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A Relationship Model Between the Perceived Economic Value of Computer Operating Systems and Their Usability: All Variables Evaluated by Copilot AI

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ABSTRACT

This article proposes and implements a relationship model between the perceived economic value of computer operating systems (OSs) and their usability where all the model variables are evaluated by the generative artificial intelligence (AI) robot Copilot of Microsoft. In the underlying study, the perceived economic value of a particular OS was estimated by a proxy variable, namely, the OS's total cost of ownership (TCO) whereas the usability of the OS was gauged by eight usability variables corresponding to the eight major usability dimensions (1) Effectiveness, (2) Efficiency, (3) Learnability, (4) Memorability, (5) Safety, (6) Utility, (7) Ergonomics, and (8) Accessibility. All these variables were evaluated on a scale of 1 (the lowest or worst, as appropriate) to 10 (the highest or best, as appropriate) by the robot Copilot based on global users' textual comments on the TCO and the above eight dimensions of the OS as appear all around the web. A total of 18 OSs were covered in the modeling, they being the popular versions of the three leading OS families of Microsoft Windows, Apple macOS, and Linux. Multiple regression of the TCO on the eight usability variables was performed, followed by individual simple regression of the TCO on each of the eight usability variables in a bid to avert multicollinearity's effect. On the one hand, the multiple regression rendered a model with a coefficient of determination $R^2 = .853$ and an F-statistic = 8.290 (df = 7, 10; $p = 0.002 < 0.01$) and (2) Efficiency being the only usability variable statistically significantly ($p < 0.05$) but negatively impinging on the TCO. On the other hand, the individual simple regression models revealed that in an individual manner, (2) Efficiency ($R^2 = 0.562$; $F = 20.542$ (df = 1, 16; $p = .000$)), (5) Safety ($R^2 = .547$; $F = 19.335$ (df = 1, 16; $p = .000$)), (6) Utility ($R^2 = .392$; $F = 10.331$ (df = 1, 16; $p = .005$)), and (7) Ergonomics ($R^2 = .253$; $F = 5.431$ (df = 1, 16; $p = .033$)) all statistically significantly but negatively impacted the TCO. Deducing from these models, the better an OS in these four usability dimensions, the lower its economic value as perceived by the market was. In other words, the market of OSs did not seem to have priced in usability or seemed to have even priced in them in a direction at odds with intuition and logic. These confounding results may be ascribable to multicollinearity and probably imperfection of the current generative AI technology, on which this study heavily hinged. After all, the multiple regression model predicts and explains the TCO and thus the perceived economic value very well.

Keywords: Artificial intelligence, Robot, Economic value, Usability, Computer operating systems, Copilot

INTRODUCTION

Total Cost of Ownership

Since the later decades of the last century, the interrelated concepts of total cost (Cavinato, 1991, 1992), life cycle costing (Jackson and Ostrom, 1980), product life cycle costs (Shields and Young, 1991), and total cost of ownership (TCO) (Ellram and Siferd, 1993, 1998; Ellram, 1993, 1994, 1995) emerged as serious notions, in particular, in the disciplines of procurement, purchasing, and supply chain management (Ferrin and Plank, 2002). For procurement/purchasing/supply-chain managers, all these concepts purport to adopt a long-term perspective, as opposed to a short-term, initial-price perspective, for the accurate evaluation of procurement scenarios (Ferrin and Plank, 2002). In particular, Ellram and Siferd (1993) proposed the concept of TCO as an integrated concept. They defined TCO from the perspective of the flow of activities related to the purchase of a good or service and the costs associated with those activities (Ferrin and Plank, 2002). Traditionally, TCO of particular goods or services can be evaluated through either the dollar-based approaches or the value-based approaches, which are, simply speaking, itemized bottom-up cost accounting methods and top-down user rating (or point allocation) methods, respectively (Cengiz, 2019).

Ferrin and Plank's (2002) survey revealed that there were 13 categories of cost drivers underlying TCO, namely, operations cost, quality, logistics, technological advantage, supplier reliability and capability, maintenance, inventory cost, life cycle, initial price, "customer-related," opportunity cost, transaction cost, and "miscellaneous." Each of these categories comprises a series of nuanced cost driver subcategories. Also, Cengiz's (2019) analysis uncovered that the TCO of particular trucks statistically significantly and positively varies with and thus is reflective of the perceived (economic or market) values of the trucks in the eyes of corporate purchasers (or customers). Assuming generalizability of Cengiz's (2019) analysis to goods and services other than trucks and specifically computer operating systems (OSs), which are to be illuminated in the next sub-section, the TCOs of particular OSs are very likely reflective of the perceived (economic or market) values of the OSs.

Usability of Computer Operating Systems

The usability of computer operating systems affects the user experience, productivity, and satisfaction of the users of OSs. Usability can be defined as "the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" (ISO, 2018). Conventionally, the usability of OSs, as software systems, can be evaluated by manual methods such as questionnaire surveys, interviews, and focus groups (Maramba, Chatterjee, and Newman, 2019), which involve collecting and analyzing data from the OS users or experts to assess the multiple perspectives of quality of the OS design (Nielsen, 1994). However, these methods are plagued by such shortcomings as being time-consuming, expensive, subjective, and dependent on the availability, representativeness, trustworthiness, and reliability of such users and experts.

Evaluation of OSs' usability can usually be implemented in several usability dimensions, for example, (1) Effectiveness (Chan, 2023; Raptis et al., 2013), (2) Efficiency (Chan, 2023; Raptis et al., 2013), (3) Learnability (Chan, 2023; Thillaieaswaran and Pasupathy, 2021), (4) Memorability (Bakiu and Guzman, 2017; Saket, Endert, Stasko, 2016), (5) Safety (Gurbuz and Tekinerdogan, 2018), (6) Utility (Okumuş et al., 2016), (7) Ergonomics (Peres et al., 2009), and (8) Accessibility (Bi et al., 2022; Chan, 2023) and/or any alternative or additional dimensions of that ilk. Effectiveness refers to the chance of users completing tasks successfully and correctly on an OS. Efficiency refers to the speed and accuracy with which users can complete their tasks using an OS. Learnability refers to the ease with which users can learn how to use an OS. Memorability is the ability of users to remember how to use an OS after a period of non-use. Safety is the extent to which an OS protects users from errors, failures, threats, and harms. Utility is the range and quality of functionality and features that an OS provides to users. Ergonomics is the physical comfort and ease of use that an OS provides to users. Accessibility is the degree to which an OS can be used by people with disabilities or special needs.

Scrutinizing these usability dimensions and the cost driver categories for TCO detailed in the last sub-section, basic logic may trivially contend that these dimensions' ratings of particular OSs would map to and thus bear on at least the cost driver categories operation costs, quality, technological advantage, maintenance, life cycle, "customer-related," and "miscellaneous" of the TCO of the OSs. In other words, it is logical to propose that these usability dimensions' ratings of particular OSs impinge on the TCOs and thus the perceived economic values of the OSs. This article is exactly to model the relationship between the usability dimensions' ratings of OSs and the perceived economic values of the OSs.

Generative Artificial Intelligence

To the end of modeling the aforesaid relationship, there must be some evaluations (or ratings, as appropriate) of OSs' usability dimensions and their TCOs. This is where generative artificial intelligence (AI) may come into play. Generative AI is a branch of AI that can learn from existing artifacts that the AI systems have been trained on, and generate at scale new, realistic artifacts that reflect the characteristics of the existing artifacts but do not repeat them (Baidoo-Anu and Ansah, 2023; Gartner, 2023; World Economic Forum, 2023). Generative AI creates new content in the form of images, text, audio, and more (Baidoo-Anu and Ansah, 2023; Gartner, 2023; World Economic Forum, 2023). Generative AI can serve as an alternative method to evaluate the usability dimensions and the TCOs of OSs (or any good or service under the sun) by, for example, surveying the opinions about particular OSs in a fast, inexpensive, objective, and broadly inclusive manner. In particular, such surveys can be carried out readily on the Internet where diverse opinions of OS users abound. In particular, the evaluation of OSs' TCOs by means of generative AI is a value-based approach of evaluation (Cengiz, 2019).

The Present Study

The author is not aware of any extant literature amalgamating the above concepts of OSs' TCOs (and thus the underlying perceived economic value), OSs' usability dimensions, and their evaluation by generative AI. This is exactly the gap that this article is to fill. In particular, this article models the relationship between the TCO, as a proxy for the perceived economic value, of an OS and its usability dimensions where both the TCO and the usability dimensions are evaluated by the generative AI robot Copilot (Cambon et al., 2023) of Microsoft as bundled with the Microsoft Edge browser. OSs covered include 18 versions of the three leading OS families of Microsoft Windows, Apple macOS, and Linux.

METHODOLOGY

Data and Materials

For the evaluation of OSs' TCOs, the present study in November 2023 submitted the following instruction to Copilot:

> "For the total cost of ownership, please give a rating score to each of the major computer operating system versions Windows XP, Windows Vista, Windows 7, Windows 8, Windows 10, Windows 11, Mac OS X, OS X, macOS, Linux Mint, Manjaro Linux, Debian Linux, Ubuntu, Antergos/EndeavourOS, Solus, Fedora, elementary OS, and openSUSE based on a scale of 1 to 10 (1 being the least costly and 10 the most costly). Please derive your scores from global users' textual comments on their perceptions of the total costs of ownership of these versions as appear all around the web. It would be nice if you put your scores in a table form."

The OSs spelt out in the instruction above were 18 prominent versions of the three leading OS families of Microsoft Windows, Apple macOS, and Linux, and were shortlisted simply by referencing some official and authoritative websites of the three OS families, for example, Britannica, T. Editors of Encyclopaedia (2023) for the Windows family, Apple (2023) for the macOS family, and Anonymous (2023) for Linux.

Subsequently, for the evaluation of OSs' usability dimensions, Copilot was instructed as follows in order to award rating scores to the eight usability dimensions of the above 18 OSs:

> "For each of the eight dimensions (1) Effectiveness, (2) Efficiency, (3) Learnability, (4) Memorability, (5) Safety, (6) Utility, (7) Ergonomics, and (8) Accessibility, please give a rating score to each of the major computer operating system versions Windows XP, Windows Vista, Windows 7, Windows 8, Windows 10, Windows 11, Mac OS X, OS X, macOS, Linux Mint, Manjaro Linux, Debian Linux, Ubuntu, Antergos/EndeavourOS, Solus, Fedora, elementary OS, openSUSE based on a scale of 1 to 10 (1 being the worst and 10 the best). Please derive your scores from global users' textual comments on these eight dimensions of these versions as appear all around the web. It would be nice if you put your scores in a table form."

With some hitches, Copilot replied with rating scores for all the eight dimensions and the 18 OSs listed in the above instruction but the rating scores for the usability dimensions (5) Safety, (6) Utility, (7) Ergonomics, and (8) Accessibility corresponding to the OSs elementary OS and openSUSE were omitted because the robot professed that it could not find enough user comments on them to derive reliable scores. It is noteworthy that the instruction above explicitly stressed "…derive your scores from global users' textual comments on these eight dimensions of these versions as appear all around the web." Stated differently, Copilot was requested to base its rating scores on global users' textual comments appearing all around the Internet instead of simply citing any comparable rating scores already in existence there. Each of the sparsely omitted usability dimension rating score was imputed by filling it with the mean of the corresponding usability dimension's rating scores for all the OSs with such rating scores present.

Analysis

Multiple regression of the TCO's rating score (as the dependent variable) on all the eight usability dimensions' rating scores (as eight independent variables) was performed over all the 18 OSs. That said, the tolerance level of any particular usability dimension rating score (i.e., any particular independent variable) had to be greater than 0.0001 for the usability dimension's rating score to enter the final multiple regression model. In fact, a tolerance level less than 0.0001 indicated rather serious multicollinearity between the corresponding usability dimension's rating score and the remaining usability dimensions' rating scores. For the final multiple regression model, the coefficient of determination R^2 was noted as the proportion of the TCO rating score's variation being explained by the usability dimension rating scores' variations. Likewise, the *F*-test outcome was pinpointed to determine whether it was statistically justifiable to include any of the usability dimension rating scores in the final model for predicting the TCO rating score. The regression coefficients corresponding to the usability dimension rating scores were also reported. For the *t*-test to test whether each regression coefficient differed from zero, the outcome was investigated to confirm whether each usability dimension rating score impacted the TCO rating score with statistical significance.

To rule out multicollinearity, individual simple regression of the TCO rating score (as the dependent variable) on the rating score (as the only independent variable) for each of the usability dimensions in the above final multiple regression model followed. Each such simple regression model's R^2, *F*-test, and *t*-test for the regression coefficient therein attested to whether the corresponding usability dimension rating score was appreciably associated with the TCO rating score.

RESULTS

The final multiple regression model was found to comprise the rating scores for all the eight usability dimensions except for (1) Effectiveness. The model statistics included: $R^2 = .853$ and the *F*-test's *F* statistic (df = 7, 10) = 8.290 with its *p*-value = .002 < 0.01, implying that 85.3% of the TCO rating score's variation was explained by the variation of the seven usability dimension rating scores in the final model and that at the 1% significance level, the final model outperformed an alternative one with no usability dimension rating score at all. In terms of predictability and explainability, the final model turned out to be "more than" acceptable. Table 1 depicts the regression coefficients with their 95% confidence intervals (CIs), alongside their t statistics with their p-values of the corresponding t-tests, in the final model.

Table 1. The regression coefficients with their 95% confidence intervals (CIs), alongside their t statistics with their p-values of the corresponding t-tests, in the final multiple regression model.

Usability Dimension Rating Score (as an Independent Variable)	Regression Coefficient / [95% CI]	t (p-value)
(2) Efficiency	−2.199 / [−3.898, −.500]	−2.883 (.016*)
(3) Learnability	−1.666 / [−4.300,.969]	−1.409 (.189)
(4) Memorability	2.827 / [−.379, 6.034]	1.965 (.078)
(5) Safety	-.389 / [−2.156, 1.378]	−.490 (.635)
(6) Utility	.157 / [−3.062, 3.376]	.109 (.916)
(7) Ergonomics	−.465 / [−4.358, 3.429]	−.266 (.796)
(8) Accessibility	.711 / [−.909, 2.331]	.978 (.351)

* $p < 0.05$

Notwithstanding seven usability dimension rating scores being in the final multiple regression model, only the regression coefficient of one usability dimension rating score (2) Efficiency was found to signify (negative) effect on the TCO rating score at the 5% significance level ($p < 0.05$), upon taking into account multicollinearity among the seven usability dimension rating scores.

As for each individual simple regression model of the TCO rating score on the rating score for each of the seven usability dimensions in the above final multiple regression model, Table 2 delineates the R^2, the F statistic with its p-value, and the t statistic with its p-value of the t-test on the corresponding regression coefficient.

Table 2. The R^2, the F statistic with its p-value, and the t statistic with its p-value of the t-test on the regression coefficient of each individual simple regression model.

Simple regression of the TCO rating score on the rating score for the usability dimension	R^2	F (p-value)	t (p-value)
(2) Efficiency	.562	20.542 (.000**)	−4.532 (.000**)
(3) Learnability	.070	1.198 (.290)	−1.094 (.290)
(4) Memorability	.000	.001 (.982)	.023 (.982)
(5) Safety	.547	19.335 (.000**)	−4.397 (.000**)
(6) Utility	.392	10.331 (.005**)	−3.214 (.005**)
(7) Ergonomics	.253	5.431 (.033*)	−2.331 (.033*)
(8) Accessibility	.152	2.859 (.110)	−1.691 (.110)

* $p < 0.05$; ** $p < 0.01$

Each of the individual simple regression models with the rating score for the usability dimension (2) Efficiency, (5) Safety, (6) Utility, or (7) Ergonomics as the independent variable yielded an appreciable R^2 and/or an F statistic with statistical significance ($p < 0.01$, $p < 0.01$, $p < 0.01$, and $p < 0.05$, respectively). Each of these models' regression coefficient also provided a t statistic with statistical significance ($p < 0.01$, $p < 0.01$, $p < 0.01$, and $p < 0.05$, respectively). In other words, the variation of each of these four models' usability dimension rating score alone individually possessed sufficient predictability and explainability of the TCO rating score's variation. Similarly, each of these four usability dimensions' rating scores per se individually bore sufficiently on the TCO rating score, in particular, negatively.

CONCLUSION AND DISCUSSION

The present article intends to construct a model to relate the TCO rating score, as a proxy for the perceived economic value, of a computer OS to its eight usability dimensions' rating scores, both the TCO rating score and the usability dimension rating scores being evaluated by the generative AI robot Microsoft Copilot. In the final multiple regression model comprising the rating scores for seven usability dimensions (2) Efficiency, (3) Learnability, (4) Memorability, (5) Safety, (6) Utility, (7) Ergonomics, and (8) Accessibility, as much as 85.3% of the TCO rating score's variation is explainable by the seven usability dimension rating scores and at the 1% significance level, the model beats an alternative one with no usability dimension rating score at all. Such a model's predictability and explainability are "more than" acceptable. Having said that, only the regression coefficient of one usability dimension rating score (2) Efficiency impacts the TCO rating score with statistical significance. Furthermore, inferring from each individual simple regression model of the TOC rating score on each of the above seven usability dimension rating scores, the variation of the rating score for the usability dimension (2) Efficiency, (5) Safety, (6) Utility, or (7) Ergonomics per se individually offers substantive predictability and explainability of the TCO rating score's variation. Specifically, each of these four usability dimensions' rating scores alone individually affects the TCO rating score adequately and negatively. In other words, the market of OSs did not seem to have priced in usability or seemed to have even priced in it in a direction at odds with intuition and logic.

In statistical theory, such confounding results may partially be attributable to multicollinearity among the seven usability dimension rating scores in the final multiple regression model. Albeit the final model predicts and explains the variation of the TCO rating score sublimely well, such multicollinearity may have channeled the effects of the rating scores for the six usability dimensions (3) Learnability, (4) Memorability, (5) Safety, (6) Utility, (7) Ergonomics, and (8) Accessibility on the TCO rating score through the rating score for only one usability dimension (2) Efficiency, which thus appears to be the only usability dimension rating score impinging on the TCO rating score. Also, the variation of the rating scores for only four usability dimensions per se individually predicts and explains the TCO rating score's variation well because the TCO rating score depends on the rating scores for all the seven usability dimensions, though interrelated through multicollinearity, instead of every one of them individually.

This study itself is not without its critics. First, rating scores awarded by Copilot based on users' textual comments on OSs were prone to imperfection due to subjectivity inevitably embedded in the users' textual comments, etc. on which the robot was trained (Chan, 2023). Second, TCO and usability of OSs were evaluated only by the generative AI robot Microsoft Copilot, which might not be representative of the bountiful robots in operation worldwide. Therefore, the findings might not be generalizable to other generative AI robots. Third, the TCO was evaluated by a value-based approach instead of a more detailed, and thus probably more precise, dollar-based approach. Therefore, it is to the benefit of future researchers to further extend this study by including more generative AI robots in order to even out the downside effects of the first two points above. Regarding the third point, dollar-based approaches to evaluate the TCO may be a way out but at a much higher cost.

In summary, whereas the interrelationship between the TCO rating score (as a proxy for the perceived economic value) and the usability dimension rating scores was rather complex and vulnerable to multicollinearity, the above multiple regression model at least managed to predict and explain well the TCO rating score and thus the perceived economic value of an OS by leveraging the rating scores for the seven usability dimensions (2) Efficiency, (3) Learnability, (4) Memorability, (5) Safety, (6) Utility, (7) Ergonomics, and (8) Accessibility of the OS. Generative AI robots are thus shown to be a very prospective technology to incisively comprehend global users' textual comments at scale, to rate the omnibus usability dimensions of an OS based on such comments, and consequently to predict and explain the TCO rating score and thus the perceived economic value of the OS.

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