JOURNAL OF BUSINESS, TECHNOLGY & LEADERSHIP
SCHOOL OF BUSINESS AND TECHNOLOGY – COLLEGE OF ADULT AND GRADUATE STUDIES
COLORADO CHRISTIAN UNIVERSITY PEER REVIEWED PUBLICATION
VOLUME 1 ISSUE 2 FALL 2019 PAGES 1-9

Moral Perspectives of Reverse Engineering

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Abstract: This paper addresses reverse engineering from both ethical and biblical perspectives. Utilitarian arguments in favor of reverse engineering and Kantian arguments against reverse engineering are provided. An initial attempt to place reverse engineering within a biblical framework is also offered, along with recommendations for future research.

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INTRODUCTION

This paper provides a preliminary discussion on the ethical and biblical perspectives of reverse engineering (RE). A short background of RE and a summary of legal precedents pertaining to RE are provided. An ethical perspective of RE is then offered with specific focus on utilitarian and Kantian arguments. An attempt to place RE within a biblical framework is subsequently provided with specific focus on offering biblically-based moral principles for RE. Contributions of this research are then provided along with follow-up recommendations for future research.

DEFINITION AND BACKGROUND OF REVERSE ENGINEERING

There are several definitions of reverse engineering (also referred to as "reverse product development"). A historical definition for reverse engineering (RE), originally offered by Chikofsky and Cross (1990, p. 13), states that it is "the process of analyzing a subject system to identify the system's components and their inter-relationships and creature presentations of the system in another form or at a higher level of abstraction". Stated in more layman's terms, RE involves "re-creating things from the existing by analyzing…how it executes, what it performs, and then try to produce the same functionality" (Gandhi et al, 2014, p. 509). From a legal perspective as discussed by Behrens and Levary (1998, p. 27), the U.S. Supreme Court has defined RE as "a fair and honest means of starting with the known product and working backwards to divine the

process which aided in its development or manufacture."

RE has a long history of accepted practice and has recently been driven in part by technological, economical, and political factors (Snider et al, 2008). More specifically, motivations for RE include military or commercial espionage, competitive technical intelligence, product security analysis, improvement of documentation shortcomings, academic/learning purposes, and illegitimate means related to creation unlicensed/unapproved duplicates (Messler, 2013). Indeed, the field of RE has helped companies to remain competitive (Burgyan, 2014).

Not surprising, RE has emerged to support organizational functions and satisfy global market demands (Snider et al, 2008). RE has been applied to support key functions across an organization including support of marketing of products/services, design/development functions, manufacturing support, and quality. Overarching uses of RE include design of new products and achievement of greater levels of production efficiencies (Messler, 2013).

The basic stages of RE for a physical product can include (1) obtaining the product that is to be reverse engineered (2), creating a 3D digital representation of the product, (3) and then converting the 3D digital representation into CAD component (Dúbravčík and Kender, 2012). Some RE methods/tools include 3D scanning/probing, automated data interpretation, intelligent 3D CAD, and model-based definition (Coy, 2015). Interestingly, one has to only look at Amazon (2018) for the multitude of books available on RE methods and tools.

SUMMARY OF LEGAL PRECEDENCE

Outside of software industries, legal precedence has mostly ruled in favor of RE (Engineering Production Plans, 2006), as long as it does not rise to the level of patent or copyright infringement and trade secret violations. Samuelson and Scotchmer (2002) point out that RE has been endorsed by both lawyers and economists as a valid process, even if the re-engineered product draws customers away from the original product. Some key historical U.S. legal precedents related to reverse engineering are shown in Table 1.

Table 1: Key Historical Legal Precedents Related to Reverse Engineering

Case	**As Pertaining to RE…**
U.S. Supreme Court: Kewanee Oil v. Bicron, 1974.	"Trade secret law does not forbid the discovery of the trade secret by fair and honest means, e. g., independent creation or reverse engineering" (Justia, 2018a, p. 416 U. S. 490).
U.S. Congress: Semiconductor Chip Protection Act (SCPA), 1984	"…permits reverse engineers to make copies of protected chip designs in order to study the layouts of circuits, but also to incorporate know-how obtained during reverse engineering in a new chip design. However, the statute also requires reverse engineers to engage in enough "forward-engineering" to develop an original chip design that itself qualifies for SCPA protection" (Samuelson and Scotchmer, 2002, p. 18).

U.S. Supreme Court: Bonito Boats, Inc. v. Thunder Craft Boats, Inc., 1989	"From their inception, the federal patent laws have embodied a careful balance between the need to promote innovation and the recognition that imitation and refinement through imitation are both necessary to invention itself and the very lifeblood of a competitive economy" (Justia, 2018b, p. 489 U. S. 146).

Reverse engineering of software products, however, has been met with mixed results in the legal realm, primarily related to copyright law, economics of interoperability, patent law, and contract law (Samuelson and Scotchmer, 2002). Indeed, the 1998 Digital Millennium Copyright Act (DMCA) passed by Congress makes RE of copyrighted material illegal, except if authorized by another statute (Lee, 2010). Yet in their comprehensive review of the law and economics of reverse engineering, Samuelson and Scotchmer, (2002, p. 71) advise policy makers that "restrictions on reverse engineering ought to be imposed only if justified in terms of the specific characteristics of the industry, a specific threat to that industry, and the economic effects of the restriction."

ETHICAL PERSPECTIVES OF REVERSE ENGINEERING

In the absence of patent infringement, copyright breach or trade secret violation, RE has enjoyed a longstanding tradition with engineers. Supporters have argued that the "purchase of a product in the open market confers personal property rights in the product, including the right to take the product apart, measure it, test it, etc.," (Samuelson, 2002, p. 16). These arguments tend to rest on utilitarian grounds in that the 'greater good' benefits if the company performs RE on a competitor's product. Dissenters have argued that RE can stray into the realm of another's creative works and that such works should be treated with dignity and respect. These arguments tend to rest on Kantian grounds, especially when the creative complexity of the product being "re-engineered" is high, even if the RE does not violate any laws.

Utilitarian Perspective

The utilitarian perspective in this paper applies "act" utilitarianism theory in that an act is morally permissible if the consequences of the act produce the greatest amount of benefit for the most persons affected by the act (Tavani, 2007).

A key utilitarian argument in favor of RE rests on the grounds of providing economic benefits to the consumer. Dissenters of RE originally applauded the popular Apple vs. Microsoft case in which Apple licensed individual desktop icons to Microsoft, but then later (after seeing Microsoft Windows 2.03) alleged copyright infringement because the overall Microsoft Windows product had the same "look and feel" as the Apple Macintosh Graphical User Interface operating system (Graham, 1999). After years of litigation, Microsoft continued to use many of the disputed icons, and the case was eventually settled. The ultimate result was that the Windows operating system has been one the most demanded computer operating systems of the past three decades, in part due to its economic viability to consumers. Thus, the utilitarian argument would suggest that Microsoft created a windows-based computer operating system, originally conceived in parts by Apple, and made it viable for consumers in a more holistic sense.

A second utilitarian argument in favor of RE, and somewhat related to the first argument above, is based on expediting product improvement (Lysne, 2018) in both performance and in ease of use. In this way, the greater good (i.e., society) benefits. The

utilitarian argument suggests that society benefits since product innovation occurs. Consumers at large can reap the benefits of a new consumer product. In this way, "forward engineering" processes are encouraged, despite the fact that a certain degree of RE is needed to get the creative juices flowing.

A third utilitarian argument in favor of RE rests on the grounds of "interoperability" (Moore, 2008). Specifically, RE should be acceptable in the market if consumers can benefit when competitor devices can operate with each other. An example could be reverse engineering a USB drive connection so that Computer Make A's USB drive can fit into Computer Make B's computer. Typically uniform industry standards evolve and interoperability issues eventually become irrelevant.

A final utilitarian argument in favor of RE relates to encouraging free market competition. As Orner, (2014, p. 1) discusses, RE allows "companies the chance to build their own product to compete with a comparable price, quality, and design. This leads to more products on the market and more opportunities for us consumers to decide which product is best". Thus, the argument here is that RE can help circumvent company abuse of monopoly power, thus keeping prices low and allowing consumers product choice. One could counter argue that RE would discourage R&D efforts. Yet while this is a concern, RE is expensive in certain industries and thus not always a viable option. In addition, legal precedence exists if RE rises to the level of copyright law or patent law, and thus even the threat of legal action may deter certain RE-oriented firms.

Kantian Perspective

Standards related to "codes of conduct" at the individual level exist, as examples, for engineers (IEEE, 2018) and project managers (PMI, 2018). Yet while these ethical guidelines and similar guidelines from other organizations may look good on paper, will companies or individuals really abide by these best practices and ethical codes of conduct in the face of an RE effort? For this paper and to help provide direction for the aforementioned question, the second formulation of Kant's categorical imperative is applied in that individuals or companies who originally designed the product have dignity and should not be treated merely means to an end (Velasquez, 2017). That is, another's entity's creative works along with the originating person/organization should be treated with respect.

A key Kantian argument against RE rests on grounds of violating *creative investment*. In other words, if a person/organization has expended both time, effort, and financial investment in developing a product, how respectful is it to that person/organization if another entity is allowed to reverse engineer it and reap any subsequent financial rewards? While legal precedence exists if RE rises to the level of copyright law or patent law and given that RE is not always a viable option for competitors, one could argue that the creative persons/ organizations' fundamental rights, from a Kantian perspective, would be violated due to RE initiative of competitors.

Another Kantian argument against RE rests of the grounds of diminishing one's *creative footprint* on society. For example, one could argue that Steve Jobs' "creative footprint" on society, at the time, was diminished when, despite the fact that Apple licensed individual desktop icons to Microsoft, later unpleasantly discovering that the Microsoft Windows product had the same "look and feel" as the Apple Macintosh Graphical User Interface operating system (Graham, 1999). The Kantian argument against RE here suggests that one's individual creative stature in an industry, and possibly the society at large, is reduced due to RE. Interestingly, the IEEE (Institute of Electrical

and Electronics Engineers) Code of Ethics (IEEE, 2018) states that its members are to "to avoid injuring others, their property, reputation, or employment by false or malicious action". While it can be argued that RE does not necessarily fall into this realm, the reputation aspect of this guideline could be relevant within the context diminishing one's *creative footprint* on society.

One final Kantian argument against RE relates to squelching one's future *creative aspirations and achievements*. For example, a gifted person/organization may lose the desire to be creative if the uniqueness of the created product itself cannot stand the test of time. While this may border on narcissism, the argument here is that based on Kantian grounds related to dignity and respect, creative legacy could be easily compromised due to RE. Indeed, creative achievements could also be compromised in that the gifted person/organization may be too focused on making the product "RE proof" as opposed to making it the best it could be, i.e., in alignment with the gifted person/organization's natural creative abilities.

BIBLICAL PERSPECTIVES OF REVERSE ENGINEERING

Biblical perspectives can help to ascertain a moral compass with respect to RE by attempting to place RE within a biblical framework. The following biblical principles can help to accomplish this: the blessing of mankind's creative abilities, acting with integrity, and the biblically endorsed 'work' mandate.

Creative Abilities

God's has blessed men and women with creative abilities. Examples relate to God's sanctioning of mankind's dominion over creation in both pre-Fall and post-Fall existences (Genesis 2:15, Genesis 3:17-19, The English Standard Version), God's delegation of leadership to Moses (Ex. 3:10), God's chartering of the tabernacle (starting in Ex. 25:10), and the directive to Solomon in building the temple (1 Kings 6). God has historically entrusted men with initiatives that required both original creativity and innovation.

Noah's Ark is considered one of the great engineering marvels of the Bible and was innovative in both its design and construction. In Genesis 6:14-16, God defined a series of design requirements for Noah and entrusted Noah to be creative, detailing the materials to be used (gopher wood and pitch), the ship's dimensions (450 feet long, 75 feet wide, 45 feet high) and its features (consisting of three decks, a skylight and a door on the side).

Mankind's ability, as demonstrated by Noah, to be creative is shown here – even accomplishing what seems to be impossible. Yet following God's requirements by Noah was critical (Genesis 6:22) and that building a product that embodied breakthrough technology like the Ark took time and patience. People have the God-given creative will and ability to design and build. The biblical examples model a behavior for mankind to trust God in accomplishing great feats in product development.

So this begs several questions. If creative acumen is a God-given ability with clear evidence as far back as Noah's time, why should RE even be necessary? On the other hand, assuming laws are not violated, is not RE a natural progression of original creative work? If a product can be improved, does not RE help foster mankind's God-given creative abilities?

Acting with Integrity

According to Merriam-Webster (2018), two definitions of integrity include

incorruptibility ("firm adherence to a code of especially moral or artistic values"), and *soundness* ("an unimpaired condition"). From a biblical perspective, integrity (incorruptibility) within the context of one's walk (i.e., actions) can result in benefits related to betterment (Proverbs 19:1; Proverbs 28:6), guidance (Proverbs 11:3), security (Proverbs 10:9), deliverance (Proverbs 28:18), blessed offspring (Proverbs 20:7), and even God's protection (Proverbs 2:7). Integrity (soundness) is biblically presented as a measure of character (Psalm 26:1; Psalm 26:11; Proverbs 2:21) and a state of one's heart (Psalm 101:2). Joseph's rejection of Potiphar's wife can be held as an example of a measure of sound (unimpaired) character, i.e., integrity (Genesis 39: 7-12), along with Job's perseverance in the face of enormous suffering (Job 2:3). Jesus exemplified integrity throughout his life, which was perhaps most strongly tested when being tempted by Satan (Luke 4:1-12) and during his time in the Garden of Gethsemane (Matthew 26:36-46).

With the biblically high standard of integrity in mind, can one really claim that RE is an act of integrity (incorruptibility)? One could argue that as long as no laws are broken when performing RE, perhaps the 'incorruptible' standard of integrity is met. However, does RE result in one's betterment (Proverbs 19:1)? Proponents of RE might counter in that RE can result in the betterment of a product, and thus the betterment of those individuals/organization involved in the RE effort, and ultimately the betterment of society at large. Regarding integrity (soundness), would one view individuals who conduct RE as those with "an unimpaired conditions"? It is possible that one could build a biblically-based argument that "integrity as a measure of sound character" and "RE" is not completely synonymous.

The Work Mandate

While mankind does not measure up to God's standard (Romans 3:23), is self-willed and prideful (Exodus. 33:5), and easily prone to sin (Genesis 3:6-7), one can counter that mankind still bears "the image of God and are truly remarkable creatures with astounding abilities and potentials that are to be protected, encouraged, and developed" (Chewning, 1989). Furthermore, one's acceptance of Christ (John 3:16), one's trust in the Lord (Proverbs 3:5-6, Matt. 11:28-30) and the work of the Holy Spirit one's life (Matt. 28:20, Gal 5:22-23) as a renewing agent, can guide us in living a self-denied, Christ-actualized professional life (Rom. 12:1-2).

With this in mind, an overarching mandate for earthly existence is for mankind to have dominion over creation – a mandate so important that it was sanctioned by God before (Genesis 1:26) and after (Genesis 3:17) the Fall. This mandate is operationalized as "work." The importance of work is revealed biblically in terms of rewards for hard labor (Proverbs 12:11, Proverbs 12:14; Proverbs 14:23; Proverbs 28:19) and regarding the perils of laziness (Proverbs 21:25, Proverbs 24:30, Matthew 25:24-26).

Proponents of RE could argue that the biblically-supported work mandate fits nicely with RE. RE can be time consuming, costly, and may not result in the intended goals. In other words, a given RE effort might not come to fruition if one does not work hard enough. Thus, if RE is conducted lawfully and diligently, the rewards for the hard work, proponents may argue, is biblically sanctioned. Certainly one could also argue that RE is alignment with Weber's protestant work ethic (Weber et al, 2002).

On the contrary, a biblically-based counter-argument against RE could rest on grounds on of whether RE is a legitimate act of work. In other words, if RE is not construed as a genuine work-related effort,

then is the biblical provision of rewards for hard work relevant? Does God really have RE in mind within the tapestry of the 'work mandate'?

DISCUSSION

This paper attempted to provide a preliminary discussion on the ethical and biblical perspectives of RE. Figure 1 provides a summary of the ethical and biblical perspectives of RE that were addressed in this paper.

A short background of RE and a summary of major legal precedents related to RE were provided. Utilitarian arguments in favor of RE were presented and rest on the grounds of economic benefits to the consumer, product improvement, interoperability of products, and encouragement of free market competition. Kantian arguments against RE were also provided and rest on the grounds of violating the product originator's creative investment, diminishing one's creative footprint on society, and squelching one's future creative aspirations and achievements. An attempt to place RE within a biblical framework was provided and was conceptualized in terms of the blessings of creative abilities, acting with integrity, and the meaning of "work."

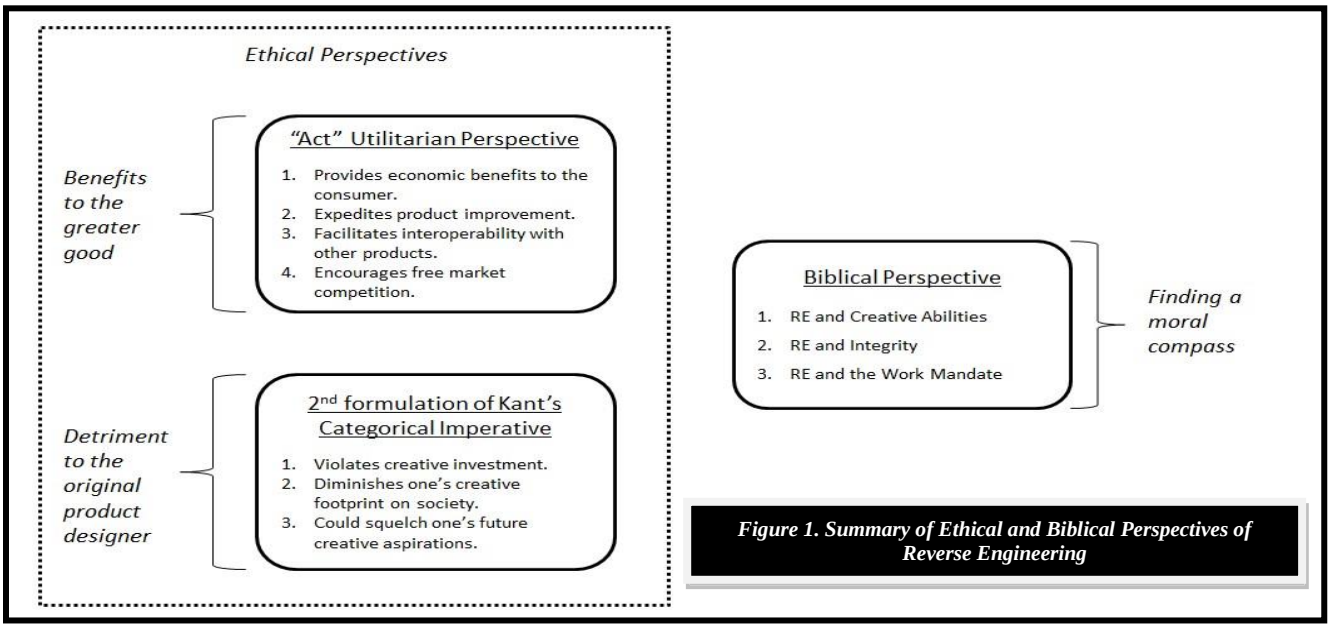

Figure 1. Summary of Ethical and Biblical Perspectives of Reverse Engineering

Contributions

One contribution of this paper is that it provides more focus on the ethical dimensions of RE. While most of the literature appears to favor RE through the lens of 'act' utilitarianism, there appears to be less available research on the Kantian aspects of RE. In addition, this paper sheds greater light on the practicality of RE from an ethical perspective. It is hoped that this work encourages others to help provide a more balance ethical treatment of RE. Another contribution of this paper is that it attempts to place RE within a Christian biblical framework, which is not addressed extensively in the literature, in an initial attempt to ascertain a moral compass with respect to RE.

Recommendations for Future Research

There are several recommendations for future research in response to this paper. Additional refinements of the Kantian ethical perspective are needed, since the perspective has enjoyed less attention in the literature. It is also recommended that justice theory be considered for possible integration into the ethical perspective related to RE. Virtue-based and covenantal ethical perspectives may also hold promise with respect to the ethical dimensions of RE.

This paper is an *initial attempt* to place RE within a biblical framework. More work in this area is needed. One approach could be to contextualize RE within Old Testament and New Testament frameworks and then compare them. Another approach is that biblical-based perspectives related to RE could be expanded to reflect Christian denominational-specific perspectives. Thus, it is recommended that future works should consult the vast literature on Christian scholarship in an attempt to provide a broader Christ-centered conceptualization of reverse engineering.

Ultimately, future research should focus on developing a fully integrated Ethical and Biblical Decision Model with respect to reverse engineering. It is hoped that such a model could be used as a guide for scholars in terms of contemplating the theoretical and spiritual dimensions of reverse engineering and for business and engineering professionals for application in practitioner settings.

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