1,542.75	1st	1st
7	Kenwood TS-890S	2019	1.33	131.76	4.9	$3,900.00	$3,900.00	4th	3rd
8	Elecraft K3	2008	1.32	120.21	4.8	$1,599.95	$1,900.17	3rd	1st
9	Elecraft K3S	2016	1.32	126.04	4.9	$2,900.00	$3,089.71	4th	2nd
10	Flex FLEX-1500	2011	1.31	113.14	4.3	$649.00	$737.88	1st	1st
11	Kenwood TS-590SG	2015	1.29	117.06	4.9	$1,759.00	$1,897.79	4th	1st
12	Icom IC-7300	2016	1.26	113.32	4.7	$1,500.00	$1,598.13	2nd	1st
13	Kenwood TS-590S	2011	1.26	115.26	4.6	$1,800.00	$2,046.51	2nd	2nd
14	Icom IC-7610	2018	1.25	121.49	4.5	$3,400.00	$3,462.29	1st	3rd
15	Icom IC-R8600	2017	1.25	117.27	4.9	$2,499.00	$2,607.08	4th	2nd
16	Drake R-4C/CF-600/6	1973	1.22	115.43	5.0	$499.95	$2,879.22	4th	2nd
17	Flex 6300	2015	1.21	113.76	4.7	$2,499.00	$2,696.18	2nd	2nd
18	Apache ANAN-7000DLE	2018	1.20	119.64	5.0	$3995.00	$4,068.19	4th	3rd
19	Elecraft K2	2000	1.20	104.25	4.8	$549.00	$815.21	3rd	1st
20	Ten-Tec Eagle	2011	1.19	109.27	4.6	$1,795.00	$2,040.82	2nd	2nd
21	Yaesu FT-950	2008	1.18	107.21	4.6	$1,500.00	$1,781.47	2nd	1st
22	Yaesu Ftdx-1200	2014	1.18	106.33	4.6	$1,600.00	$1,728.43	2nd	1st
23	Flex FLEX-5000A	2008	1.16	111.78	4.8	$2,799.00	$3,324.22	3rd	3rd
24	Flex 6700	2015	1.16	130.52	4.7	$6,999.00	$7,551.24	2nd	4nd
25	Flex FLEX-3000	2009	1.15	104.83	4.7	$1,599.00	$1,906.13	2nd	1st
26	Ten-Tec Argonaut VI	2013	1.14	100.62	4.4	$995.00	$1,091.94	1st	1st
27	Icom IC-703+	2003	1.14	99.79	4.3	$750.00	$1,042.26	1st	1st
28	Kenwood TS-480HX	2004	1.13	100.83	4.8	$1,080.00	$1,461.92	3rd	1st
29	Yaesu FT-991	2015	1.13	101.53	4.0	$1,550.00	$1,672.30	1st	1st
30	Yaesu Ftdx-3000	2013	1.12	106.99	4.7	$2,700.00	$2,963.05	2nd	2nd
31	Yaesu FT-891	2017	1.12	97.19	4.3	$699.00	$729.23	1st	1st

Color Coding: *All* rigs are in the *top quartile* (75% and above) of Performance-to-Price Ratio and ranked in this table by the Ratio. Three classes of rigs are highlighted based upon the quartiles of Average eHam Satisfaction Score and Price in 2019 dollars. ***Sweet Spot*** rigs are in the highest consumer satisfaction quartile and in the lowest half of price rankings (i.e., cheaper). ***Hot Rod*** rigs are in the second quartile of consumer satisfaction and in the lowest half of price rankings. ***Contender*** rigs are in the top quartile of consumer satisfaction but in the third quartile of price rankings.

Sweet Spot: Top eHam, *1st or 2nd Quartile Price*	**Hot Rod:** *2nd eHam, 1st or 2nd Quartile Price*	**Contender:** Top eHam, *3rd Quartile Price*

Figure 7. Top Quartile Performance-to-Price Rigs with eHam Satisfaction Rankings and Price

Regression Model Summary for Rig Performance Index and Satisfaction

Dependent Variable:	Rig Performance Index		eham Satisfaction	
	Coefficients		*Coefficients*	
Model parameter:	B	Beta	B	Beta
Intercept	60.203***		3.371	
(LN) Rig Price in 2019 $	6.888***	.341	.110***	.289
Decade: Pre-1970s (1=yes)	-27.910***	-.326	.060^{ns}	.085
Decade: 1970s (1=yes)	-25.473***	-.534	.004^{ns}	.188
Decade: 1980s (1=yes)	-24.800***	-.688	-.013^{ns}	-.015
Decade: 1990s (1=yes)	-20.555***	-.547	.017^{ns}	.024
Decade: 2000s (1=yes)	-13.715***	-.365	.096^{ns}	.136
Elecraft Rig (1=yes)	17.022***	.222	.029^{ns}	.018
Flex Rig (1=yes)	12.085*	.185	.260^{ns}	.179
Icom Rig (1=yes)	-.264ns	-.008	-.003^{ns}	-.003
Kenwood Rig (1=yes)	-2.808ns	-.071	-.044^{ns}	-.067
Yaesu Rig (1=yes)	-3.715ns	-.091	.157^{ns}	.210
Number of eHam Reviews	NA	NA	-.047^{ns}	-.061
Legend:				
*** $p < .001$				
* $p < .05$	R^2= .688***		R^2= .199*	
ns not sig.	F=30.03***	MSE=9.72	F=2.15*	MSE=0.27

Note: The list of decade and major manufacturer rows are measured as 0,1 where 1 = Yes versus an omitted category. For decade, 2010 is the reference category whereas Other manufacturer is the omitted reference for that set of variables. These are commonly referred to as dummy or indicator variables in multiple regression models.

Figure 8. Multiple Regression Models for Rig Performance Index and eHam Satisfaction Rating

Tests of Mean Scores on Major Manufacturer and Decade

Dependent Variable: Performance-to-Price Ratio

Source:	Type III Sum of Squares	df	Mean Square	F	p-value
Corrected Model	2.551	24	.106	7.281***	.000
Intercept	62.289	1	62.289	4267.644***	.000
Major Manufacturer	.360	5	.072	4.933***	.000
Decade	1.121	5	.224	15.363***	.000
Major Manufacturer X Decade	.160	14	.011	.783ns	.685
Error	1.489	102	.015		
Total	134.568	127			
Corrected Total	4.039	126			

R-Squared = .631 (Adjusted R Squared = .545) *** p< .001 ns= not sig.

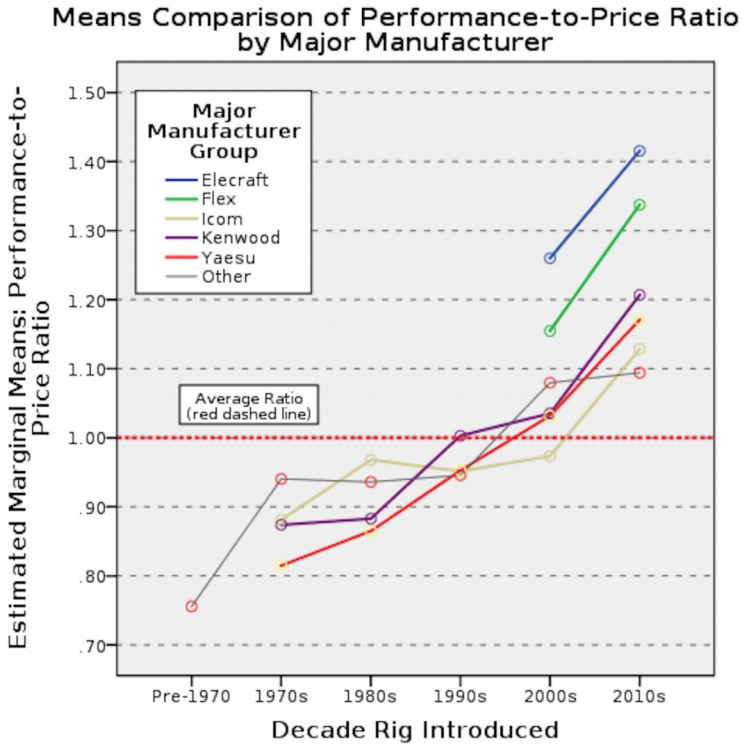

Figure 9. Comparisons of Means on Performance-to-Price Ratio by Major Manufacturer and Decade of Release to Market

Tests of Mean eHam Satisfaction Scores on Major Manufacturer and Decade

Dependent Variable: Average eHam Satisfaction

Source:	Type III Sum of Squares	df	Mean Square	F	p-value
Corrected Model	2.166	24	.090	1.164^{ns}	.293
Intercept	1291.137	1	1291.137	16655.538***	.000
Major Manufacturer	.664	5	.133	1.712^{ns}	.138
Decade	.174	5	.035	.449^{ns}	.813
Major Manufacturer X Decade	1.481	14	.106	1.365^{ns}	.184
Error	7.907	102	.078		
Total	2739.880	127			
Corrected Total	10.073	126			

R Squared = .215 (Adjusted R Squared = .030) *** p< .001 ns= not sig.

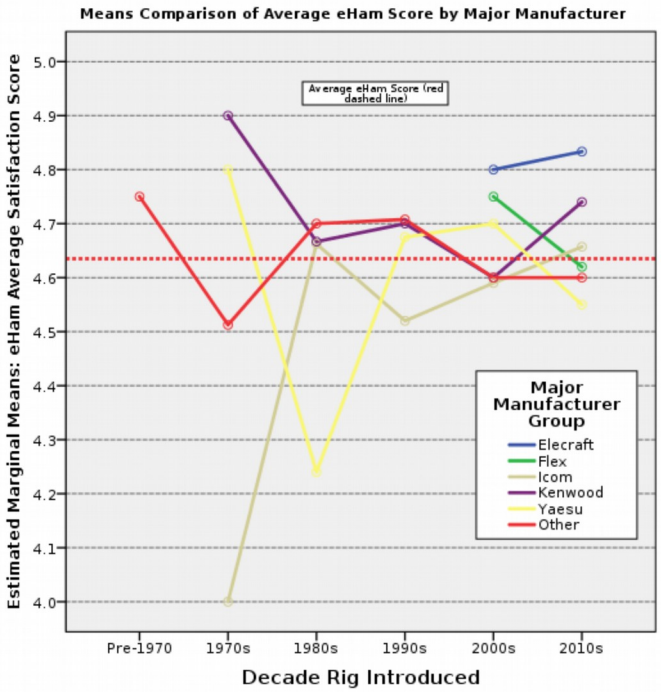

Figure 10. Comparisons of Means on Average eHam Satisfaction Score by Major Manufacturer and Decade of Release to Market