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THESIS

**PEER PRODUCTION IN THE U.S. NAVY: ENLISTING
COASE'S PENGUIN**

by

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December 2009

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PEER PRODUCTION IN THE U.S. NAVY: ENLISTING COASE'S PENGUIN

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

Peer Production is an emerging model in the information age. It takes advantage of greatly reduced transaction costs enabled by the combination of a networked information economy and ubiquitous personal computing power. This thesis outlines why this new model is so significant to the U.S. Navy. This is done in part through modeling and simulation in ARENA. The model demonstrates how incomplete specification of agent talent and task difficulty adversely affect traditional firm production and cause both cost and schedule overruns as well as project failure. Modeling the peer production process demonstrates how a significant portion of these shortcomings are overcome in the new economic model. The model also quantifies the significant gains in efficiency, higher probability of success, increased rate of innovation, and reduced cost result from PP. Finally, we present a first look at how peer production can be systematically applied and reapplied successfully—through a stakeholder analysis and functional decomposition.

By combining the model with the theoretical understanding of PP presented here, the Navy will be able to apply peer production in numerous areas, to include: advertising, recruiting, maintenance, casualty response, family services, health care, R&D, and ship construction.

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LIST OF ACRONYMS AND ABBREVIATIONS

CBPP	Commons Based Peer Production
CNO SSG	Chief of Naval Operations, Strategic Studies Group
COTS	Commercial Off The Shelf
CSE	Customer Service Engineer
DoD	Department of Defense
IVE	Immersive Virtual Environment
JIT	Just In Time
MMORPG	Massively Multi-Player Online Role Playing Game
NIE	Networked Information Economy
OSS	Open Source Software
OSSD	Open Source Software Development
OT&E	Operational Test & Evaluation
PMO	Project Management Office
PP	Peer Production
TCE	Transaction Cost Economics
TQM	Total Quality Management
VTC	Video Tele-Conference

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EXECUTIVE SUMMARY

This research began by challenging one of the most basic assumptions in typical systems procurement and development. That assumption entails the belief that in order to maintain control of the design and production process one must also maintain direct supervisory control over the individuals performing the specific task. This research will explore an alternative hypothesis: abandoning control can lead directly to increases in efficiency and timeliness of the development process, as well as increased relevancy and quality of the system being developed, or a product being produced.

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I. PREFACE

A. ORIGIN OF THIS RESEARCH

The Chief of Naval Operations' Strategic Studies Group (CNO SSG) is tasked with discovering the Warfighting strategies of the future. Specifically, SSG XXVI's work focused on making these discoveries for the year 2030 with respect to cyberspace and the Navy. The goal is to take the revolutionary ideas posed by the SSG and apply them in a manner that is relevant today. In doing so, a clearer path from today to 2030 can be developed. This research outlines an immediate course of action that will lead to the future envisioned by SSG XXVI.

The foundation, upon which this research was built, is the SSG's definition of cyberspace. The thesis conclusions do not follow from the presently accepted definition of cyberspace ("A global domain within the information environment consisting of the interdependent network of information technology infrastructures, including the Internet, telecommunications networks, computer systems, and embedded processors and controllers.") found in JP 1-02. Cyberspace was redefined by SSG XXVI (SSG XXVI Report, July 2007) to better encapsulate the possibilities that will be available in 2030. The comprehensive definition also encompasses the evolution of disruptive and innovative concepts expected over the next twenty years.

This more comprehensive understanding of cyberspace leads one to think of human socialization and interaction as the realization of more effective communications, with notions that result in more effective models of social and economic behavior. This is in stark contrast to a JP 1-02 cyberspace that is "controlled". For example, human interactions currently available through immersive virtual environments (IVE) are significantly more than just digitized information transferred via networked computers controlled by access restrictions, protocols, and levels of trust. In the IVE, a system of elements (people) and domains (affinity groups) are created or formed through a routine (resulting from a general modus operandi) or phylointerests (defined as the state of relationship between people and groups of people, resulting in resemblance in structure

or structural parts, Langford 2008) that attracts and absorbs the human psyche into it. By doing so (the mechanism), a presence in cyberspace is created.

SSG XXVI defined cyberspace as

An unconstrained interaction space for human activity, relationships and cognition,...where data, information, and value are created and exchanged,...enabled by the convergence of multiple disciplines, technologies, and global networks...that permits near instantaneous communication, simultaneously among any number of nodes, independent of boundaries. (SSG XXVI Report, July 2007)

It is through this understanding of cyberspace that the accomplishments, developments, and possibilities that have been outlined here, begin to make sense. This research, like the SSG definition, focuses on the opportunities that are present through human interactions in cyberspace and not upon cyberspace itself. It is through this understanding of cyberspace, that we can undertake predictions of where we and our adversaries will go in the future.

B. HOW TO PROCEED

The contents of this thesis is focused on two questions: (1) Can a solution that addresses project overruns and escalating costs of labor be characterized by a new economic operations model—peer production; and (2) how does peer production solve this problem? To answer the first question, we will first consider descriptive information that focuses on a solid understanding of peer production as a concept. In doing so, peer production is viewed from a number of academic perspectives. We will then use a model and simulation of PP to demonstrate that it can address the aforementioned overruns and cost escalation. The second question will be addressed by applying the fundamentals of sound Systems Engineering. PP will be functionally decomposed to discern a repeatable approach for its application. A stakeholder analysis will also be presented to describe the critical players in making PP successful. Finally, some applications for PP within the Navy, based on successful examples from the commercial sector, are presented for immediate pursuit.

II. INTRODUCTION

A tough new business rule is emerging: Harness the new collaboration or perish. Those who fail to grasp this will find themselves ever more isolated—cut off from the networks that are sharing, adapting, and updating knowledge to create value.

Tapscott & Williams, WIKINOMICS

A. DEFINITION OF PEER PRODUCTION

Peer Production (PP) is an economic model of production on par with firm and market production methodologies (Benkler, 2006, p. 107). PP is executed through an Internet based, coordinated effort of volunteers who contribute project components. PP incorporates some process to combine project components into a unified intellectual work (Krowne, 2005, p. 6). The realm of PP is knowledge, information, and culture; or in more general economic terms, PP creates non-rival goods.

This definition encapsulates PP rather succinctly but it also oversimplifies the concept significantly. This thesis begins with this definition as a point of reference. From this starting point, PP is described as the third economic model of production alongside the firm and market methodologies. PP is then developed into a model of production that can be applied by the Navy in numerous areas such as maintenance, advertising, R&D, and recruiting.

B. EXAMPLES OF PEER PRODUCTION

Table 1 is provided as a demonstration of the breadth of well-known projects and tools that utilize PP techniques. The table gives a brief description of how the listed examples use PP with respect to the definition given in the previous section. In most cases, the example is not solely a product of PP but rather a combination of computing power, proprietary development, and PP. The common thread among the examples is that none of them would be possible without incorporating PP techniques.

Google Search Engine	The aspect of the Google search engine that sets it apart from other search engines is the way it ranks results. Its ranking system is comprised of three equally important components. Without any one of them the search engine would not work. One of these components is a product of peer production. Google considers how many Web pages link to a particular site to determine its relevance. Each link is produced by, in this case, an unknowing peer. Google compiles the links into a cumulative work that ranks Web page relevancy (Brin & Page, 1998).
InnoCentive	InnoCentive is a Web-based enterprise that uses peer production to solve previously unsolvable engineering challenges for its clients. Obviously, InnoCentive could not solve these problems if they were truly unsolvable. Rather these challenges were only unsolvable with the resources available to the client "in house". By pooling together the individual resources and talents of anonymous Internet users, InnoCentive matches problems with individuals able to solve them.
MMORPGs	Massively Multi-Player Online Role Playing Games are the most successful genre of video games ever created. Collectively they have hundreds of millions of players worldwide. The popularity of these games is due to the application of a PP methodology. MMORPGs are designed to be unwinnable by an individual player. They require coordination and cooperation among a multitude of players with different skills to accomplish the necessary tasks in the game. It is this design requirement for cooperation that has stimulated the use of PP within these game communities.
Wikipedia	Wikipedia is the best known product of peer production. Jimmy Wales, founder of Wikipedia, developed the "wiki" to harness the power of PP to produce an online, free, self-correcting, and dynamic encyclopedia. The "wiki" has stimulated tremendous growth in the number of peer produced projects, large and small. However, it is important to realize that use of a "wiki" is not a sufficient condition for applying peer production.
Amazon	Buying a book from Amazon.com places the purchaser directly inside a peer production process to which they are a key contributor. Amazon has made the process of combining project components into a unified intellectual work part of their business model. The project components are the purchase history of Amazon's customers. By compiling and correlating this information Amazon can make customized recommendation for other products that may interest an individual. This not only increases Amazon's sales but also provides a very valuable and time saving service to the consumer/peer contributor.
EBay	Where Amazon's use of PP serves to enhance its productivity, EBay's business model is wholly a product of PP. EBay has compiled individual product exchanges that were occurring locally between seller and buyer into a worldwide marketplace. EBay uses a PP process within a PP process to give the consumer confidence in its marketplace. By providing a means to grade individual sellers and buyers on each transaction and compiling the individual inputs into an overall score for the individual, a prospective consumer gains confidence that her next transaction will be fulfilled successfully with minimal risk of loss.
YouTube	YouTube's model follows nearly the same form as Wikipedia; the only difference is the form of the content being generated and the presentation of the exchange forum. Wikipedia uses the "wiki" and YouTube uses the searchable database with Website interface to collect, sort, display, and share peer produced video clips.
Second Life	Second life is another example that follows the Wikipedia model. It is a free, online, 3D, unbounded world (or metaverse) whose content was created completely by peer producers. The founders of Second Life (Linden Labs) simply created the blank slate upon which the metaverse was built.
Digg	"Digg is a social news Website made for people to discover and share content from anywhere on the Internet. By submitting links and stories, voting and commenting on submitted links and stories, stories are voted up and down, respectively called "digging" and "burying". Many stories get submitted every day, but only the most "Dugg" stories appear on the front page. Digg's popularity has prompted the creation of other social networking sites with story submission and voting systems." ¹ The Digg Website is simply a collector and compiler of peer contributions.

¹ <http://en.wikipedia.org/wiki/Digg>, accessed 15 March 2009.

NASA Clickworkers	Clickworkers was an experiment conducted by NASA researchers (Kanefsky and Barlow, 1997) to determine if distributed volunteers could accomplish massive data analysis. The project posted raw photos of Mars landscape and requested volunteers characterize the topography. The result of the voluntary submissions was statistically equivalent to the work produced by post doctoral research. The only difference was that the volunteers accomplished it in a fraction of the time expected. Once again, the only work required by NASA workers was to establish a forum for the volunteers to contribute and to integrate the contributions into an intelligible whole.
Humangrid	Humangrid (Human Powered Data Services) is a Dutch based corporate enterprise that is applying the NASA Clickworkers model. ²
Xerox Eureka	The Eureka project was a Xerox initiative in the late nineties. It was conceived to combat a falling customer satisfaction rating and the rise in product repair time and cost. The result of the project was a peer production system that was instituted at the repair technician level company wide. Through the use of this PP methodology, Xerox was able to set the standard in customer satisfaction within their market sector.

Table 1. Notable Peer Produced Projects

These examples listed in Table 1 outline the characteristics of peer production rather succinctly. The characteristics are:

- Self-selection
- Modularity
- Granularity
- Quantifiable (by the peer producer) value exchange
- Method of verification and integration

Self-selection is a characteristic of the PP process that applies to the peer producer. Self-selection means that the individual peer producer determines when, what, and how to contribute. Top-down orders are not compatible. Modularity and granularity are characteristics of the project which is being pursued. As an example, Wikipedia is modular. Each topic is a standalone entity that contributes towards the value of Wikipedia as a whole. Granularity refers to the size of the module; size is a measure of the amount of effort necessary to complete the task or module. Ideally, a well conceived PP project will be comprised of tasks of varying granularity to permit participation from individuals with different amounts of available time. An inherent value exchange is what makes PP an economic model of production and not just a good business practice. It is also what gives the peer producers a reason to contribute. It is because the individual

² <http://www.humangrid.eu/>, accessed 13 November 2008.

value does not have to be pre-negotiated or guaranteed that makes PP such an effective method of production. Lastly, the method of validation and integration is necessary to extract value from the individual peer contributions.

C. TYPES OF PEER PRODUCTION

PP can be thought of in terms of three types: Pinpoint, Broad spectrum, and Indiscriminant. They are displayed pictorially in Figure 1. Pinpoint PP is a project that requires a very specific knowledge contribution from one or a few expert contributors. Broad Spectrum PP solicits contributions from skilled contributors around a common theme and integrates these contributions into an intelligible whole. This type of PP is the most like the definition given previously. Lastly, Indiscriminate PP requires the highest volume of contributions. These contributions are of a sort that requires very little effort and no specific skill, i.e., they have very high granularity.

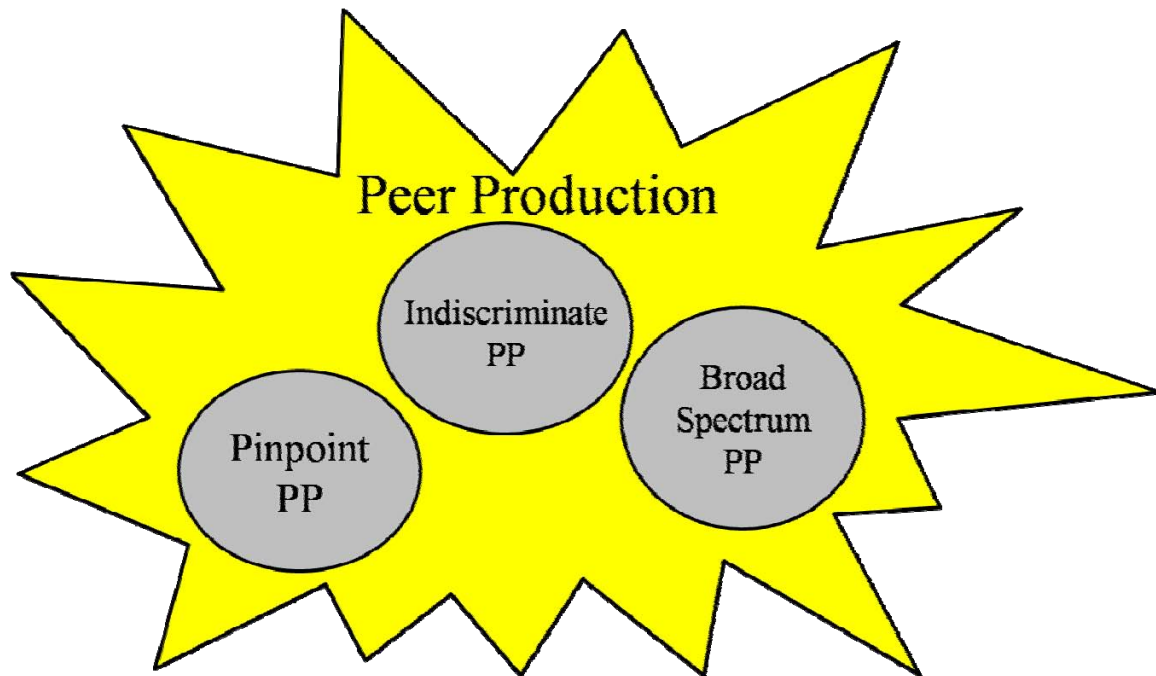


Figure 1. Types of PP

The representation given in Figure 1 will be used throughout this thesis to highlight (1) the characteristics of peer production and (2) how PP can be used to accomplish various goals. The jagged nature of the pictograph in Figure 1 represents the

rapid expansion of PP techniques into new applications that is currently occurring. Not all of these attempts will be successful, but the sum total of them all will provide a good idea of the potential of the methodology. While the distinctions between the PP types are not as well defined as presented in this model, the divisions provide concept clarity. In application, individual projects can utilize multiple types. In general, however, the distinction supplied in Figure 1 will prove extremely useful in understanding the broad characteristics of PP. The case-by-case nuances need to be determined in application only and will only serve to cloud the discussion in a theoretical presentation.

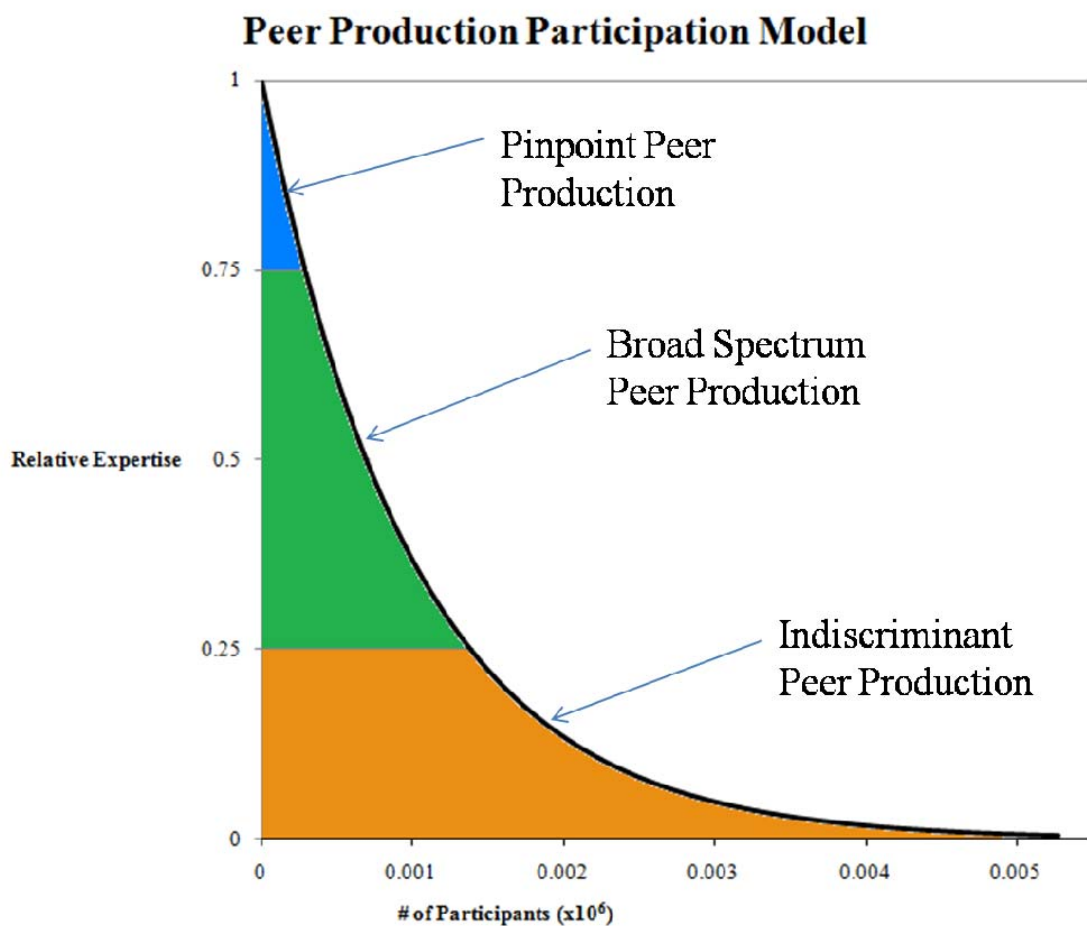


Figure 2. PP Participation Model

Figure 2 depicts the major differences between the three types of PP. These differences are the relative expertise of the contributors and the number of independent contributors necessary for a project. From the figure it can be seen that the types actually

make up a continuum where one type blends to the next (The hard line drawn in the figure is just for clarity and was placed arbitrarily. Ideally, orange blends into green, and green into blue.) The *y axis* in figure 2 refers to the talent level of an individual participant of a peer produced project. The *x axis* represents the potential number of participants available with that skill level. This should make logical sense because it parallels projects needs in the physical world. Not everyone on a project needs to have or should have a PhD. There is also a need for journeyman, apprentices, and support staff as well. Likewise, any peer produced project is going to have the need for participants from all talent levels, but the relative numbers will vary from project to project.

A little more clarity can be gained by associating an example of PP with each type. Brief descriptions are provided here, but for a more detailed description of three important examples of peer production refer to the Real World Examples in Appendix A.

InnoCentive (<http://www.innocentive.com/contact-us.php>) is a Web-based tool for soliciting peer producers for specific scientific and engineering projects. An assessment of InnoCentive online reveals very specific problems that are in need of solutions. The owner of a problem does not care who provides its solution, the only concern is that a solution is found. To achieve a solution, in most cases just one peer is necessary. That peer will need either a relatively high level of expertise in a particular field or an understanding of a solution to an analogous problem that has been solved in another field. InnoCentive is an example of Pinpoint PP.

Wikipedia is an example of Broad Spectrum PP. It uses a relatively large number of semi-skilled individuals to generate its content.

Clickworkers was a project sponsored by NASA which started in November 1997. Clickworkers exemplifies perfectly an application for Indiscriminant PP. The goal of the project was to evaluate images of the surface of Mars and identify craters. To accomplish this, the images were made available on the Web to individuals who were asked to scan the imagery and mark the craters with a series of mouse clicks. The project was highly successful in both the speed and accuracy with which the task was

accomplished. These examples identify the breadth of projects for which PP is applicable, given the willingness of the project managers to give up a certain amount of control.

D. CLASSES OF PEER PRODUCTION

Another useful way to characterize PP is by classes. We can distinguish three classes worth noting: internal, outside-in, and inside-out. The differentiating feature between the classes is the relationship between the peer community that is generating knowledge content and the sponsoring organization of the PP project. Figures 3, 4, & 5 represent these classes pictorially.

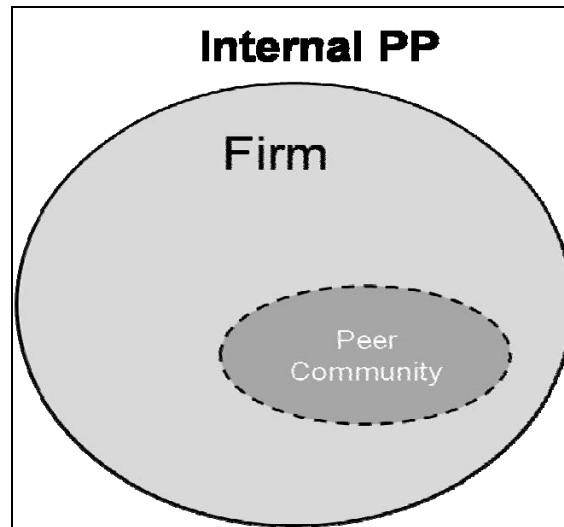


Figure 3. Internal Peer Production

With internal PP, the peer community is a subset within the larger parent organization. The contributions made by the peer community are compiled to directly benefit the larger organization.

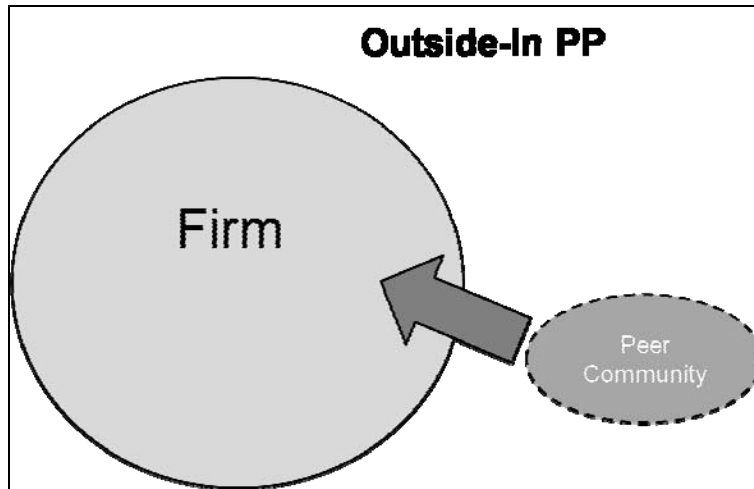


Figure 4. Outside-In PP

Outside-In PP uses an external peer community to make contributions that are compiled to benefit the larger organization. The NASA Clickworkers project is an example of this class of PP.

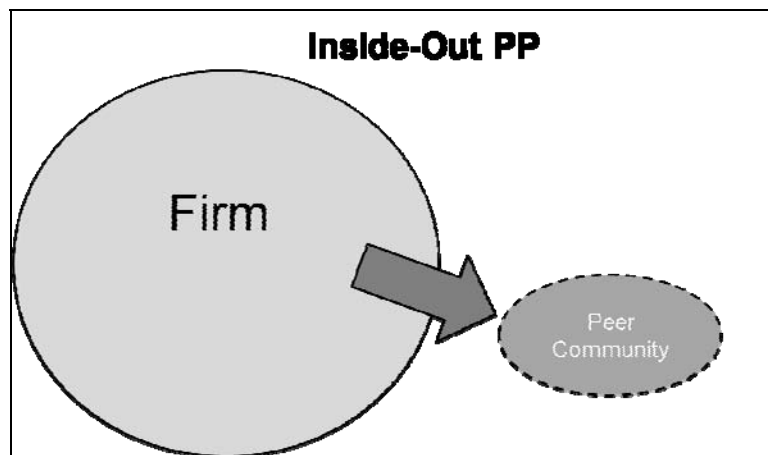


Figure 5. Inside-Out Peer Production

Inside-Out PP utilizes a peer community that is external to the parent organization. The parent organization compiles the contributions into a product that will benefit a larger constituent of the general public. Wikipedia, YouTube, and Second Life represent Inside-Out PP.

E. OVERVIEW OF ECONOMIC PRINCIPLES

From an academic perspective, peer production represents a significantly more substantial development than the other public movements that have found traction in the Navy. Total Quality Management (TQM), LEAN, "Just in time" (JIT) inventory management, and Learning Organizations are all good business practices that have infiltrated Navy processes and structure with the hope of increasing productivity. Recognizing PP as the third model of economic production is much bigger than these "good practices". Calling PP the third economic model of production is comparable to saying, with respect to Nuclear Engineering, that there is now a third way to release nuclear energy. (Fission and fusion are the other two.) PP is much more than a good idea; it is a revolution in the field of economics.

1. What Makes PP Possible

There are two characteristics of modern society that have caused the development of PP into a model of economic production. They are:

- Transition into a networked information economy.
- Ubiquitous personal computing power.

It seems that economic production in the U.S. shifts more and more to either a service based or a knowledge based product. America produces a dearth of durable goods. It is this shift towards knowledge that is the basis of the networked information economy.

Individuals with home access to the Internet are capable of contributing to the networked information economy. There is no longer a need for large corporate overhead to provide the means for production. Consequently, peer production has developed as a means to produce knowledge goods efficiently outside traditional firms or corporations.

2. Why Individuals Contribute.

The premise behind why individuals contribute to PP projects is rooted in human psychology. It is best summarized by the Reward Equation.

$R = M + H + SP$ (Benkler, 2002) where

R = reward

M = monetary compensation

H = hedonistic value

SP = social-psychological motivations

The reward equation attempts to explain why people choose to do the things they do. The reward equation maintains that individual human actions are performed to achieve some reward that is a combination of three components. In general, PP works any time monetary compensation is not the primary motivating characteristic (Benkler, 2002).

It is important to note that the reward equation is not a universal equation that can be directly applied like the Pythagorean Theorem. It is a subjective equation that must be applied by each individual or applied across groups of individuals with similar motivations to attempt to predict how they will behave. To be useful, a unit conversion must take place, because as written, monetary compensation is measured in dollars and hedonistic value, and social-psychological motivations are unitless. This is typically accomplished by translating monetary compensation into a unitless quantity that measures personal worth to the individual. This is similar to the process of conducting a tradeoff analysis during system design to ascertain the most important characteristics of the system to the customer. In this case, monetary compensation is converted to personal value. For example, a yearly salary of \$100K may be worth a three on a scale of 1–10 in terms of personal value but a salary of \$500K is a ten. Of course the \$500K position may also have a -20 value in terms of social-psychological motivations because it involves moving to Iraq without one's family for a year. However, it should be clear how the reward equation can be used as an indicator of contributor likelihood to participate in PP.

3. How Individuals Decide What to Do.

Peer production is developed around the central premise of self-selection. Because monetary compensation is no longer the primary motivating factor; there is no longer a "boss" to give direction. Self-selection requires the individual to decide what to do on her own. Understanding how a person makes this decision is essential to effective application of PP methodologies.

To decide between competing alternatives a comparison must be made. It is theorized that this comparison is based on a value to cost ratio (V/C). Value (V) is a function of the reward, R, from the reward equation. Cost, C, is a function of the money, time, and resources an individual must invest to perform a particular action. Any action that has a $V/C > 1$ is an action that is worth doing. To decide exactly what action to take an individual must compare all competing V/C ratios and simply pick the largest. Of course, individuals do not actually calculate V/C ratios but this model is an effective means of understanding the mental process of deciding. It also explains why individuals would contribute to a PP project for free, over getting paid for their services elsewhere.

F. THE SIGNIFICANCE OF PEER PRODUCTION

At the highest level, peer production is the economic model of production that has resulted from a globally connected information environment. It operates in the area between market and firm dynamics that did not exist before the Internet. The principles behind PP permit coordination between individuals that could not be orchestrated by the other economic production methods. The organization hierarchy required by firm dynamics could prove difficult to accommodate the degree of geographical dispersion that is seen in peer communities. Market dynamics could not effectively determine a price structure among peer production's participants. The number and size of contributions, is too varied to be negotiated individually. Peer production is uniquely suited to function in a completely distributed fashion. As a result, PP's use will continue to grow as the marketplace proceeds into Web 2.0, develops into Web 3.0 and eventually results in a seamless integration between the real and virtual.

The economic significance of PP is lost in each individual application of the methodology. At the application level, PP is simply a process. It is similar to Henry Ford's use of the assembly line. The assembly line was a way to restructure how labor was applied to the task of building an automobile. By more efficiently using labor resources Ford Motor Company was able to undersell its competitors and capture a lion's share of the market with its Model T. Likewise, PP is a technique to effectively use

knowledge resources in a way that not only changes the landscape of existing markets but also permits the development of entirely new markets.

If the theory is correct, and PP truly is the third model of economic production alongside market and firm dynamics, then the Navy cannot avoid understanding and utilizing PP methodologies. The last 20 years has seen a proliferation of outsourcing within the DoD. Peer Production represents the means to "buy-back" some of our core processes while simultaneously reducing cost and increasing quality. To fully understand PP, this research approaches the topic from multiple angles which include economics, psychology, systems engineering, and philosophy. This approach produces an understanding of PP at the macro and micro level. The result is an evaluation of what it takes to implement PP methodologies. With the framework in place, a systems approach to PP is taken and an implementation strategy is presented. Finally, this research concludes with a discussion about what PP means to the DoD and where we should go from here.

III. HISTORICAL PERSPECTIVE

A. THE BIRTH OF THE TERM "PEER PRODUCTION"

Peer production techniques predated the term. Modern PP began with the computer network, USENET, in the late 1970's. Yochai Benkler coined the term "commons based peer production" in 2002 in an article in *The Yale Law Journal* titled "Coase's Penguin, or, Linux and the Nature of the Firm". Coase refers to Robert Coase who, in 1930, postulated transaction cost economics in *The Nature of the Firm* and the Penguin refers to the mascot of the Linux kernel development community (Benkler, 2002, p. 369). It is important to note that the first reference to PP is in a discussion of economic theory. It is also important to note that this first mention of the term occurred more than 20 years after the computer networked techniques first surfaced.

In Coase's Penguin, Benkler does not explicitly define "commons based peer production" (CBPP) but instead talks about it as a production methodology. He compares this methodology to markets and firms. Firms have relied on internal markets organized into formal and informal networks to take advantage of shared purpose and collaboration. It is through this development that CBPP is defined. In 2005, Aaron Krowne posited a succinct definition of CBPP in *Free Software Magazine*. He states that "commons based peer production refers to any coordinated, (chiefly) Internet-based effort whereby volunteers contribute project components, and there exists some process to combine them to produce a unified intellectual work." (Krowne, 2005, p. 6) While this definition captures a complex concept so that it is easily understandable in colloquial language, it does not explain the usefulness of CBPP or what is necessary to effectively apply PP to produce a desired result. For this, Benkler's approach is necessary.

B. THE BIRTH OF PEER PRODUCTION TECHNIQUES

A brief historical perspective is presented here to demonstrate that PP is nothing new. To begin this discussion, consider an adaptation of Krowne's definition to define a more general term, Peer Production (as opposed to commons based peer production). Peer production is any coordinated effort whereby volunteers contribute project

components, and there exists some process to combine them to produce a unified intellectual work. By removing the caveat for "Internet-based" we can now look at PP with a historical eye and see if any significant examples are prominent.

Consider the fairly well known document called the United States Constitution. Given the broader definition of PP, it is apparent that this document is a product of it. Although James Madison is often referred to as the "Father of the Constitution", the document was actually a compilation of documents and ideas. It is based on the plan of Charles Pinckney, the Virginia Plan by Edmund Randolph, the New Jersey Plan by William Paterson, the Hamilton Plan by Alexander Hamilton, and the Connecticut Compromise by Roger Sherman. None of these plans are identifiable explicitly in the Constitution; rather they were uniquely blended by the 55 delegates of the Constitutional Convention.³ The final compilation of ideas was so unique and profound that it prompted Benjamin Franklin to exclaim:

There are several parts of this Constitution which I do not at present approve, but I am not sure I shall never approve them. ... I doubt to whether any other Convention we can obtain, may be able to make a better Constitution. ... It therefore astonishes me, Sir, to find this system approaching so near to perfection as it does; and I think it will astonish our enemies...⁴

Other than the technology applied, there is no difference between the PP used in 1787 and that used today.

Of course, the technology difference between historical and modern PP is significant. It is because PP is now executed via the Internet that many of the objections of PP are voiced. Questions of trust and security are the most prominent of these. Both trust and security were present when PP was used to produce the Constitution. Although all of the participants in the Constitutional Convention were volunteers they brought with them a level of trust because they were selected to represent their respective colony. Because they attended the convention in person there was also a sense of security. This

³ <http://www.usconstitution.net/franklin.html>http://en.wikipedia.org/wiki/Philadelphia_Convention, 22 September 2008.

⁴ <http://www.usconstitution.net/franklin.html>, 22 September 2008.

trust in the individuals and security of the forum did not translate into trust in the Constitution. As Ben Franklin's words above suggest, the worth of the document produced was based on the ideas it contained and not the prominence of the individuals who contributed them. This embodiment of worth is important because PP critics often discount the value of peer produced products because they do not trust the individual contributors that made the product possible.

By considering the prominent PP projects of the last 25 years it is shown that the result of these processes are valid, trustworthy solutions to the problems they were designed to solve. By considering the engineering behind these PP systems it is shown how trust of the process replaces trust of the individual. It is also shown that security has not changed and that it is a related, but separate issue. Security is necessary to ensure sensitive information is not released unknowingly or prematurely. Sometimes PP will meet security requirements, sometimes it will not. This does not invalidate PP; rather it limits the application of PP.

C. MODERN PEER PRODUCTION TIMELINE

Today's PP projects follow much of the same format as described by the historical perspective above. They start with a baseline usually provided by one or a few individuals, and then through a common interest, contributors voluntarily devote time and effort to improve the project. This process continues until the project eventually takes on a life of its own. This is true for the Constitution, which now has 27 Amendments, and for the examples that follow.

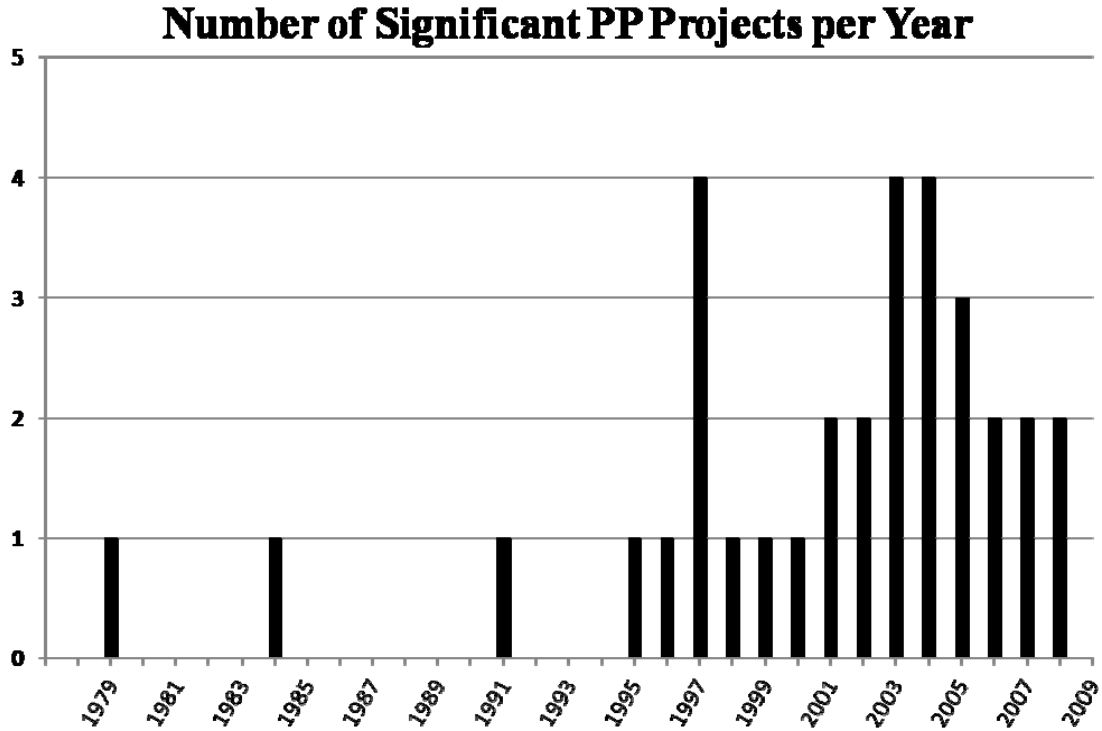


Figure 6. Successful PP Projects Since the Advent of USENET

Figure 6 lists a few noteworthy examples of PP that have occurred since 1979. Figure 6 represents the examples of PP that are both overwhelmingly successful and representative of the application of PP for an innovative purpose. This can be better understood by considering Figure 7.

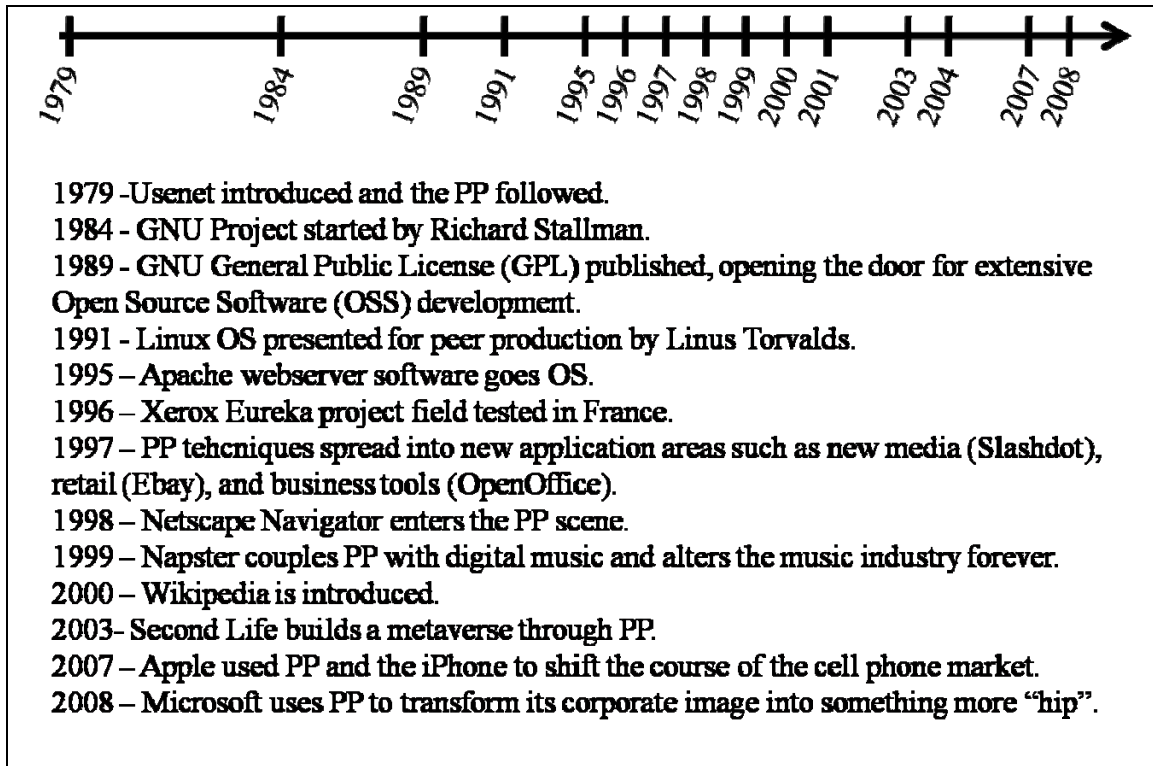


Figure 7. Timeline of Significant Application of PP

The foundation for modern (Internet-based) PP was laid in the 1960s, when the sharing of computer code among programmers in academia and industry was commonplace. In 1979, the sharing of code picked up tremendous momentum with the advent of USENET, a computer network to link the UNIX programming community together (Lerner & Tirole, 2000, p. 201). Today, the most well known CBPP project is GNU/Linux. The GNU Project was started by Richard Stallman in 1984 to create a "complete Unix-compatible software system"⁵ comprised entirely of free software. In 1985, Stallman created the Free Software Foundation and in 1989, wrote the GNU General Public License (GNU GPL) to facilitate the development of the GNU Project. The GNU GPL paved the road for the Open Source Software movement, which still thrives today. The GNU GPL is also the legal foundation upon which CBPP projects depend.⁶

⁵ <http://www.gnu.org/gnu/initial-announcement.html>, 22 September 2008.

⁶ <http://www.usconstitution.net/franklin.html>, 22 September 2008.

Richard Stallman laid the foundation for CBPP but it was Linus Torvalds, in 1991, which started the revolution. It began with a simple USENET posting to a newsgroup.

Hello everybody out there using minix — I'm doing a (free) operating system (just a hobby, won't be big and professional like gnu) for 386(486) AT clones. This has been brewing since April, and is starting to get ready. I'd like any feedback on things people like/dislike in minix, as my OS resembles it somewhat (same physical layout of the file-system (due to practical reasons) among other things).

I've currently ported [bash\(1.08\)](#) and [gcc\(1.40\)](#), and things seem to work. This implies that I'll get something practical within a few months, and I'd like to know what features most people would want. Any suggestions are welcome, but I won't promise I'll implement them :-)

Linus (torvalds@kruuna.helsinki.fi)

PS. Yes – it's free of any minix code, and it has a multi-threaded fs. It is NOT portable (uses 386 task switching etc), and it probably never will support anything other than AT-harddisks, as that's all I have :-).

– *Linus Torvalds*⁷

With this first notice of the existence of what would eventually be known as Linux, the stage was already set for mass collaboration. Torvalds knew he could not engineer a complete solution without outside input. Linux was first released under its own license but in December 1992, Torvalds released version 0.99 under the GNU GPL. Presently, the community does most of the work on GNU/Linux development. Programmers that use Linux around the world send their input to maintainers who perform the function of quality and standards control.⁸ Corporations, like IBM and HP, have also seen the benefit of Open Source Software (OSS) and frequently contribute both money and work force to its development. This process provides an excellent example how traditional models of production can be blended with the PP methodology with benefits for all involved.⁹

⁷ <http://www.linux.org/info/linus.html>, accessed 22 September 2008.

⁸ http://en.wikipedia.org/wiki/History_of_Linux, accessed 22 September 2008.

⁹ The birth of modern peer production essentially occurred when human collaboration was combined with P2P networks.

The combination of the Linux kernel and GNU software has led to the restructuring of major corporations, the revision of well-established economic theory and the formation of an entire sub-culture based on OSS development. This last event is so significant that in September 2000, the President's Information Technology Advisory Committee wrote

The open source development model represents a viable strategy for producing high quality software through a mixture of public, private, and academic partnerships. This open source approach permits new software to be openly shared, possibly under certain conditions determined by a licensing agreement, and allows users to modify, study, or augment the software's functionality, and then redistribute the modified software under similar licensing restrictions. By its very nature, this approach offers government the additional promise of leveraging its software research investments with expertise in academia and the private sector.¹⁰

Cooperative software development was a natural evolution once computer programmers became networked through computer systems. Ultimately, a computer programmer's objective is to get working code. The software firm's objective, however, is to generate revenue by introducing a functioning application to market. Cooperative software development is compatible with computer programmers; rather it is incompatible with the firm's proprietary nature and need to generate return on investment.

If it was not for the OSS movement (and peer production), it is safe to say that the growth of the Internet would not have been nearly as rapid in its formative years. In 1995, the Apache Web server went open source. Since 1996 it has been the most popular server on the World Wide Web. To this day, Apache runs more than 46% of all Websites and over 66% of the Web's most highly trafficked.¹¹ It is this free, community-developed, software that permitted millions of Websites to be introduced and reliably accessed practically over-night.

¹⁰ Letter to the President from the PITAC dated 11 September 2000, <http://www.nitrd.gov/pubs/pitac/pres-oss-11sep00.pdf>, accessed 22 September 2008.

¹¹ Apache HTTP Server. (2009, April 3). In *Wikipedia, The Free Encyclopedia*. Retrieved 22:47, 3 April 2009, from http://en.wikipedia.org/w/index.php?title=Apache_HTTP_Server&oldid=321408899.

In 1996, the first significant use of PP techniques outside of software development was implemented. Xerox, with its customer satisfaction rating plummeting within its copy machine market, was in desperate need of a new organizational model to help its field technicians effectively maintain their customer's machines. Xerox found its solution in a peer production process that they implemented worldwide. See Appendix A for more detail on this project.

In 1997, the dot com boom was rapidly gaining momentum. It was during this year that PP techniques reached out into many new markets. Three noteworthy PP endeavors started at this time. They now represent the first of many applications that use PP in each of their respective genres. Slashdot started the peer produced news media frenzy. This movement developed into the blogosphere and eventually forced the major news networks to adopt PP techniques just to maintain relevancy. EBay, a peer produced retail enterprise, provides sole-source and supplemental income to hundreds of thousands of individuals in the United States and world-wide. It is the small business's doorway to a global marketplace. It could not be possible without PP. OpenOffice also arrived on the scene in 1997 as the only alternative to proprietary word processing software.

1998–2000 saw further expansion of PP techniques into new markets. Netscape Navigator was the open source alternative for Web browsers in 1998. In 1999, Napster used PP to turn the music industry upside down. Napster was

...a centralized service that greatly simplifies and expands the ability of Internet users to copy MP3 music files from other persons' computers. It does so by providing a "virtual meeting place" where an individual user of the Napster system can find MP3 music files on the hard drive of other computers participating, at that moment, in the Napster "community." Napster then facilitates the direct "peer-to-peer" copying and transfer of those files (U.S. Court of Appeals, 2001).

Napster was eventually shut down, but not before costing millions in legal fees and forcing a revolution in the music media distribution model.

Wikipedia changed the encyclopedia business in 2000. Today, Wikipedia still receives a significant amount of criticism, but it is interesting that the majority of the criticism comes from those that are most threatened by its existence, namely academia. The users of knowledge rather than the creators of it (academia) are much more comfortable with Wikipedia.

Second Life is a virtual 3-D environment fielded in 2003. It has become a premier example of peer production since then. The founding company, Linden Labs, designed the virtual environments software and operates and maintains the servers. All of the virtual content is a result of peer contributions, however. This virtual environment has been so successful that it now has over 15 million accounts worldwide with its own functioning economy. There are over 25 different virtual environments available for membership on the Internet but in terms of membership, none are as successful as the Second Life. None of the other virtual environments use and encourage peer production to the extent of Second Life.

In 2007, Apple introduced the iPhone into the cell phone market. This was unique because with the phone, Apple and AT&T introduced a new business model. With the iPhone, AT&T provides the service coverage, and Apple maintains the software support. This new model has permitted Apple to open up the support software market to a PP process. Apple has been able to provide faster software updates and an unprecedented selection of support and accessory application software.

The unthinkable occurred in 2008. Microsoft, a company that invests billions in R&D and property rights protection, realized that they could no longer keep up with the pace of peer production. Microsoft unleashed two PP models. The first is devoted to development of its Web browsing software, Internet Explorer. The other project is dedicated to redefining Microsoft's corporate image into a fun, user friendly and hip institution. Whether either of these attempts will be successful has yet to be determined, but it says a lot when one of the largest corporate institutions recognizes they cannot secure a successful future using the traditional techniques alone.

Since the start of the GNU project, the OSS development model has expanded and now applies to anything that is considered non-rival; namely all instances of knowledge, information, and culture. PP encompasses this broader application and represents a viable strategy for engineering high quality solutions through a mixture of public, private and academic partnerships. Two conclusions can be made from the chronological depiction of PP. The first is that PP techniques have undergone a long development process which has demonstrated the applicability of these techniques in many different application areas. The second is that the success of the above listed projects makes PP worth both the risk and cultural change necessary to implement them.

IV. ECONOMICS OF PEER PRODUCTION

If I give you a pfennig, you will be one pfennig richer and I'll be one pfennig poorer. But, if I give you an idea, you will have a new idea, but I shall still have it, too.

Albert Einstein

Existing work with peer production falls into two categories: applying PP techniques, or economic analysis of the outcomes that have been produced with PP methods. The most important conclusion of these economic studies is that PP is compatible with and enhances a free market economy.¹² The PP model is applicable in the public, private, and academic worlds. PP will make these enterprises more efficient when applied appropriately. The corollary, however, is that PP does not improve all applications. Consequently, PP cannot replace all other production methodologies of the free market, but rather augments them. Thus far, PP has been successfully utilized in the realm of information, knowledge, and culture generation (Benkler, 2006). However, the boundaries of PP are yet to be fully determined. For now, the existence of limitations seems a plausible hypothesis.

A. ECONOMIC ACCOMPLISHMENTS

Consider what has been accomplished to date with PP.

- The Open Source software community and its work continually increase.
- The English version of Wikipedia contains 2,365,688 articles as of May 2008 and there are more than 100,000 articles in each of 18 other languages.
- Second Life is an online, 3D, virtual world, whose content is completely created by users. There are over 15 million accounts worldwide.
- In October 2006, Google acquired YouTube for \$1.65 billion in Google stock. Not bad for a Website that just hosts other people's videos. As of April 2008, there were 83.4 million videos on YouTube.

¹² The studies include those by Benkler (2002), Lerner and Tirole (2005), Bobrow and Whalen (2002), Lerner, Pathak and Tirole (2006), Johnson (2001), Tapscott and Williams (2006).

- EBay uses PP to build user confidence through the rating of buyers and sellers. EBay then draws revenue from the combined effect of millions of individual sales between millions of buyers and thousands of sellers.

B. ECONOMIC BACKGROUND

Peer production is usually studied from an economic perspective. In the industrial age, it was often more efficient for an organization to subsume a function or vertically integrate it to fulfill a need (Haque, 2005). Historically, if a company was in the business of making cars, it would also assume the task of designing and making engines because (1) the management costs of doing it internally were less than the transaction cost of finding an external supplier, and (2) ownership of intellectual property is fundamental to control. Vertical integration was considered "good practice" through the industrial information economy, and, in many cases, is still the most efficient means of enterprise organization. However, an increasing number of examples demonstrate that the model inadequately addresses business needs for efficiencies in the information age.

This thesis was a study of the importance and viability of PP methodologies to the DoD. It also highlighted the process repertoire needed to implement PP successfully. As such, it was first necessary to understand what makes PP economically significant as well as to understand pre-PP economic theory. This discussion starts with transaction cost economics (TCE) (Coase, 1937). The author accepts TCE as correct, and takes it as the economic baseline from which PP is evaluated. However, there are competing and complementary theories about the nature of the firm—to account for shortcomings in TCE.¹³ Some of these do apply to PP. Nonetheless, most of the useful questions about PP originate from a TCE point of view. This thesis uses TCE to convey how PP relates to the traditional economic theory of production. This view of PP was then projected to its logical end, which suggested the need for refinement of economic theories of firm boundaries. Figure 8 summarizes the process.

¹³ Some of the alternative theories to TCE for the nature of the firm are outlined in the following: Jensen, Michael C., and Meckling, William H., "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure", *Journal of Financial Economics*, 3(4), 305–360, 1976., Cyert, Richard and March, James. *Behavioral Theory of the Firm*, Oxford: Blackwell, 1963.

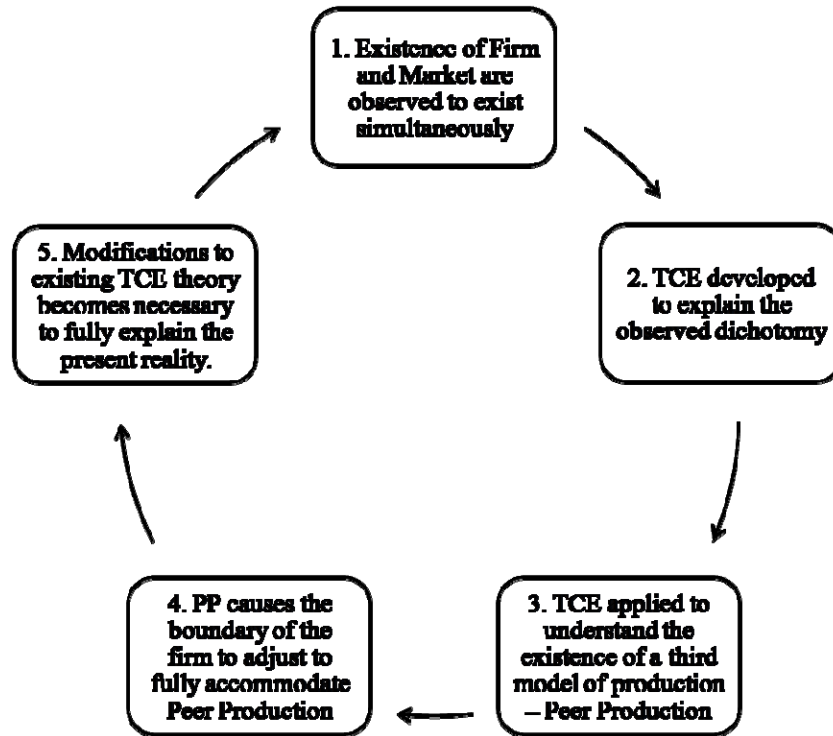


Figure 8. Incorporating Peer Production into Economic Theory

TCE, first suggested in 1937 by Ronald Coase, explains the nature of the firm and how its organization and operation were not just an extension of market dynamics and the differences in price structure. Coase first questioned existing assumptions and made his own observations. The assumption under question was that market enabled interactions (supply and demand) determined resource flow. This was assumed to be true both inside and outside the boundary of the firm. Coase, however, observed that an employee inside a firm does not move from division X to division Y because market prices tell him to do so. He does it because his boss tells him.

Outside the firm, price movements direct production, which is coordinated through a series of exchange transactions in the market. Within a firm, these market transactions are eliminated and in place of the complicated market structure with exchange transactions is substituted the entrepreneur-coordinator, who directs production (Coase, 1937, p. 19).

Coase concluded there were obviously two methods of production — firm and market. The question was then, if production could be coordinated entirely through the market, why did firms exist at all? Coase surmised that the reason firms exist, is because there is

a cost associated with both discovering the appropriate price and negotiating individual contracts for each exchange in the market. In fact, the firm exists to reduce or eliminate these costs. “A firm, therefore, consists of the system of relationships which comes into existence when the direction of resources is dependent on an entrepreneur.” (Coase, 1937, p. 22)

A firm will internalize a function as long as the management cost of doing so is less than the transaction cost of conducting the same function on the market. Eventually, “diminishing returns on management” will be experienced, and the firm will cease growing. Conversely, PP does not depend on direction from a hierarchical entity. It is a network of peers, which comes into existence around a particular purpose, where in most cases the only resource necessary is knowledge and the direction of resource flow is self-selecting.

With the above understanding of TCE, we consider the current economic landscape and how it has paved the way for peer production—making PP economically beneficial in some applications. In addition, this section concludes by suggesting what is necessary to seamlessly integrate PP into economic theory. Note, that Coase has already set the stage for this in his original document.

...it would appear that the costs of organizing and the losses through mistakes will increase with an increase in the spatial distribution of the transactions organized, in the dissimilarity of the transactions, and in the probability of changes in the relevant prices. As more transactions are organized by an entrepreneur, it would appear that the transactions would tend to be either different in kind or in different places. This furnishes an additional reason why efficiency will tend to decrease as the firm gets larger. Inventions which tend to bring factors of production nearer together, by lessening spatial distribution, tend to increase the size of the firm. Changes like the telephone and the telegraph which tend to reduce the cost of organizing spatially will tend to increase the size of the firm. All changes which improve managerial technique will tend to increase the size of the firm. (Coase, 1937, p. 25)

It appears that Coase was mistaken about the effect of future technological innovation. Although he correctly observed that inventions such as the telegraph, telephone, VTC, and email have made it possible to increase the size of the firm, numerous examples of

global corporations like IBM and Proctor and Gamble abound. The rise of peer production represents use of technology to bypass the firm completely.

C. ECONOMIC SHIFT

Yochai Benkler, the originator of the term peer production, is largely responsible for drawing academic attention to this surprising change in market dynamics. Like Coase before him, he first noticed that the way the free market was being described was not in sync with the new ways in which it was beginning to operate. The traditional firm vs. market standard cannot account for PP methods, undirected by either price structure or organizing authority. Benkler explained this by describing a series of economic shifts that have occurred since the dawn of the Internet.

According to Benkler, there has been a shift in economic production methods in developed nations. That shift can be characterized as a transition to an “industrial information economy” where “practical individual freedom to cooperate with others in making things of value was limited by the extent of the capital requirements of production” to a “networked information economy” where “the physical capital required for production is broadly distributed throughout society”. This happens because

personal computers and network connections are ubiquitous.....The result is that a good deal more that human beings value can now be done by individuals, who interact with each other socially, as human beings and as social beings, rather than as market actors through the price system. Sometimes these non-market collaborations can be better at motivating effort and can allow creative people to work on information projects more efficiently than would traditional market mechanisms and corporations. (Benkler, 2006, p. 6)

Benkler's description seems to be consistent with what is observed in the economy from a street level view. The media industry provides support for the new view. Just 25 years ago, news came from one of four sources: word of mouth, newspaper, TV, or radio. With the exception of word of mouth, behind each of these media was a huge, highly structured industrial complex that took little, if any, input from outside channels. Now there is almost a complete reversal of information flow. Newspapers are approaching obsolescence. Radio is evolving towards super-

specialization in the form of satellite radio or personal customization in the form of Internet radio. The big three networks are still around but they have been joined by over a hundred more. At the individual level, EVERYONE can completely personalize both where they get their news and what topics are highlighted. At the TV network level, news broadcast content and entertainment programming is now determined by the collective interest of the masses through blogging, online surveys, peer produced reporting, and reality TV. This is essentially "word of mouth" on technological steroids.

The overarching shift is primarily based on two smaller shifts. The first is a shift to an economy centered on information and cultural production. This shift actually began with the start of the industrial information economy and can be tied closely to globalization. In the United States, as more and more production moved off shore, the value generation in this country turned to the production of culture, information, and knowledge to compensate. Now factor in the second shift, the proliferation of tremendous personal computing power and the stage is set to bypass the structure that the industrial complex established to maximize profit and minimize cost. Combining these shifts has resulted in the rise of large-scale cooperative efforts now termed peer production. (Benkler, 2006)

D. A NEW MODEL OF PRODUCTION

The idea of PP typically meets much resistance because it is incompatible with the traditional measure of business effectiveness, i.e., cost. Until recently, two models of production existed in the United States. They were markets and firms. The decision between the two is essentially a "make or buy" decision (Franck, 2004). A major determining factor used to differentiate when to use each is cost.¹⁴ Operating in markets entails incurring associated transaction costs. These costs can be understood as resulting from the "friction" in the market. This friction is a function of expenditure of time, resources and management attention that is required to conduct market transactions

¹⁴ The other biggie is intellectual property ownership. Underpinning a market expansion or consolidation is the need to "own" the basis from which you achieve and hold market share. Ownership is a still a factor in deciding to use PP. Sometimes it means giving up ownership to experiences gains through other avenues as in IBM's use of the Linux operating system. Other times, ownership is maintained as in Proctor and Gamble's use of InnoCentive.

(Franck, 2004). Likewise, the “make” decision incurs operation costs.¹⁵ If transaction cost is less than operation cost then markets may be more attractive. When the reverse is true, firms are more appealing. PP also subscribes to a cost analysis but it can be thought of as a blend of market and firm. Since PP deals primarily with knowledge, information, and culture, which are more broadly termed non-rival goods, there are no lost economies of production. Transaction costs in the market are incurred at the beginning of the market exchange. Management costs in firm dynamics are seen throughout the process. PP's costs, called integration costs, represent the overhead required to implement the PP process. This inefficiency is a function of the effort required to prepare the project for presentation to the peer community and then to assemble the individual peer contributions into an intelligible whole. This must be done “in-house” and is essentially a project management function. Often, however, the integration can be transparent (it is accomplished as part of completing the task) or it can be automated (as in the NASA Clickworker’s case). It is simply the cost of doing business in this particular model of production. Before PP in an Internet environment, the right choice of production was the one with the lowest cost. This is still the case. The only difference is the presence of a third option in PP.

E. ECONOMIC PLAYERS

To understand this peer production methodology fully, one must also consider the nature of the “peers” in the PP model. From Webster’s Dictionary, a peer is “a person or thing of the same rank, value, quality, ability, etc.” In the context of peer production, the peer refers to the notion of same rank. There is no hierarchical structure and there is no presupposed value based on an individual's position. This is because with PP the value is not placed on the individual who provides the knowledge, but rather the knowledge itself. If this was not the case, then procedurally PP would have to vet the participants to assure they are peers.

¹⁵ These operations costs can be further categorized as a combination of lost economies of production, “Agency” costs, and “Influence” costs. For more information see *Business Case Analysis and Contractor vs. Organic Support: A First-Principles View*, Franck, 2004.

Just because the peers are of the same rank it is not to say that there are not differences in ability among the peers. Wikipedia provides a good demonstration of this concept. In Wikipedia, everyone is an equal in that they have the ability to contribute to the project equally but not everyone has the expertise to contribute on every subject. This is also not to say that there is not a distinct and definable relationship between the customer who desires the system, and the entirety of the peers that are doing the constructing. What this does say is that these relationships within the peer community are not hierarchical.

Peer production's core concept is the "Prosumer."¹⁶ The prosumer is touted as the central character in a global revolution of production and value generation. Communities of prosumers have created the open source subculture in software development. Prosumers are responsible for the incredible growth, accuracy, and value of the "Wikipedia," which now boasts over 1.9 million articles in English and over eight million articles combined in 253 different languages.^{17,18} Prosumer involvement allowed YouTube to create \$1.65 billion in wealth, as measured by the value of Google stock received for their conglomeration of user created content. Prosumers have created revolutionary results in a number of cases even though the application of PP methods is still in its infancy. Ultimately, it is the prosumer that gives the networked information economy its potency. The prosumer with his personal computer has completely transformed the value chain of the industrial information economy.

¹⁶ The concept of the "producer-consumer" is not new. It was first suggested in the 1972 book, *Take Today*, by Marshall McLuhan but was officially coined in *The Third Wave* (1980) by futurist Alvin Toffler. Prosumer. (11 August 2007). In *Wikipedia, The Free Encyclopedia*. Retrieved 11 August 2007, <http://en.wikipedia.org/w/index.php?title=Prosumer&oldid=321940037>.

¹⁷ Wikipedia metadata, www.wikipedia.org, accessed 11 August 2007.

¹⁸ There are many, especially in academia, who do not recognize Wikipedia as a reputable source of information. Accuracy is viewed as a function of peer review. This is the means through which new information and theories are tested and are the purpose of the many academic and professional journals that are published. This process takes a tremendous amount of time especially for the most innovative discoveries. For example, the article upon which the economic portion of this thesis is based took over 20 years to be vetted and accepted by the economics community. Wikipedia is not meant to be a forum for the vetting of new ideas. Rather, it is an online encyclopedia that responds to the very high rate of knowledge generation and in that manner creates awareness of new knowledge, which facilitates a faster vetting process. This is something that traditional encyclopedias could never accomplish.

F. VALUE CHAINS

Figure 9 describes the traditional TCE value chain (Coase, 1937) The TCE value chain depicts how market and firm dynamics combine to create value for the consumer. Each step in the chain adds value at ever increasing cost, which is ultimately assumed by the consumer. The consumer only gets to influence the chain indirectly through demand feedback unless a company spends resources directly on market research. Production decisions are inferred most often from data collected on customer purchasing trends. Likewise, in most cases, the consumer must choose from the products brought to market. Customization is either discouraged through intellectual property rights and patents or generally cost prohibitive for the general public. In peer production, the opposite is true; the right to customize and improve is what is protected by law.

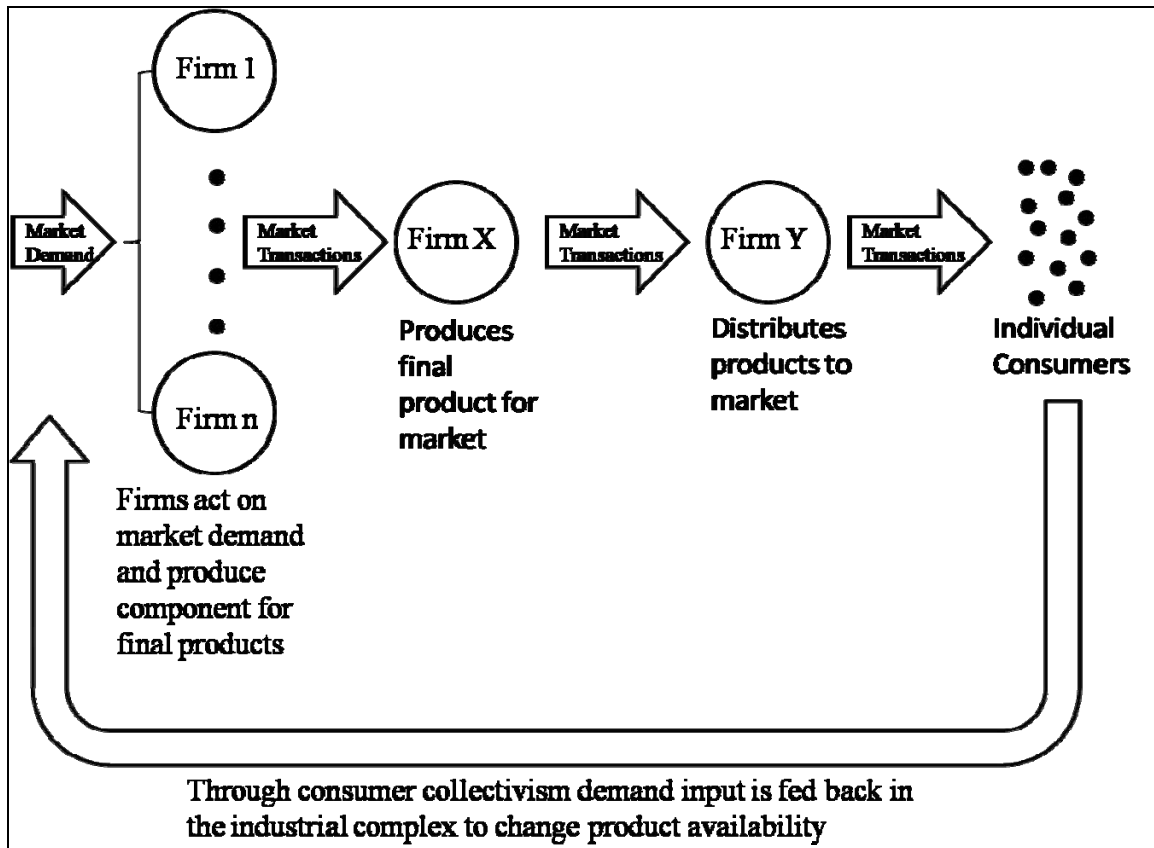


Figure 9. TCE Value Chain

Figure 10 shows the PP value chain. In the PP value chain, feedback is given directly to the community generating the product, to which they can immediately respond. This permits a much faster and less expensive innovation cycle. There is still an opportunity for profit generation by the firm, because the consumer community is always much larger than the prosumer community. This is because, by definition, the prosumer community is a subset of the consumer community. An analogy would be the number of users of automobile transportation (consumer) versus the number of drivers (prosumers). In broader terms, it is to the non-technical user (consumer community) that support and customization services based on the peer produced product can be marketed by the firm. To continue with the analogy, it is the family of five that supports the production of the minivans, even though there are often only two drivers involved.

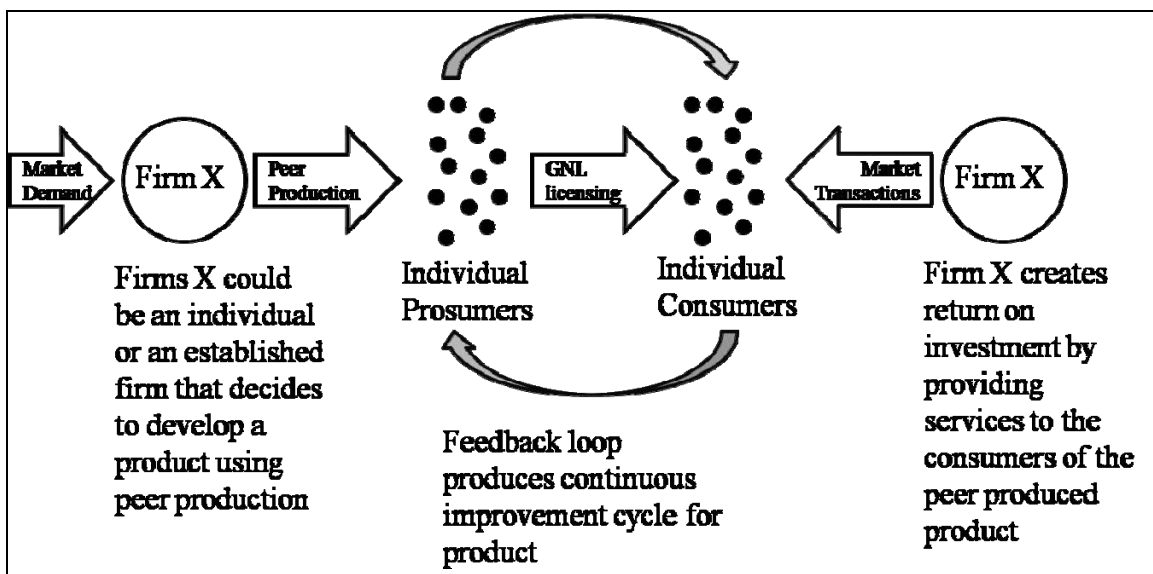


Figure 10. Peer Production Value Chain

To highlight this shortened innovation cycle; consider two competing products of widespread use; Internet Explorer and Firefox. Internet Explorer (IE) is a proprietary Web browser designed by a traditional TCE firm whereas Mozilla Firefox is an open source Web browser. The difference in the innovation cycle can be seen firsthand through a Web search for “add-ons” for each of the applications, there are at least five times as many "add-ons" for the Firefox browser. Innovation means two different things

for the two product lines. The innovation plan for IE is to introduce new features as necessary to maintain profitability. Innovation for Firefox is the end goal itself, not profitability. Innovation is accomplished to improve the product as necessary, without regard to maintaining profitability.¹⁹

G. IN DEPTH ANALYSIS OF MARKETS, FIRMS AND PEER PRODUCTION

Table 2 lists the important symbols for understanding PP within the guidelines of TCE. It represents an adaptation from that seen in Benkler, 2002. These symbols will be used to present a qualitative analysis of the specific benefits of PP over the market and firm models.

Symbol	Description
A	Individual agent that is available to perform a task as part of a peer produced process.
e	Effort level put forth by agent A to perform required task
r	Resource available to agent to perform task. ²⁰
a	An action, this is a combination of effort, e , and the resource, r , upon which the effort is exercised.
t_A	Talent, t , is A 's talent for performing a particular action a . It takes into account complementary and undermining actions by other agents. It can be represented as a probability that a particular agent will be successful at performing an action.
O_a	Expected outcome of action a . For example, action a could be writing the code for an add-on to Mozilla Firefox. The expected outcome is that agent A will have use of the add-on in Firefox.

¹⁹ It should also be noted that IE now provides the opportunity for users to create their own add-ons for IE8 and share them with others through a PP process. The "OpenService Accelerators Development Guide" can be found at [http://msdn.microsoft.com/en-us/library/cc289775\(VS.85\).aspx](http://msdn.microsoft.com/en-us/library/cc289775(VS.85).aspx). It appears that at least one firm has realized it cannot keep up with the pace and cost of innovation on its own.

²⁰ Resources take on two types, rival and non-rival. Rival resources are not available to A_2 when in use by A_1 . Non-rival resources can have an unlimited number of agents using them simultaneously. Resources can be anything from knowledge of physical laws of the universe (Like the First Law of Thermodynamics) which would always be non-rival. Another resource could be considered a word-processing capability. Although this is technically a rival resource, it can be assumed to be non-rival. Any agent that would be capable of performing a task in a peer-produced project will have access to word processing capability. Mainframe computing power is a rival resource and is not available simultaneously to all agents.

Symbol	Description
V_a	Private Value, this is the value to agent A of action a . This private value is discounted by the probability that O_a will be achieved. ²¹
P	Productivity is the “potential social value” (Benkler, 2002, p. 416) of the efforts of one or more agents toward accomplishing the specific project.
C_t	Transaction cost due to market “friction”.

Table 2. Important nomenclature to understand PP (Benkler, 2002, p. 406–422)

1. Creating Value

The value of agent A 's action, V_A , can be used to determine if an action, a_n , is worth performing. A will do a_n using resources r_n and applying effort e_n as long as its value V_n is higher than both doing nothing and doing some alternative action a_m . It is important to note that this process is not exclusive to the peer production model. It is applicable to all models of production and decision making in general. What changes are the values assigned for each variable in the process. A comparison of these values will show that some actions are both more valuable to the individual and more productive to the organization, if performed in a peer produced manner. Since this comparison can be made, it shows that the competition among the methodologies is directed at creating the most value for the minimal cost. The competition should result in equilibrium among the available options. Sometimes PP provides an opportunity to accomplish tasks efficiently that is not possible with the other modes of production. At other times, an action will be valuable if performed in any mode of production. In these cases, the lowest cost production mode should be used. This is a result of how each model achieves production. “Market and firm-based production processes rely on property and contract to secure access to bounded sets of agents and resources. In the pursuit of specified projects...Peer production relies on making an unbounded set of agents, who can apply themselves toward an unbounded set of projects.” (Benkler, 2002, p. 416) Ultimately, PP

²¹ Benkler differentiates between private value, V_a , and reward, R . He claims different actions have different expected rewards for an individual agent. These perceived rewards are used to select one action from a range of possible actions. A rational agent will choose based on the value of R . The author feels that this perceived reward is the basis of determining private value. Private value then becomes R discounted by the $p(O_a)$. Reward will be discussed further in the section on the Psychology of PP.

is just another tool in the tool bag; it just happens to be a specialty tool that is genuinely good in certain applications, and simply not appropriate in others.

2. Being Productive

The principles of market, firm, or PP dynamics, depending on which model is deemed appropriate based on the goals of the project sponsor, have been applied to determine a desired course of action. According to Benkler, productivity then is a measurement of one's ability to achieve the desired end. Productivity is a function of the resources available, the agent's effort level, and inherent talent to perform the applicable task (Benkler, 2002, p. 416). To maximize production effectiveness, the objective is to ensure that the people (or agents in Benkler's terms) assigned to perform the required tasks have the necessary skills (or talent, t) to be successful. With all other things being equal, this will provide the greatest productivity, P . This measure of productivity can be used to demonstrate how PP can add efficiency to this process. Assume the production model to be used is the firm construct. Assume also that it is known which person (agent) is the most talented to perform a task (see Figure 11). A_8 is the most talented agent overall to use resources r_1 and r_4 to perform task a_n . A_8 is a member of Firm 2. The most talented person in Firm 1 is A_2 . Consequently, if the $P_{A8} - C_t > P_{A2}$ then A_8 should be contracted to perform the task. This is how agents are used when market and firm production is the only model. In a PP space, it is always possible to have the most talented person on the task without paying a C_t . With everything else being equal except the boundaries between agents, Benkler maintains $P_{F1} + P_{F2} < P_{F1+F2}$ (See Figures 11 and 12).

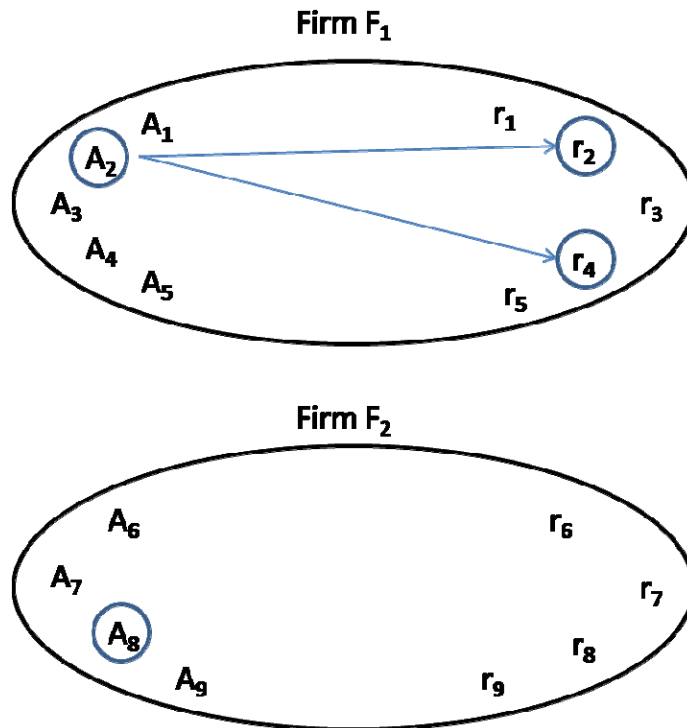


Figure 11. Applying agents to resources separated in different firms (after Benkler, 2002, p. 418)

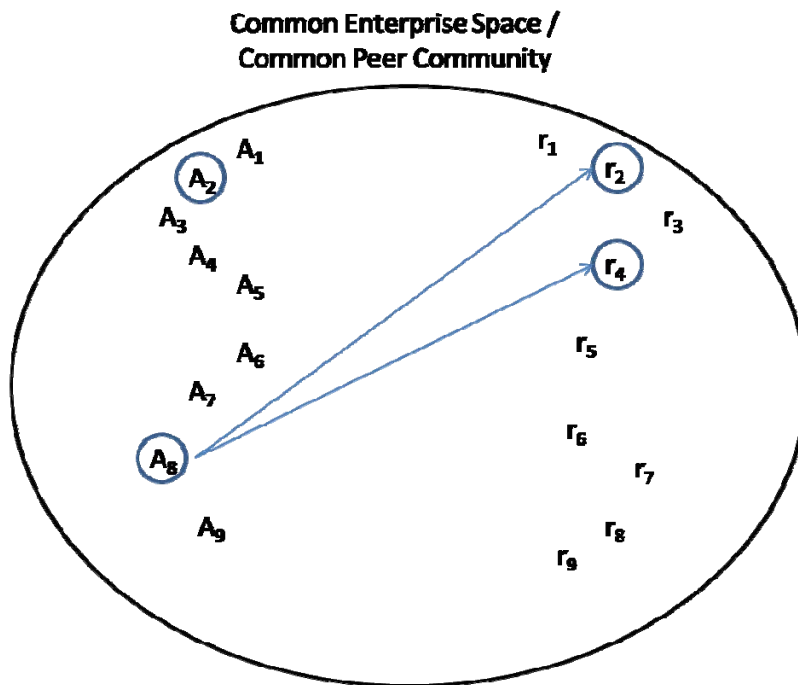


Figure 12. Resources and agents in common space (after Benkler, 2002, p. 418)

In reality, everything else is not equal. The sources of these inequalities will be discussed next.

3. Job Specification

The question “What should I do?”, is answered by a set of very different processes in the firm, market and PP models. In a market, prices are attached to alternative courses of action. From these, a person (agent) can discern how to allocate his time. A firm directs action through a hierarchical structure where the "boss" decides what employees should do (Benkler, 2002, p. 372). In PP, what an agent works on is self-determined or self-selected. The agent evaluates the task with respect to value and cost while knowing their own talent level (better than any manager could) and selects the best tasks on which to work. It should make sense that an agent is not going to self-select a task with no chance of completing it because the personal value, V_a , received will then be zero. It is no longer the responsibility of a manager to assign an agent nor does the market need to assign a proper price indexing to ensure the most profitable tasks are accomplished.

The key attribute to the process of self-selection is the value to cost ratio, V/C . The value, as previously stated, is what an individual hopes to get out of performing a certain action. It is important to realize that this value is not a certainty. Value is the expected payout or reward for performing an action times the probability of receiving that reward. The probability of payout does not have to be equal to 1 for that action to be the most profitable choice. The other part of the V/C ratio is cost. Cost takes on a very different evaluation process for the different types of production methodologies. For PP, cost is evaluated by the individual performing the action. In most cases, this cost consists exclusively of the time it will take to perform a particular task, summarized as an opportunity cost. It is the V/C that permits peer producers to first decide if a task is worth performing ($V/C > 1$) and if they should follow through and perform the task ($V/C > \text{alternative } V/Cs$). This concept will be used more extensively in Chapter V.

4. Inefficiencies

Job specification entails determining what is necessary in terms of time and resources to accomplish the necessary tasks. Job specification must be accomplished before the job can be completed. Because it is impossible to determine what is necessary with absolute certainty, inefficiencies in allocating resources and assigning agents are introduced into firm and market production. Some of these inefficiencies are resolved with PP. It is unlikely to know the characteristics of each human, resource, and opportunity. Consequently, it is impossible to obtain perfect specification. Self-specification minimizes the effects of this inefficiency. In PP, the persons performing the required task assess their own talents and assign themselves to the jobs for which they are best suited. The process will still not guarantee perfect specification because even though the people are aware of their particular talents, the tasks still cannot be specified fully. The probability of a bad decision is reduced by removing one variable; and efficiency is increased by removing an organizational level from the decision process.

5. Surplus of Workforce

The difference between a PP community and a firm or market based organization is best exemplified by looking at the boundary of each system as exemplified by Figure 13. In a market the system boundary is ill-defined. Players are independent entities interacting based on individual self-interests. The firm is the other end of the spectrum where all associations are defined and there is a distinct wall delineating what resources and agents are part of the firm and those that are not. Inside the boundary of the firm is a hierarchy that directs resources. As demand exceeds capacity, a shortfall of agents and resources develops. Active efforts must be made to expand the boundary of the firm, and consequently it grows in size. The firm will continue to grow in size as long as demand supports it. It will also grow in breadth by assuming new functions as long as it is economically advantageous. Eventually, the firm will become too large and difficult to manage, efficiency will drop, cost will rise, and the firm will discontinue growth.

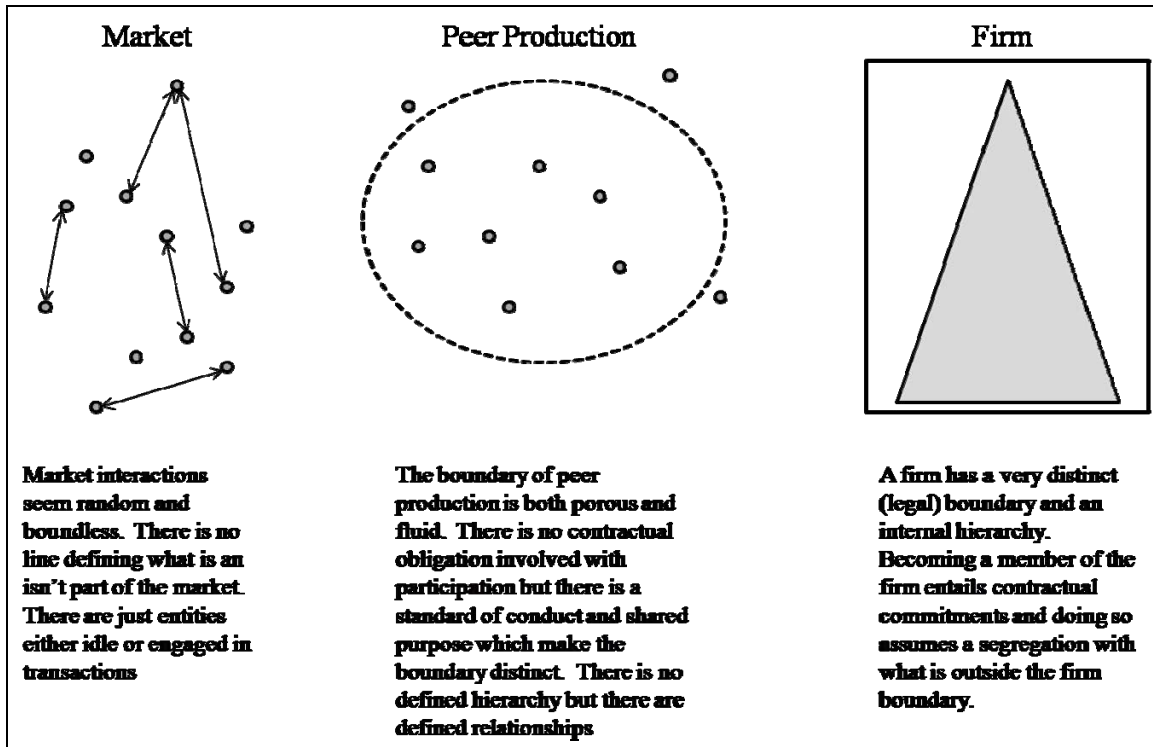


Figure 13. Economic Model Boundaries

In PP, the community will naturally expand as the demand for people to accomplish tasks increases. As more and more consumers find a particular project useful, more and more of those consumers will naturally choose to participate as prosumers; thereby, increasing the available workforce, and as a result, the net output of the project. This cannot be stressed enough, because it represents a significant advantage of PP over the firm model. A firm requires effort to grow in response to demand, a peer community responds organically with demand and grows with it. This is because a firm is structured as a hierarchy; and PP is a network. This natural growth seen in peer communities is due to network externalities, also called network effects.

Network externality has been defined as a change in benefit, or surplus, that an agent derives from a good when the number of other agents consuming the same kind of good changes. As fax machines increase in popularity, for example, your fax machine becomes increasingly valuable since you will have greater use for it. This allows, in principle, the value received by consumers to be separated into two distinct parts. One component (termed autarky value) is the value generated by the product even if there are no other users. The second component (termed

synchronization value) is the additional value derived from being able to interact with other users of the product, and it is this later value that is the essence of network effects (Liebowitz and Margolis, 1998).

It is also this later value that is the reason peer produced projects expand naturally with demand.

6. Parallel vs. Serial Task Accomplishment

In market and firm strategies, resources are always constrained. There are always a finite number of contractors or employees on any project. Consequently, the rate at which a project is completed is limited by the total required work and by the speed at which the available resources can accomplish that work. In PP this is not the case; the resources available are only bounded by the perceived importance of the tasks and not by some limitation on the organization performing them.

7. Task Duplication

In the context of PP, since no cost is associated with a workers time, there is no cost overrun associated with a task taking longer than expected. The only concern is the eventual task completion. As such, it is permissible to allow task duplication. In markets and firm, this is a source of increased cost and inefficiency. Duplication is not a source of inefficiency in PP. Rather, it is one of PP's advantages as long as the principles of PP are upheld. These principles will be discussed in Chapter VII.

8. Ownership

The next question arises because the traditional point of view for evaluating the value of certain courses of action is from the industrial information economy, which relies largely on proprietary information. It is “How will the products of these collaborative efforts interact with society and the industrial complex?” So far, “its outputs are not treated as exclusive property. They are instead subject to an increasing robust ethic of open sharing, open for all others to build on, extend, and make their own.”(Benkler, 2006, p. 7) In a DoD sponsored PP effort, in most cases, the specific output generated will not be subject to open sharing outside of the specific government

organization. The effect generated, increased effectiveness of the military, will be shared with the American people. This will be made clear in the section on the Psychology of Peer Production.

H. ECONOMIC CONCLUSION

Just as Coase did in 1937, economic theory was used to explain what is seen in practice. This is important because it highlights that these theories are not meant to predict something that may develop in the future. PP is already here; what will change is the frequency and scale at which it is being used. The DoD in general, and the Navy specifically, has the opportunity to harness its benefits early or it can attempt to play catch up later.

The discussion in this chapter has shown that PP is another result of the same principles that brought about the development of the firm. It is simply a cost reduction process. PP is only possible because of two principles—self-selection and value exchange. Peer contributors are free to choose where to participate. When they do participate, they exchange value; it just is not necessarily monetary. Because this value exchange exists, PP cannot be contradictory to the ideals that have made enterprises economically powerful. In reality, PP may be the means to keep this country economically powerful.

Further work is necessary in determining the boundaries of PP. A starting place is the reward equation. The reward equation gets at the heart of human motivation. It seems that technology has lowered the transaction costs of the market so that the hedonistic and social-psychological portions of the reward equation can play a more significant role. As a result, it has become much less expensive for those with something to add to have their input heard. The problem is that this applies to both those that are motivated to help as well as those motivated to hurt. The success of PP then depends on two things. Those attempting to help must significantly outnumber the other; and a mechanism must be in place to minimize the effect of disruptive contributions while maximizing beneficial ones.

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V. PSYCHOLOGY OF PEER PRODUCTION

Happiness lies in the joy of achievement and the thrill of creative effort.

Franklin Delano Roosevelt

A. WHY DO PEERS PRODUCE?

At this point, it should be clear that PP is economically advantageous in some applications. PP is a natural extension of transaction cost economics, resulting from both the development of a ubiquitous personal computing power and a transition to a networked information economy. This understanding of PP provides us with a macro understanding of PP. Answering the question, "Why would an individual choose to participate in a peer produced project?" will supply a micro understanding. From these two points of view, a model of PP can be systematically construed and applied.

Just as it was necessary to understand some economic theory before it was possible to grasp the economics of PP, it is also essential to describe some basic theory of human psychology to appreciate the full impact and potential of PP. Psychological theory maintains that there are two broad categories of human motivation. These categories are termed intrinsic and extrinsic. Intrinsic rewards are internal to the person such as a sense of accomplishment or fulfilling a desire to help. Extrinsic motivations are external and include things such as monetary compensation and praise.²² These concepts become important in our understanding of PP when we apply Benkler's reward theory (Benkler, 2002).

²² For further discussion of intrinsic and extrinsic motivations please see Benebou, Roland, and Tirole, Jean, Intrinsic and Extrinsic Motivation, *Review of Economic Studies* (2003) 70, 489–520.

The next psychological theory to consider is Maslow's hierarchy of needs because it will begin to address some of the needs that contribute to deciding a person's actions.²³ They include physiological needs; safety needs; needs of love, affection, and belonging; needs of esteem; and needs of self actualization. It is generally accepted that humans experience all these needs to different degrees at different times. The fulfillment of these needs can come in various forms. It is plausible that because humans have these needs and are continuously trying to satisfy them, they are drawn to participate in peer produced products when no monetary compensation is offered. This underlying premise within PP takes the form of the reward equation, and will become particularly important to the stakeholder analysis in Chapter VI.

With this background of human motivation in mind, consider the study conducted by Pearce (1983), which examined “job attitude and motivation differences between volunteers and employees from comparable organizations”. Pearce did not look at extrinsic motivations like pay, fringe benefits, and promotion because such benefits were not available to the volunteers. The motivations considered were a mix of both intrinsic and extrinsic ones that Pearce divided into three categories: intrinsic, social, and service rewards. Table 3 summarizes the rewards.

Intrinsic	Social	Service
1. Doing tasks that hold my interest	1. Enjoyment of the company of my co-workers	1. The chance to further the goals of this organization.
2. An interesting job	2. Working with people I like	2. A chance to make a real contribution.
3. Enjoyment of just doing the work	3. Associating with a good group of people	3. Identification with the mission of the organization.

Table 3. Potential rewards to compare volunteer work vs. employment²⁴

²³ The author accepts the fact that the hierarchy has received significant criticism. He also understands that proof has yet to be given that the hierarchy exists as Maslow proposed or at all. There is no argument, however, that these different types of needs do exist; the criticism is around their arrangement into a hierarchy.

²⁴ These motivations are very important to all to all of the services. They are exactly the types of things used to recruit volunteers into the military. Even though monetary rewards are given for military service, the money is not typically what makes people put themselves in harm's way.

Pearce found that

...volunteers, doing the same work as employees, are more likely to report that they work for the rewards of social interaction and service to others, that their work is more praiseworthy, and that they are more satisfied and less likely to leave their organizations (Pearce, 1983, p. 650).

These results of Pearce's work speak volumes about the reproducibility and reliability of the peer production labor force. If volunteers are more satisfied and less likely to leave an organization but still accomplish the tasks that employees are doing in other organizations then turnover, one of the largest sources of inefficiency in firm production, has been greatly reduced. The fact the people routinely leave employment for other positions impose a major cost for firms. Often an argument against peer production is that peers cannot be depended on because there is no contractual agreement with them. This claim, however, is shown by Pearce's study to not be true necessarily. Volunteers within the right structure can be more reliable than paid employees. Understanding what motivates people and designing the project around that will actually increase the probability that volunteers will see a task through to completion. Of course, the assumption is that volunteers in brick and mortar organizations that perform tangible tasks are motivated by the same factors and experience the same return on investment that peer production volunteers do. Demonstrating that this assumption is correct requires further study of peer produced projects. However, the similarities between the two volunteer opportunities are such that significant faith can be applied to the acceptance of this assumption.

Recognizing that humans are motivated by a drive to satisfy a multitude of needs, is the basis of understanding why people volunteer. To say that people are only motivated by money, oversimplifies the situation at the risk of eliminating tremendous opportunity. This oversimplification is the foundation of many objections to PP. It is often stated that people will not contribute to PP because they are not getting paid. It is the sum of all the diverse motivations which drive humans to work, to give blood, volunteer their time, and at certain times, risk their lives. It is also these motivations in combination with the networked information economy that answers the question "why do people participate in PP".

To add a little more clarity to this idea of motivation, it is possible to reexamine it from Benkler's economic perspective to ascertain that it remains consistent with what is seen in the marketplace and not just in the non-profit organization. Benkler surmises that “at the broadest level, wherever PP can motivate behavior better than markets or firms, then certainly it will be superior” (Benkler, 2002, p. 427). Benkler proposes an equation for reward, R .

$$R = M + H + SP \text{ where}$$

R = individual agents reward for performing an action

M = Monetary compensation

H = Intrinsic rewards

SP = Social-psychological rewards

Although Benkler's terminology is slightly different, his concepts are compatible with the previously discussed psychological theories. Now, remembering that private value is

- $V_a = p(O_a) * R$
- V_a = private value to a individual for performing an action
- $p(O_a)$ = probability that an assumed outcome of performing a given task will be realized.
- R = individual reward for performing an action

Therefore, as long as the reward is sufficient to justify performing an action a then the agent may choose to participate. Since R may be positive with zero or even negative monetary compensation, it is possible to fully understand why people participate. Final determination of participation then is based on the V/C as compared to alternative V/C ratios.

When comparing a generic propensity for volunteering in traditional ways like a soup kitchen or other non-profit organization with volunteering online in a peer production project it seems that PP should have a greater V/C ratio. Given equal value, V , for each type of volunteer work PP will have a greater V/C because its cost is lower. It may be much easier to sit in the comfort of your home and select when and how to participate than it is to find and commute to a brick and mortar establishment to volunteer.

B. HOW IS PRODUCTION PROMOTED?

It is worth a little more effort to understand motivation in PP in greater detail because it will permit later differentiation between which projects are good candidates for PP and which are not. It will also allow those applicable projects to be structured and presented in a manner that maximizes participation. To accomplish this, research is reviewed that has been done in the open source software development (OSSD) community. As previously mentioned, OSSD is the nucleus of modern PP but PP is beginning to grow extensively in other applications by applying some of the same principles. These applications include: advertising, consumer product service and repair, news media, and consumer product research and development, to name a few.

In general, it has been found that the OSSD community is very “elitist,” which means that although anyone can contribute; there exists an "inner circle" of contributors in most projects that contribute a large portion of the key contributions. By analyzing 25 million lines of code from 3149 distinct open source projects, found that 72% of the code was written by 10% of the contributors (Ghosh & Prakash, 2000). This does not mean that for all PP projects that 20% of the contributors will produce 80% of the work. The Clickworkers study found that 37% of the work was accomplished by one-time only contributors to the project (Kanefsky, B., N. G. Barlow and V. C. Gulick, 2001).²⁵ What it does say is that there is some work breakdown ratio that needs to be considered in the planning process of the project. The research suggests that the ratio is related to the modularity and granularity of the tasks being performed as well as the required volume.

In the OSSD example, this core group of individuals is both highly motivated and sufficiently talented. It is believed that this characterization will also apply to all contributors involved in any "Broad Spectrum PP" where specific talents or knowledge is necessary but it is available from a relatively large number of professionals. Typically, a

²⁵ Clickworkers was a study conducted by NASA researchers Virginia Gulick and Bob Kanefsky in the late nineties to see if distributed, anonymous online data analysis could produce results consistent with proprietary expert analysis. When this research began in late 2007 extensive information was available through a NASA sponsored Website detailing the scope, implementation and results of the Clickworkers experiment. As late as April 2008 the project was still ongoing and producing relevant data analysis. Sometime after April 2008 all record of the project was removed from the NASA sponsored sites. The only thing that remained was a Wikipedia entry and a two page unpublished report by the researchers.

mailing list soliciting solutions to the most difficult problems serves to both identify these core individuals and support the "inner-circle: within the larger peer community. This suggests a few things about the OSSD process. First, massive collaboration (except in Indiscriminate PP) is unnecessary to guarantee the success of a peer produced project; in fact, it is probably detrimental to most (Broad Spectrum and Pinpoint PP) projects.²⁶ All that is necessary is a small group of core individuals whose individual reward for contributing is greater than their cost (mostly in time) of participating. To achieve this core group, wide scale exposure of the project is required. Mass exposure is the practice of unbounded solicitation of contributors. For example, if computer programmers are required, then contact could be made to every university alumni association. In this manner, potential contributors are made aware of the project and the community around it. Self-selection and network externalities will then take over to build the necessary capacity from the community. By continuing this process of mass exposure, self-selection, and network externalities, a sufficient replacement pool to make up for losses in the core group will be sustained.

Second, the presence of a core group is compatible with the reward theory, previously discussed. Since there is no direct monetary compensation given to OSSD contributions from the community, the other components of the reward equation dominate.²⁷

$$R = M(\rightarrow 0) + H(\uparrow) + SP(\uparrow)$$

As the value of M goes to zero, the value of H and SP increases. Membership in the core group represents a significant increase in SP reward.

²⁶ By examining various OSSD communities and other peer produced projects it is seen that successful projects do not have thousands of contributors. Rather, what is seen is a lower number, in the hundreds at most, of contributors that will participate in the community for an extended period thereby providing some continuity. Massive collaboration (an excessive number of participants) cannot be sustained by any one project because there are insufficient rewards available and the competition for those rewards is too great.

²⁷ This requirement does not exclude corporations paying some employees to participate in an OSSD project because payment is not coming from the community but instead from a third party. The monetary exchange transaction is in essence invisible to the community. It is also important to note that peer producers on corporate salaries are few compared to the OSSD community as a whole.

Consider one programmer who must decide to participate in an OSSD project or perform another task, such as work for her employer, study for a test, sit on the couch, or participate in a fantasy football league. The specifics of the competing tasks are not important except for their associated costs and consequences (i.e., rewards and problems caused). In a simplified model of PP, the costs of participating in OSSD (specifically) and PP (generally), are essentially limited to one type, the cost of time. Since PP seeks contributions of a non-rival nature, tangible resources, i.e., raw materials, are not consumed.²⁸

Now, consider some of the specifics that go into the cumulative reward for participating. For application of PP by the Navy, the importance of the social-psychological contribution to the total reward for participating cannot be understated. This is because the social-psychological reward motivations that make people join the military are the same ones that will encourage them to participate in PP to support the military. Within this social-psychological reward lie specific intrinsic and extrinsic motivations. There is a distinct ego boost and reinforcement of one's belief in one's talents, which coincides with being a key contributor in the elite group. The desire to achieve this sentiment is an intrinsic motivation and a reward of contributing. There is an extrinsic motivation that complements the intrinsic and directly relates to an individual's belief that participating will further one's career in the long term (Lerner & Tirole, 2002). The combinations of these ego and career motivations are, in economic terms, termed signal incentives.²⁹ The strength of the signal to participate increases with:

- The visibility of the task performance to the relevant audience
- The positive direct correlation between efforts invested and demonstrated performance
- The perceived positive correlation by the relevant audience between an individual's performance and their talent (Holmstrom, 1999)

²⁸ There could be a real loss of monetary compensation (the opportunity cost of participating), however. For example, instead of participating in PP, an individual could use that time and get a paper route or mow lawns for extra cash. This is not being neglected; rather, it is accounted for in the value of the specific competing task.

²⁹ It is important to realize that the signal is directed toward the individual and not toward the community. The signal given is "participate". The strength of that signal greatly affects an individual's choice to participate or not.

All of these attributes that enhance signal incentives can be designed into a PP system. The result is a PP system with a higher retention rate, lower churn, higher levels of production, and people who genuinely feel they are simultaneously serving their country and themselves.

Once again, these studies and conclusions were originally made about the OSSD community but can be generalized to apply to PP as a whole. To do this the specific application of the theoretical discussion only needs to be adapted to the specific characteristic of each project and the community that will support it. It seems plausible that a community of mechanical engineers will measure effort, talent, and cost of participation differently than computer programmers. Consequently, the presentation of the specific peer produced project will need to be tailored to maximize the reward potential of the applicable community. For the purposes of a DoD sponsored PP project, it will be very important to realize who the primary participants are. This group will ideally be those with the strongest signaling incentives and the most available time (this minimizes the cost of devoting that time) but it may also include those with little time but view the benefit worth it. This will be seen in more detail in the stakeholder section of Chapter VI.

There are also temporal effects that need clarification with respect to the reward equation. Lerner and Tirole (2002) describe this effect. There are both long- and short-term rewards that factor into the peer's decision to participate. Any monetary compensation can be considered short-term. Hedonistic rewards, like contributing to OSSD to get the benefits of the project for personal use, also tend to be short-term rewards. Social-psychological rewards tend to be more long-term because they take time to develop.³⁰ If monetary compensation is a factor, then firm production definitely is an advantage over PP. There are some short term rewards that favor PP, however. Error correction, for example, is traditionally much faster in peer-produced projects, simply because more eyes are available to identify and fix the errors. This is a very strong

³⁰ Some monetary rewards turn out to be long term but they are usually of an unexpected nature. For example, key contributors in Linux software development being awarded stock in companies that owed their success to the project. This is a monetary reward but was unanticipated by the contributors, and as such, did not factor into their decision to participate.

incentive for the decision by firms and individuals to release a project to an open community in the first place. From the long-term perspective, PP has the advantage whenever signaling incentives play a significant role (Lerner & Tirole, 2002).

What is the differentiating factor if some rewards favor firm production, some provide a preference for markets, and others advantage PP? Non-information products are well-suited for market and firm production because information sharing is facilitated by the Internet and World Wide Web. Product sharing potentially involves a higher cost of presentation and communication. However, for knowledge, information, and culture products, this is not as clear cut. A given product, for example, a software operating system, could be produced as proprietary intellectual property (e.g., Windows, MAC OS) or through open source (e.g., Linux). The decision comes down to motivation both by the originator of the project (those contributing to its development) and by market demand. If financial profit is the primary motive, firm production is the natural choice. Fundamentally, people need income to function in society. Some will voluntarily enter into a contractual relationship with a firm or choose to be self-employed and interface directly with the market. Through these formal relationships, individuals then permit the firm to produce and generate revenue.

Other individuals, however, either do not need to or cannot participate in such relationships. These individuals (e.g., stay at home parents, unemployed individuals, college students, and retired persons) may have motivating factors that favor the non-monetary portions of the reward equation. Organizations originating projects may also not be interested in turning a profit. The author maintains that the DoD falls into this category. While there are some projects, due to security concerns, that are inappropriate for PP there are also many others that do not have these concerns. This discussion leads us into Chapter V, the Philosophy of Peer Production.

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VI. PHILOSOPHY OF PEER PRODUCTION

Innovation is not the product of logical thought, even though the final product is tied to a logical structure.

Albert Einstein

This research began by challenging one of the most basic assumptions in typical systems procurement and development. That assumption entails the belief that in order to maintain control of the design and production process, one must also maintain direct supervisory control over the individuals performing the specific task. This research explores an alternative hypothesis: abandoning control can lead directly to increases in efficiency and timeliness of the development process, as well as increased relevancy and quality of the system being developed or product being produced.

Why do people volunteer their time and talent to contribute to a peer produced project? Answering this question is essential to being able to structure a project in a way that will attract and retain a sufficient number of contributors. The answer also will be incorporated into the system engineering principles of PP. The best way to grasp this answer is to once again consider the fundamental difference between firm production and peer production. People contribute in the firm model because they are directed to contribute. Granted, individuals voluntarily enter into a contractual agreement to perform some functions within the construct of a firm. There are two aspects to this volunteerism. First, it stems from necessity, and as such, is not entirely free. The necessity to provide for oneself and one's family dictates that sometimes something must be done. The freedom is just in choosing what that something will be. Once the choice is made, an individual freedom is deferred for security and a paycheck because the individual is now contractually bound to perform the tasks directed by another person. As a result, individuals often experience diminished H and SP rewards in return for increased M rewards.

In PP, individual freedom is never sacrificed. It is important to realize that this is a result of individual security being provided by another means. As soon as the M of the reward equation is not the primary motivator, the SP and H assume the role of the dominant contributor. An individual may knowingly sacrifice immediate M reward for immediate SP reward, which has the potential of leading to future M reward. Ultimately, the true draw of PP is self-selection.

A. INCREASING THE SUCCESS PROBABILITY

Self Selection is the single greatest factor in the success of PP. The flip side of self-selection is control, or rather the apparent lack of it. However, this distinction is a matter of perspective. In PP, the individual agent has the power of self-selection, which seems to imply that the originating entity has forfeited control over the assignment of tasks, and in turn, control of the individuals performing them. From an economic perspective, it has already been shown that this apparent lack of control is an advantage of PP because it is associated with the decrease in responsibility of having to control individuals and tasks. Consequently, an increase in efficiency and effectiveness are experienced. It also permits a higher probability of task completion as will be shown.

Unfortunately, the apparent lack of control characteristic of PP is not typically viewed as a favorable attribute. Rather, it is seen as a liability, because without control, there appears to be a greater risk of failure. This perspective is a misconception. In reality, the only thing forfeited is the opportunity for retribution if failure does occur and depending on your position in the value chain, this opportunity may not be lost at all. Recall from the firm production methodology that the customer's direct interaction in the value chain is unidirectional. She is a receiver of the finished knowledge product and only feeds back into the value chain indirectly as shown in Figure 14.

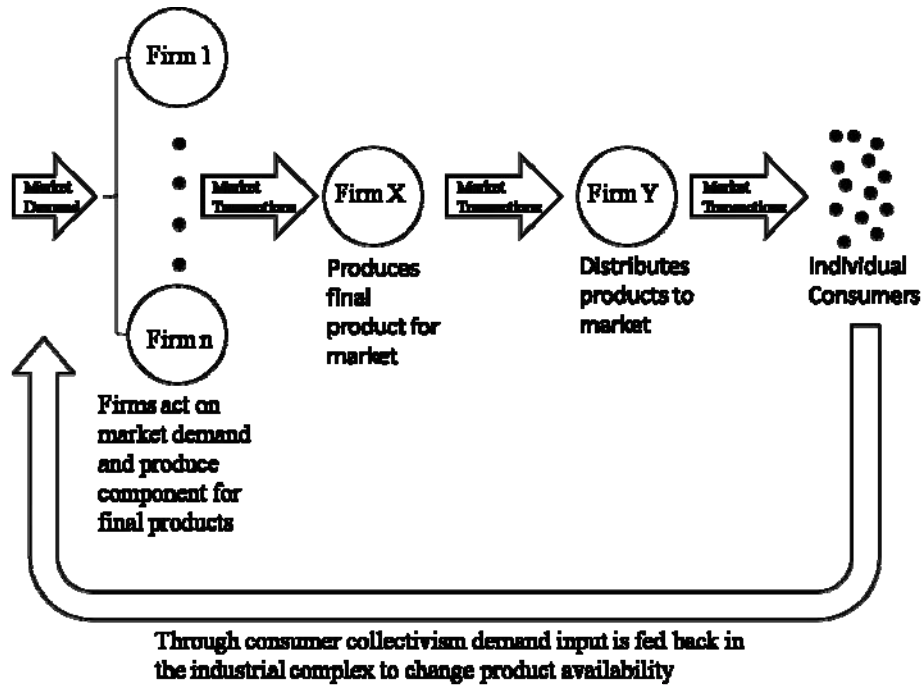


Figure 14. Firm production value chain

Consequently, the customer never really has any control at all. All of the control rests with the hierarchy in the firm structure. The customer normally only has retribution authority against the firm in the case of negligence or failure. In the PP value chain, shown in Figure 15, the customer has a two-way interaction with the value chain, and consequently, much more direct influence on the knowledge product received. This increased influence comes at the expense of the firm's hierarchy (i.e., control). As a result, by properly applying PP, the risk of failure is actually decreased, while at the same time customer retribution capability is increased. This occurs due to four distinct attributes of PP: self-selection, alignment of priorities, task duplication, and talent availability.

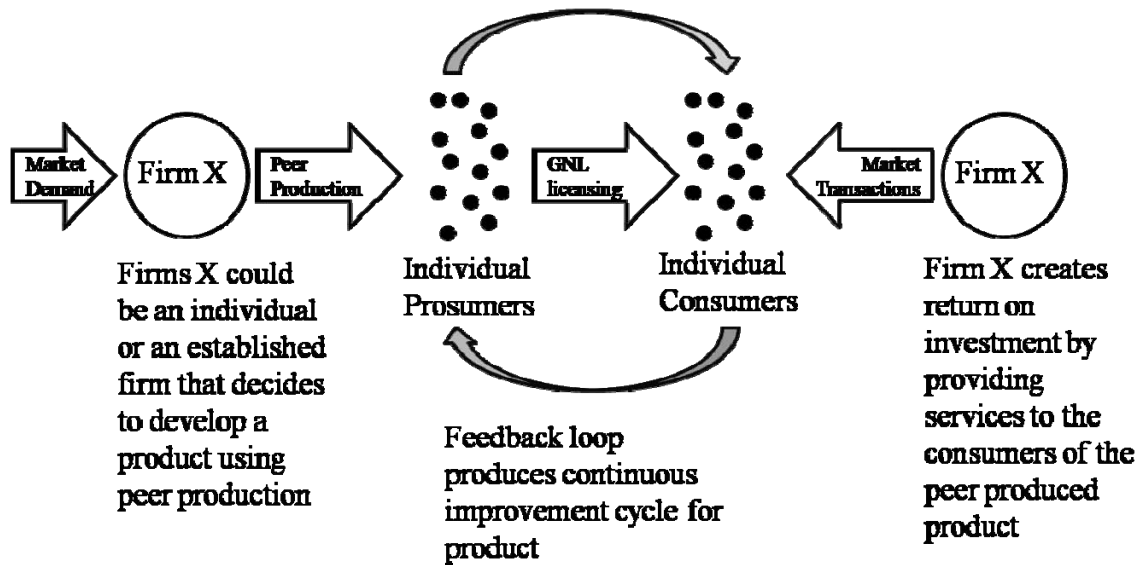


Figure 15. Peer production value chain

1. Effects of Self-Selection

Although it is safe to say that no professional tries to fail, failure still occurs. Self-selection makes failure personally attributable. Consider the firm's hierarchical approach to assigning tasks against PP's self-selection. In the firm construct, customer X hires corporation A to produce product X. Manager A, in firm A, assigns agent A to perform the task. Agent A, for some reason, fails to accomplish the task. As a result, agent A receives a bad review from manager A. Manager A is ultimately held responsible for the failure and is delayed a promotion. Corporation A explains away the failure and describes the corrective action and the extent of the delay to customer X. The true nature of the failure is invisible to customer X, and consequently, the customer really has no option but to accept the new conditions, which most likely are associated with additional cost. As a result, it can be seen that customer X really has very little control over the success of the project. All the customer really has is legal repercussions against corporation A if they choose to pursue them. The result of legal action is additional cost and delay.

Alternatively, customer X decides to complete the project in a PP manner. Task A is now self-selected by agent A. Although customer X still has no say in who performs the task, the probability of success of task A has increased because now the repercussion

of failure is directly attributable to the performer of the task. The performer has accepted the task with some reward in mind for successful completion. Failure to accomplish is now not only a failure for the customer but also for the performer. The rewards that they set out to achieve will not be realized. In the firm example, unless the failure was so egregious to warrant dismissal, the agent responsible for the failure really lost nothing except the possibility of an undisclosed reward in the future (e.g., a promotion). The agent will still receive their paycheck at the end of the week. In PP, not only will the rewards not be realized but now the failure takes place in a very public forum. The failure is directly attributable to the agent, and as a result, any reward for future participation may also be in jeopardy. Consequently, company X now has more protection against failure at no increased cost because the system has built in retribution.

2. Effects of Alignment of Priorities

In firm production, agent A is a participant in the process out of necessity. Although they may love what they do, they are still doing it for the pay.³¹ In firm production, agent A's loyalty lies with their firm, their hobbies, their children among others and at some point, the customer may work into the equation. There will be times in which the firm is not even a top priority for agent A. Family illness, school concerns, moving homes all potentially detract from a person's focus on the task and result in a decrease in the probability of successful completion of the task. In PP, this is not the case. The agent has chosen to participate in the customer's project from among others because they can identify with it (which increases both their H and SP reward components). They also do not have to participate. So, if life is getting the best of them, they will not complicate things by taking on extra responsibilities. Agents will only select the tasks they are willing to complete. This, in turn, increases the probability of success.

³¹ It is important to remember that the discussion centers on probabilities. The author is not trying to suggest that these scenarios always exist but rather that they can exist. If they do materialize then the probability of success is decreased. In that regard, anything that relieves the situation from these potential problems will increase the probability of success.

3. Effects of Task Duplication and Verification

In the firm production process, it is a source of inefficiency to have two individuals working on the same problem simultaneously. Sometimes this inefficiency is necessary for redundancy or competitive positioning of departments; however, it is still an inefficient practice with respect to the specific project being pursued. Personnel time is a very expensive commodity and seemingly it is often the organization that is most effective at utilizing personnel effectively that develops a competitive advantage. In PP, task duplication is not a source of inefficiency but rather a natural outcome of self-selection that adds credibility to the peer produced outcome without increasing costs.

Since reward is not monetary, there is no increased cost with facilitating duplication of effort. Since the reward sought is H and SP based, the actual reward achieved by the individual contributor is not diminished if another proposes the same solution. In fact, the reward is often increased because the likelihood of the contribution being incorporated in the final product is increased. The more duplication experienced, the higher the probability of soliciting the correct answer. In certain applications of PP, particularly those involving Indiscriminant PP³², duplication will also lower the probability of error. As seen in the Clickworkers project, it was through task duplication that the final product could be given the same credibility as the result created by the individual subject matter expert.

Since the PP community around a particular project is open and non-hierarchical, both the problems to be solved and the proposed solutions are potentially viewable by all within the community. As a result, concurrence on a solution is an inexpensive proposition. Once again, this increases the reward of the individual contributor. It is through exposure of a contribution to mass review that both the solution and the contributor gain credibility. The approval of the more experienced contributors is, in many cases, the exact reward being sought.

³² Indiscriminant PP was discussed as one of the three types of PP in Chapter II of this thesis.

4. Effects of Talent Availability

The best way to understand the effects of talent availability is to recall the discussion in the economics of PP (see chapter III, section F). In the firm model, a project manager knows the talent pool available for a particular project. Specifically, it is known how many individual agents are available to work on the project. The manager also knows within some tolerance the respective talents of those agents. It is from this information, along with information about the project that estimates can be made for completion time and total cost. The pool of agents and talents assigned to a project is typically constant. There are barriers to adding additional agents during the course of the project. If additional agents come from within the firm then they must first be made available from another source. If they are brought in from outside the firm then a concerted effort must be made to recruit and bring them under contract. Either of these options will necessarily increase the cost of the project.

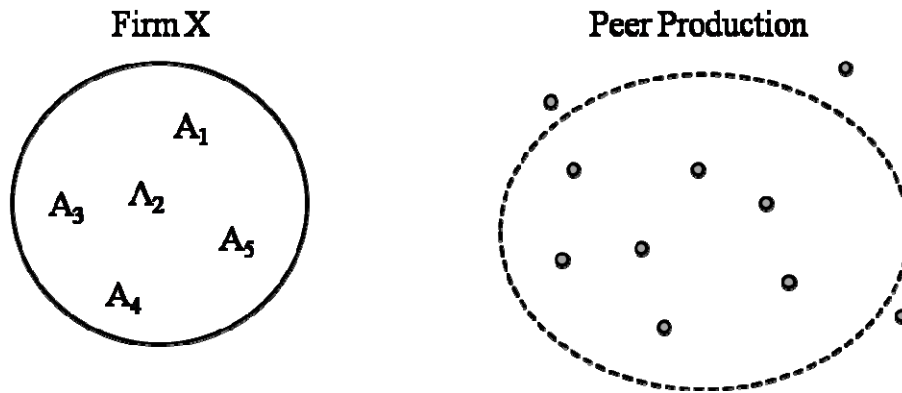


Figure 16. Boundary depictions of Firm and PP constructs

The relative talents of the agents tend to be relatively constant over the course of an individual project. This could cause a greater problem than insufficient agents. If a problem arises which requires a special talent that is not readily available in-house, then a premium price will be incurred to solicit that expertise from outside sources. Pictorially, this is represented in Figure 16. The boundary of the firm is solid and signifies that it is not easily (i.e., free) to cross. Also, the individual agents are known and designated 1 through 5.

Immediately from Figure 16 it is apparent how PP is different. The boundary to the PP community is porous. As requirements grow within the project, the community has the ability to respond to this demand automatically if the community is a vibrant one and the project is generally believed to be of significant value. If the community does not spontaneously compensate then growth can be stimulated actively by the project sponsors. Typically this is done by promoting awareness to a larger body of individuals and can be accomplished easily and quickly with little expense. It is also seen in the figure that the peer producers are non-descript (i.e., they are not individualized by assigning number designations) since they are neither known in number nor talent level. What is known is that they are willing to participate to some degree. This ambiguity is acceptable for a few reasons. First, there is no cost associated with the peers either in salary or management responsibility. Second, because there is no management responsibility, there is no need to know individual talents. All that is important is that the individuals assess their talent correctly and choose tasks that are achievable. Remember the peer contributors have significant incentive to assess their talents accurately because the reward is only achievable through successful completion of the self-selected task. Ultimately then, because the talent pool in a PP project is porous and new talent is always arriving, the ability to respond to difficulties is greatly improved. As a result, the probability of successful completion is also improved.

B. INCREASING THE SPEED OF INNOVATION

The complimentary effect of the collective influence of self-selection, alignment of priorities, task duplication, and talent availability is a dramatic increase in the speed of innovation. Since there are more agents collectively working towards the same goal with greatly varied talent and experience who share a common knowledge of the project, there is a much greater probability that one agent will spontaneously spawn an innovation in another individual. As agents can self-select, they can begin work immediately in a new direction as soon as the idea occurs. No approval from a higher authority is necessary. This is also where an agent with a potential innovation will experience the greatest gains with no risk of failure. Not only can the agent gain reward for accomplishing a task but also for envisioning the opportunity. In the event the new idea does not come to fruition,

nothing is lost except the time invested. Given that no one was expecting the potential innovation, no one will be disappointed when it does not appear. Typically, however, innovation will be the result of collectivism and not individualism. Innovation actually occurs in a series of rapid incremental changes. Seeing that the project is open, a domino effect is possible where one small improvement leads to another and another until the end state surpasses what was initially deemed possible. This is not to say that disruptive innovation is not possible, but in this case, the disruption will usually result in the development of another community around the offshoot innovation.

C. CHANGING THE CULTURE

If PP is economically advantageous, compatible with human motivations, and technologically possible, then what is the hurdle to implementation? Primarily, it is culture and the belief that control begets success. The above description has shown how control is not only a fallacy but also its mere pursuit presents a hindrance to success and innovation. Consequently, it is necessary to address culture to pave the path for PP implementation.

The culture that needs to be changed to implement PP centers chiefly on the notion of control. While this is true for any organization trying to implement PP, it is especially true for a strictly hierarchical organization like the military where everything is eligible for inspection and the tolerance for failure is small. How to effect culture change within an organization must be determined from within the organization itself. Understanding why this culture change is necessary for PP is best approached from a direction external to PP.

Ricardo Semler is CEO of the Brazilian Company, SEMCO and author of books on alternative business management theory including *Maverick* and *The Seven Day Week-End*. *The Seven Day Week-End* is particularly significant because even though Semler never mentions the term PP, the book essentially amounts to a handbook for preparing an organization to implement PP. In the book, Semler describes an alternative organization structure based on democracy and not hierarchy, based on freedom and not control, based on innovation and not efficiency. All of these dichotomies are also true

about PP. The difference, however, is that it is difficult to imagine the military functioning at all in Semler's construct. With PP, however, the military can experience the benefits of freedom in the workplace without forfeiting command authority. The key to this experience is realizing the difference between leadership and management. For example, the term "micro-leader" does not make any sense but the term "micro-manager" is universally understood as "the guy you do not want to work for." Leadership directs the course of an organization and trusts that the individuals, through prior preparation, can work out the details to proceed smartly in the intended direction. Management concerns itself with accounting for time, ensuring procedure is followed, documentation and training, scheduling and maintenance. It is in the area of management that PP is most applicable.

Semler, in describing his control-free management strategy, states it "has led to an unprecedented record of innovation, customer satisfaction, growth, and an end to repressive command and control management practices that cause much labor unrest and personal misery, from the top to the bottom of many organizations."(Semler, 2003, p. 5) He continues by stating there "is the need—the absolute necessity—to give up control in order to cope with changes that are transforming the way we live and work."(Semler, 2003, p. 5) The major changes that organizations are currently experiencing primarily stem from the transition to the (global) networked information economy. The speed of information flow has made traditional management techniques obsolete overnight. It is no longer possible for the manager to be the most informed, so consequently much of his power has been eroded. The new manager, the manager using PP within a hierarchical structure, now becomes a facilitator, one that empowers rather than projects power. It is in this manner that both the individual within the organization and the organization as a whole will achieve their respective goals simultaneously. Semler wrote "Employees must be free to question, to analyze, and to investigate; and a company must be flexible enough to listen to the answers. These habits are the key to longevity, growth, and profit."(Semler, 2003, p. 17) PP does this; it provides an avenue for questions, insight, and experimentation that should not be deemed threatening to the command structure. PP can be and must be focused around specific communities within the larger organization.

Through the implementation of PP the objective becomes the generation of knowledge and not the maintenance of control.

Specifically, the principles of investigation, questioning and analysis applied through PP within a hierarchical organization serve to sustain superior performance by always maintaining focus on continual process improvement. These practices, when encouraged at the organizational level, allow an individual to “dip into their reservoirs of talent, that pool of inherent interests and skills that is unique to us all. They dip to make themselves feel alive, to provide purpose and identity, to satisfy their egos with the trappings of status, to feel that their lives are worth living.”(Semler, 2003, p. 104) Individuals will "dip" no matter what. If the practice is not encouraged within their organization then the workers will look elsewhere to fulfill their psyche and needs for fulfillment. If PP is supported by their employers, individuals will not only achieve their own objectives, but as importantly, individuals and employers will also achieve the companies' objectives.

Every organization, including the DoD, states it is their people who are its greatest asset. Anything short of encouraging these individuals to utilize every aspect of their reservoir of talent fully is a failure to treat people as the greatest asset. Semler goes on to say, “...organizations mistakenly believe that productivity can always be raised. Productivity stagnates or falls when workers are waiting for someone to tell them what to do, or when they are following a formal plan, or confining themselves to the dictates of their job descriptions.”(Semler, 2003, p. 160) The idea that productivity is tied directly to empowering the individual raises a distinction between traditional management and PP compatible management. If management is synonymous with direction, it will eventually reduce productivity because the system will only function with direction as an input. If management guides instead of directs then individuals are empowered to proceed without specific instructions. Management then takes on a much wider perspective that permits freedom of movement beneath it, inspired self-direction, efficient employment of time, and effective use of resources. This is the definition of management, which is necessary to permit a culture that is permissive to PP.

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VII. THE PEER PRODUCTION SYSTEM

Imagination is more important than knowledge. For knowledge is limited, whereas, imagination embraces the entire world, stimulating progress, giving birth to evolution.

Albert Einstein

Thus far, this thesis has been dedicated to describing why PP is both possible and beneficial to employ. The task now is to describe how to apply PP in a manner that is consistent with the guiding principles previously documented. In doing so, a generic PP system is presented based on a functional perspective. This system was derived by analyzing both successful PP projects and the associated research performed on these specific projects. In this regard, the thesis defines and explores new territory. No known research has yet provided an engineered solution for designing and applying peer production systems. Although beyond the scope of this thesis, a validation of this research should be pursued. It would entail conducting an in depth inspection of less successful and failed PP projects. There are many examples in the OSSD movement alone. These projects can be examined with respect to their adherence to the model presented here to determine if the source of their failure can be identified and consequently their performance could be improved through a revised approach.

After describing the functions of applying PP, a stakeholder analysis of a DoD PP process is presented. This is essential for two reasons. First, the stakeholders are the members of the peer community and are therefore the means to applying PP successfully. Second, from the stakeholder perspective, DoD PP is slightly different from commercial applications of PP in how the reward equation is fulfilled. This will be made clear in the stakeholder analysis.

Lastly, this section concludes with the presentation of a PP model created in the modeling and simulation software, ARENA. The model serves two purposes. It presents the PP system from a perspective that systematically steps through the application of PP. This process provides more insight on how PP operates by juxtaposing the PP model with

a firm model applied toward a similar project. It also is the basis for a simulation of a peer production project compared to a similar firm production project. The results of the simulation illustrate and quantify the benefits of PP discussed in previous sections.

A. PEER PRODUCTION SYSTEM LIFECYCLE

PP systems are like any other systems with respect to its lifecycle considerations. PP systems must be conceived, designed and architected, and setup to promote peer contribution, collect submissions, and integrate them into an intelligible whole. To do this, a system engineering approach was adopted that captures the essential “technological activities within the system lifecycle process”, as recommended by Fabrycky and Blanchard (see Figure 17).

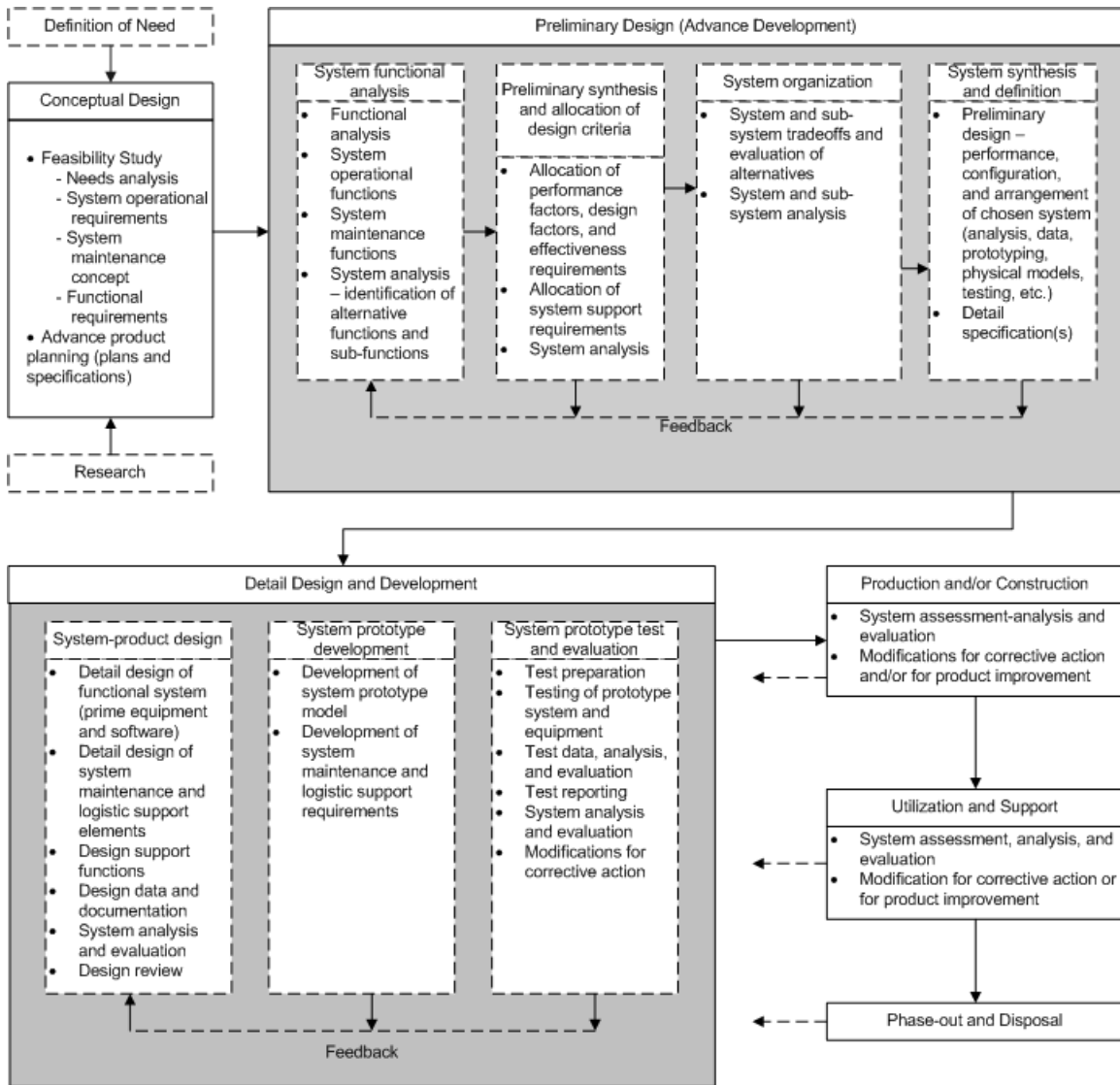


Figure 17. System Lifecycle (From Blanchard and Fabrycky, 2006)

To gain the most benefit from PP, each PP system must be engineered individually in the context of the organizational interests and needs. Perhaps there is a common subset of PP system structure, that while commoditized can still be meaningful and effective. Without amplifying this notion, we assume that every PP system has a unique design, because it must be constructed with respect to a unique community of peers. This assumption does not impose a formidable task, however. PP systems are not complex and they do not require any technological innovation. They only require current technology, applied in a PP fashion. Essentially, all of these systems can be produced

with Commercial Off The Shelf (COTS) components. From a hardware perspective PP systems are inexpensive, require no customization for DoD applications, and are based on technology that has already been tested and applied commercially. It is low risk technologically to implement PP systems.

Designing a unique PP system is also not as daunting as it seems. They are all uniquely designed, but comprised of similar components, assembled in similar fashion, and operating on similar principles. In this fashion, PP system design becomes manageable with respect to cost and schedule. There is significant duplication from one PP system to the next and the portion of new design necessary is limited typically to presentation of the specific project and marketing to the desired group of potential peer contributors. Common parts and similar methods make the model presented here invaluable because it promotes reuse and identifies the few unique portions of each system. The model illustrates a greatly flattened learning curve for applying PP within the DoD.

B. PEER PRODUCTION DECOMPOSED

The functional decomposition is the critical first step to on time, on budget delivery of a system that meets all expectations. A complete functional decomposition does not guarantee successful system development because many other tasks are also necessary. Without it however the finished system will not fulfill its potential and the process to produce it will be wrought with inefficiencies. The functional decomposition presented below serves as the first step for applying PP within the DoD.

The important thing to remember about a functional decomposition is it is not meant to be sequential. Systems engineers apply process flow diagrams to capture the dependency and interaction between functions. Functions are applied (and should be viewed) concurrently rather than sequentially. At any time during the course of a project there could be at least one sub-function from each top level function being performed simultaneously.

Three real world examples are presented in Appendix A that examines successful public sector applications of PP. The examples provide a practical understanding of PP. They are also written to illustrate how the functional decomposition presented here applies to real applications. All of the functions below are found in these examples.

1. Top Level Functions

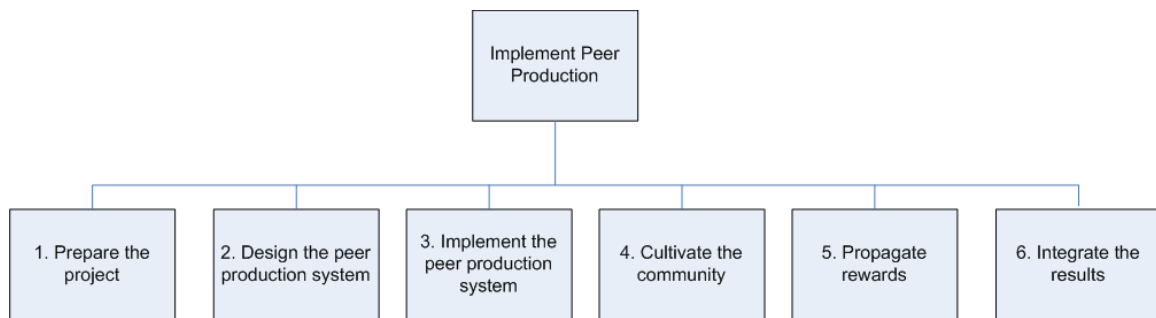


Figure 18. Peer Production implementation top-level functions

The top level functions of applying PP, as seen in Figure 18, describe the process that begins with identifying the opportunity for PP and ends with the incorporation of the product of PP to achieve the desired effect. The path from beginning to end involves the design and implementation of a PP system around a peer community that will self-select to participate based on the inherent rewards of the project. The continued success of the system and the collective health of the peer community rely upon the appropriate propagation of those rewards. The following sections describe the specifics for each of six top level functions. These descriptions were decomposed into two lower levels. The complete functional decomposition is shown in Appendix B.

2. Preparation of the Peer Production Project

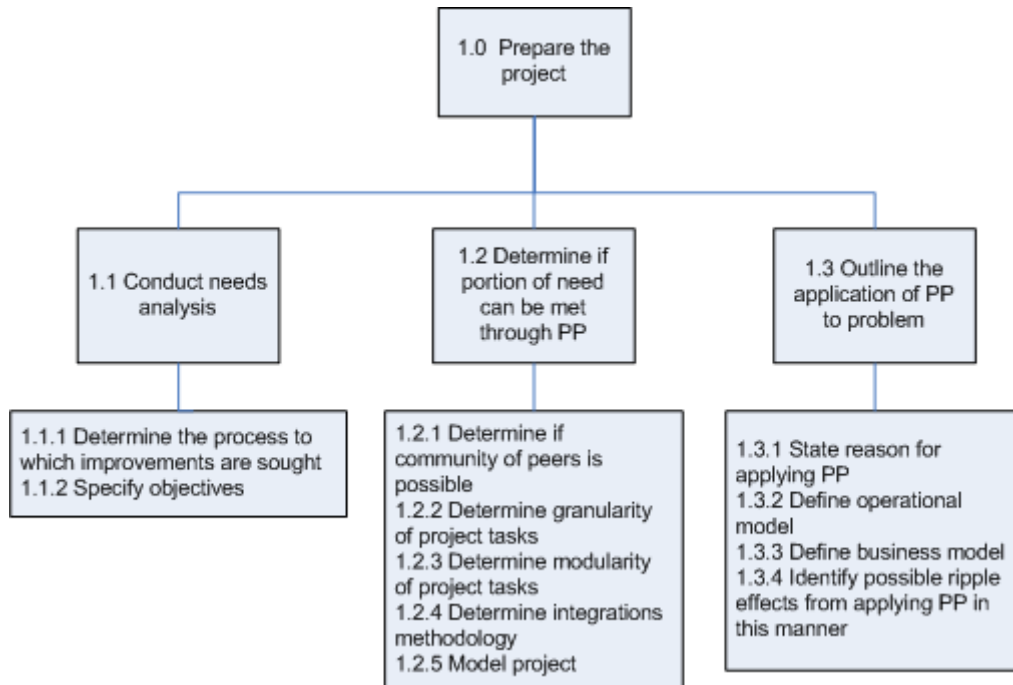


Figure 19. Determining if PP applies

PP has been established as a valid model of production. But, it will not be viewed as an option in system development until the system designer accepts the PP model and understands the benefits of its use. Therefore part of the process of preparing a project is to determine if it is strategically, economically, or politically advantageous for the parent organization to pursue PP development for the applicable components. This process is outlined in Figure 19.

The process of determining how PP applies begins with an analysis of the needs, or alternatively, recognition of the problem that must be solved. A needs analysis or problem definition can be (and usually is) the most difficult part of the design and implementation process. The key is not to proceed into design with a perceived need. The result of an effective needs analysis is an explicit need statement that accounts for all customers' (stakeholders) true needs. Often these true needs are not even remotely similar to the stated need that initiated the analysis. The transition from perceived to true need is accomplished in part by determining the process to which improvements are

necessary and identifying the root objectives. Once the root objectives are known and an awareness of PP exists, an opportunity to use PP may present itself.

Determining if an opportunity exists for PP is the second sub-function of preparing the project. It is in this step that the principles of PP previously listed in section B of this chapter are first applied. PP simply will not succeed if a community of peers to perform the work cannot be identified. Likewise, if the project cannot be distributed to those peers with sufficient granularity and modularity to get the V/C ratio for the proposed peer community to greater than one, then PP will also fail. If a community can be identified and the project characteristics are such to permit PP then its application is feasible. However, feasibility does not mean that it is advantageous to do so. Once the peers produce their individual components these parts need to be incorporated into an intelligible whole. In this case, although possible, PP is not the best option.

The next step is to model the proposed PP process. Modeling gives some quantifiable bounds to the scope of the project and serves as a bridge to the next step of outlining the application of PP to aid in solving the problem. Once the model is created it can be updated periodically to reflect new and more detailed information.

The function of outlining the application of PP ensures the spirit and intent of PP is not violated. The need for retaining the essential qualities of PP is absolutely necessary as there is no contractual obligation governing the performance of the peer community. The single biggest factor contributing to the demise of a successful OSSD project will be the corruption of the peer community towards the benefit of a select few. Outlining the PP process needs to focus on describing the project in a non-hierarchical process so that once it is introduced to the peer community it will be adopted.

3. Designing the Peer Production System

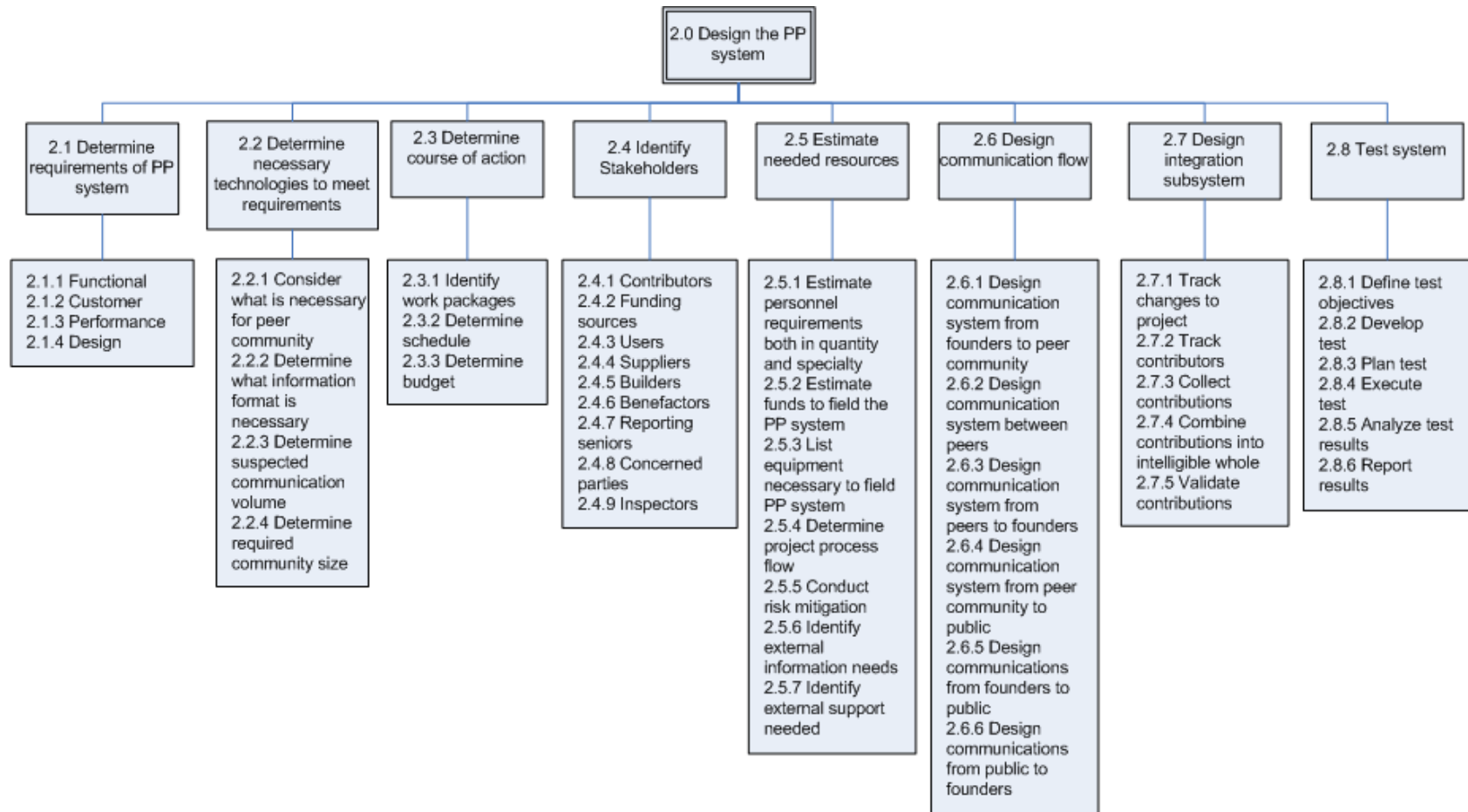


Figure 20. Designing the PP system

System design (see Figure 20) is the most generic of all of the top level functions of implementing PP. It is largely the same for any system being developed, PP or otherwise. Subsequently, only the sub-functions that are specific to PP systems are explained. In particular, the design of the communication flow and the design of the integration subsystem will be emphasized.

Communication flow is unique because it must be designed to be flat or non-hierarchical. Information distribution needs to be somewhat automated to ensure the most current information is presented and synchronous to assure all participants have access simultaneously (i.e., no preferential treatment). These practices, besides being particularly efficient for flat organizations, promote a healthy peer community.

The integration function describes how value is extracted from the PP system. Its sub-functions involve tracking both the individual contributions and the peers who produce them. This function provides for the validation of contributions and facilitates the distribution of rewards. The integration subsystem may come in many forms but the broadest categories are automatic or manual. Automatic integration is similar to that found in the Clickworkers example. A computer algorithm compiles the individual contributions, weights them to reduce the effect of erroneous inputs, and presents the results. Another automatic option is the use of a "Wiki" like that applied in Wikipedia. Here the automatic integration is accomplished through a data structure which indexes and promotes compilation via a database. The database is updated with each peer submission while maintaining version control and protecting against the effects of erroneous or malevolent submission. A sub-function of the integration process is to prevent corruption of the product through the actions of subversive behaviors. Of course there is a limit to the degree any integration system can prevent or minimize the effect of subversion. The success of the project will depend on the majority of contributions being beneficial. Manual integration is much more costly to perform but may be necessary. Sometimes integration can be accomplished by one or a group of super-contributors, as is often seen in OSSD. Other times it is accomplished through peer review. With a simple set of rules, a peer review method is used by EBay to provide confidence in individual

sellers. In the design process, it will be readily apparent which type of integration subsystem is most appropriate.

4. Implementation of the peer production system

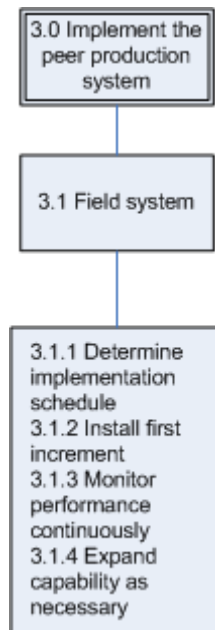


Figure 21. PP implementation

Implementation is another of the functions that is relatively generic as seen in Figure 21. This is because PP systems are by design, technologically simple. There is really no need for extensive engineering as would be the case in computer software or a hardware product like an armored vehicle. Consider implementation of a software system for example. It is typically accomplished in phased release of both content and controls. As such it would have a much more complex functional decomposition associated with the implementation. The PP system simply does not have the same complexity. Consider the development of LINUX as an example. The operating system has gone through much iteration of programming changes, beta version release, debugging, and full version release. The community and communication tools used to develop the operating system did not go through the same iterative process. The PP system is analogous to the hierarchical organization. Just as there is turnover in the hierarchy that produces any product between iterations, there will also be changes in the PP community

between product versions. However, there will be no need to redesign the PP system every time redesign of the PP product is necessary. Because of the simplicity of the PP system it is something that should be functional after the first design iteration. Linus Torvalds did not design the LINUX Open Source programming community. He simply shared a functional baseline with other likeminded individuals. It is important to remember that the PP system is not the end in itself; rather it is the means to the end. As such it needs to be as simple as possible.

5. Promoting a Healthy Peer Community

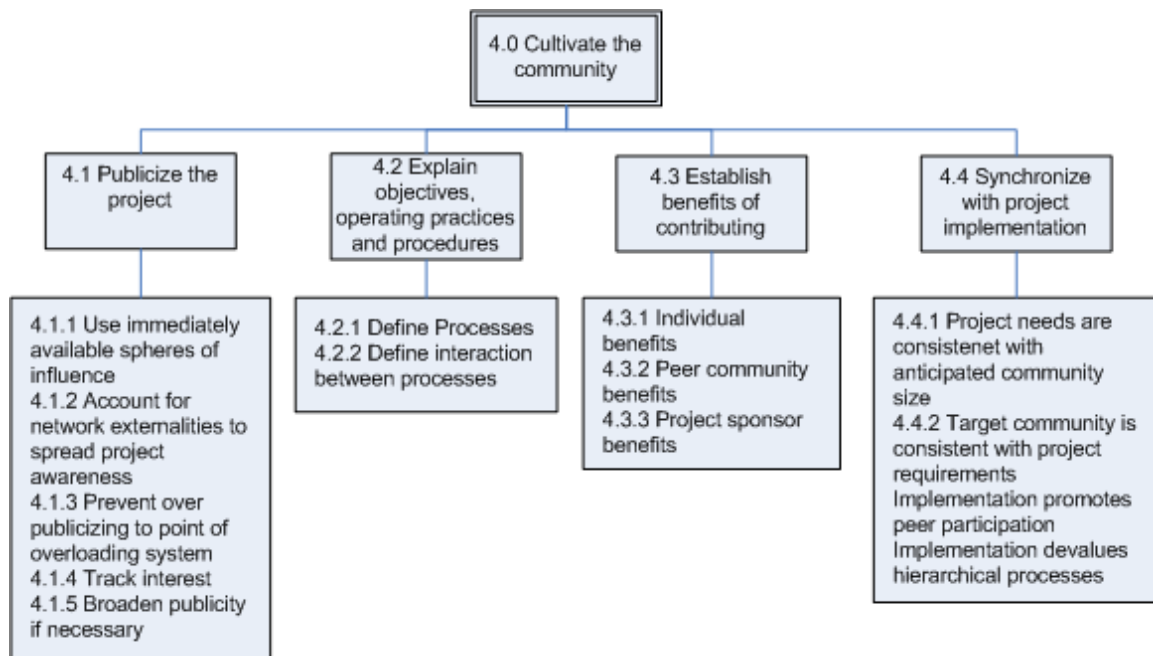


Figure 22. PP community cultivation

Where system implementation is generic to all systems, peer community cultivation is another function unique to PP processes. The specific methods employed to achieve this function will also be tailored to the characteristic of the particular community being promoted. In some cases, a well defined community will already exist and the project just needs to be publicized. In other cases the community will need to be grown from a few well placed seeds. In these cases, the speed of growth may need to be controlled to prevent exceeding the capacity limitations of the PP system. Sometimes community growth will need to be restricted to prevent the size of the community from

exceeding the rewards potential of the project. If the community is permitted to grow too large too fast then withering may occur. Withering is where the community rapidly grows and then quickly dissipates to the point where it can no longer sustain the project. This is caused by not having sufficient demand for the available peer producers. Other times rapid, unrestricted growth will be more appropriate. Proper synchronization with system implementation will assist in the function of community size regulation. Establishing the benefits of contributing represents the primary means of promoting longevity in the community. If the benefits are real, attainable, and documentable then they will promote continuous renewal of the community.

6. Propagation of Rewards

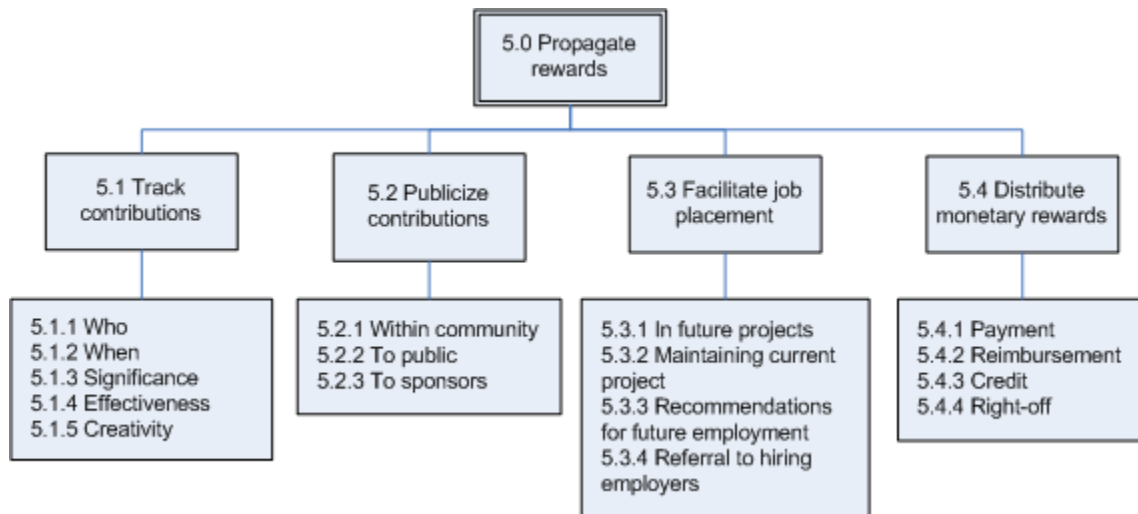


Figure 23. Rewards propagation

The function of reward propagation (Figure 23) needs to operate in support of the reward equation at all times.

$$R = M + H + SP \text{ where}$$

R = individual agents reward for performing an action

M = Monetary compensation

H = Hedonistic rewards

SP = Social-psychological rewards

First and foremost it is necessary to track contributions. This is typically automated as part of the submission process. This documentation process facilitates the SP rewards process. This is particularly well-demonstrated in the OSSD communities. Lerner and Tirole documented that more than 90% of code contributions can be traced back to their contributor and that altering this record in any way is the gravest of ethical violations within the community (Lerner & Tirole, 2002). The publicity of contributions is the function that promotes the SP rewards; it is also the function that assists in community longevity. Seeing the recognition that other contributors receive will promote future contributions from others.

7. Integration

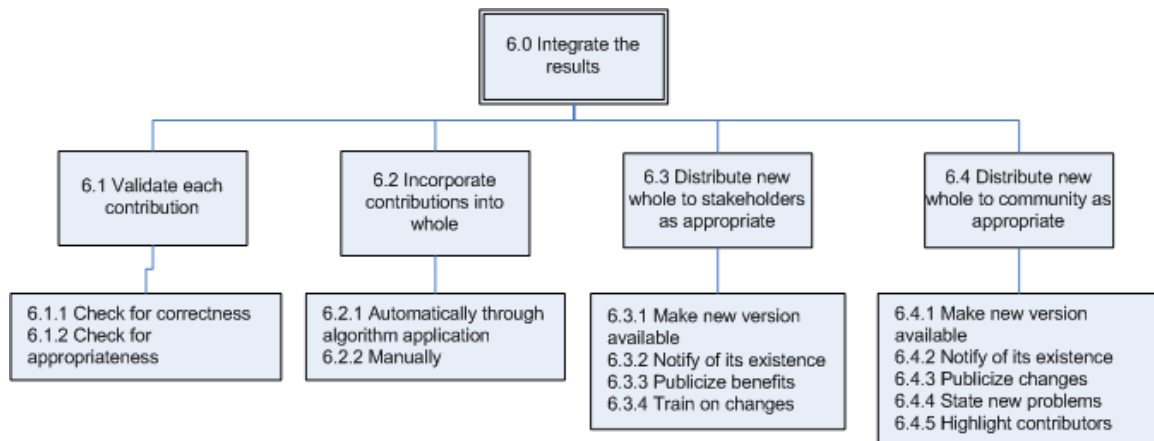


Figure 24. Result integration

If the integration process was considered properly in the project preparation phase and then constructed with the appropriate detail in the design phase then the actual integration of results should be the easiest part of the whole PP process. This integration process is outlined in Figure 24. In other methodologies making sense of inputs coming in from hundreds and even thousands of sources continuously would be nearly impossible. In PP this is not the case because although the content is unique the format of each submission is standardized through the PP system employed. This can be seen in Linux development communities, Wikipedia, Second Life, InnoCentive and Digg to name a few. It is simply the way PP does business. The contributors abide by the rules because it is the only way to get their voice heard. Simply, no rewards can be generated

by a submission that is not accepted into the project. If one submission is not standardized then the transaction cost of integrating that contribution will rise drastically. Consequently, the contribution must be discarded regardless of its internal value. If none of the submissions are standardized then the peer production model is no longer viable.

Because format is standardized, it is easy to execute the rest of the integration process. The results are easily searchable, filterable, verifiable, and distributable. These are all of the things necessary to make the product useful to both the project sponsor and the peer community.

C. STAKEHOLDER ANALYSIS

A complete stakeholder analysis is essential to successful systems engineering when applying traditional (firm or market) production methodologies. This is still the case when applying PP methodologies but the result of that analysis will be different for the same application. Typically, the most important stakeholder in firm production of product X will be different from the primary stakeholder in a peer produced version of the same product. In a firm produced project it makes sense that the stakeholder with the most influence behind his voice is the one that is providing the capital investment for the project. With PP this is not necessarily the case. Although there is some capital investment required to prepare a project for PP and establish and maintain the process this investment is not nearly as substantial as that required for a similar project produced through the firm or market models. Consequently, the capital provider should not and cannot be involved in a PP process in the same way in which they are involved in other models. In PP the collective interest of the peers must hold at least the same weight as any other individual stakeholder. This is simply because no amount of funding is going to make a PP process work without a strong peer community. However, the converse is not true. The coordinated effort of a peer community can and does produce real coherent results without large capital investment.

With respect to the stakeholders in PP two factors must be considered; the function of the stakeholders with regards to the development of a PP system and the function of the stakeholders in the application of that system. These two points will first

be considered with respect to PP in general. Then they will be applied in a discussion on the specifics of applying PP within the DoD.

1. Peer Production Stakeholders in General

Engineering design within the firm production model is not designed historically to be receptive to outside input. It is because outside input is so difficult to incorporate into a hierarchical engineering process that makes the stakeholder analysis so important. If a very specific and concerted effort is not made before system design and architecture occurs to seek out those that have a stake in an individual product then very important input will be unavailable until too late. This forgotten input is then usually first seen when the system is employed. This can only result in two outcomes. Either the unconsulted stakeholder must accept an inferior or incomplete product or the system must be reworked at additional cost and time.

Because PP is just another model of economic production it is never the end in itself. This should not seem odd. Firms are not formed for their own sake either. They are created to produce a product, provide a service, or distribute a good. Likewise the point of PP is not to do PP; it is to generate an effect. In the development of a PP system, there are founding stakeholders. These stakeholders are those that recognize the effect that must be generated or the need that must be filled. It is their responsibility to conduct the search for the other stakeholders, which will be the peer contributors. This search is conducted for an additional objective above that for which the stakeholder analysis is normally conducted. Normally, stakeholders are sought and consulted to discover the requirements of the system. While this is still the case, additional information is necessary. This additional information refers to the needs and requirements of the group of stakeholders called peer contributors. Identifying the correct peer contributors is a most critical process in the stakeholder analysis. The PP system will be designed differently for different groups of peer contributors.

a. *Function of Stakeholders in the Development of the PP System*

In developing a PP system, all of the stakeholders should be thought of as peers themselves. In that manner, they are stakeholders of equal weight with different functions. The community of stakeholders then looks like Figure 25.

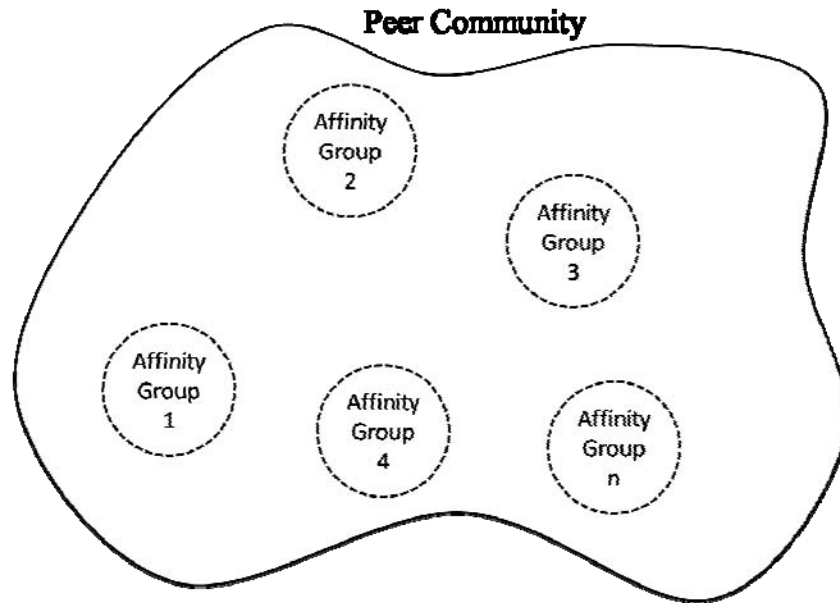


Figure 25. Peer community of stakeholders

The community is composed of anyone who has a stake in the problem or interest in the fulfillment of the need. The affinity groups within the community are differentiated by the particulars of that stake. There are affinity groups for those:

- concerned with the results created by the system
- using the system
- assuming the risk of the system
- designing
- financing
- constructing
- maintaining
- etc.

Filling the interests of each of the affinity groups in the development of the PP system begins by fulfilling the interests of the user (peer contributors) of the PP system.

Everything else becomes relative to these interests because on the system is fielded the peer community will singlehandedly make or break the systems success.³³

b. Function of Stakeholders in Application of the PP System

Once the system is enacted, the affinity groups will play a different role. The primary focus remains with the user affinity group but the nature of that focus shifts from active to reactive. In the development process, active effort was made to first identify the potential peer contributors and then discern their needs to ensure and effective PP system is created. On implementation, the peer contributor affinity group takes over the active role and begins fulfilling the need for which the system was created. The other stakeholder affinity groups react to the performance of the peer contributors in two ways. They ensure the reward equation is fulfilled continually and the V/C ratio of the peer community as a whole remains greater than one. They also react to the effects created by the peer community. Because of the unconstrained nature of PP, there will be both favorable and adverse secondary and tertiary effects of the PP process. These will need to be addressed as appropriate as the community operates.³⁴

2. DoD Peer Production Stakeholders

When PP is utilized within the DoD all of the general discussions on stakeholder interactions apply so it will not be restated here. What is necessary to consider is who will make up the user (peer contributor) affinity group in government sponsored PP. Of course the peer contributors of any specific application will be comprised of a relatively small and well defined group of individuals. In general, however, the potential

³³ This description is an example the release of "control" and the culture change discussed in Section IV are necessary to permit PP to be implemented. The idea of equally weighted stakeholders is in direct opposition to how systems engineering is currently conducted. It implies "no control" by any one individual or group of stakeholders. This is important because the stakeholder with the most importance is the peer community. This group has no direct voice in the stakeholder discussions. Therefore, the other stakeholders must be equally weighted to protect the peer community.

³⁴ There is an interesting side effect to the stakeholder affinity groups. Each member of each affinity group has an affinity group of its own. This is one of the reasons why PP is effective. In the course of performing their function with respect to the PP process, each stakeholder interacts with their external affinity group and takes information from the PP community and brings new information into it. This will lead to new peers joining the current PP system and the creation of other PP systems for other problems. In essence this is another way of describing the effect of network externalities.

candidates for contributing to DoD PP are essentially limitless. In theory it can be opened to anyone whose interests lie with the success of the United States military.

a. Binary Service to Country

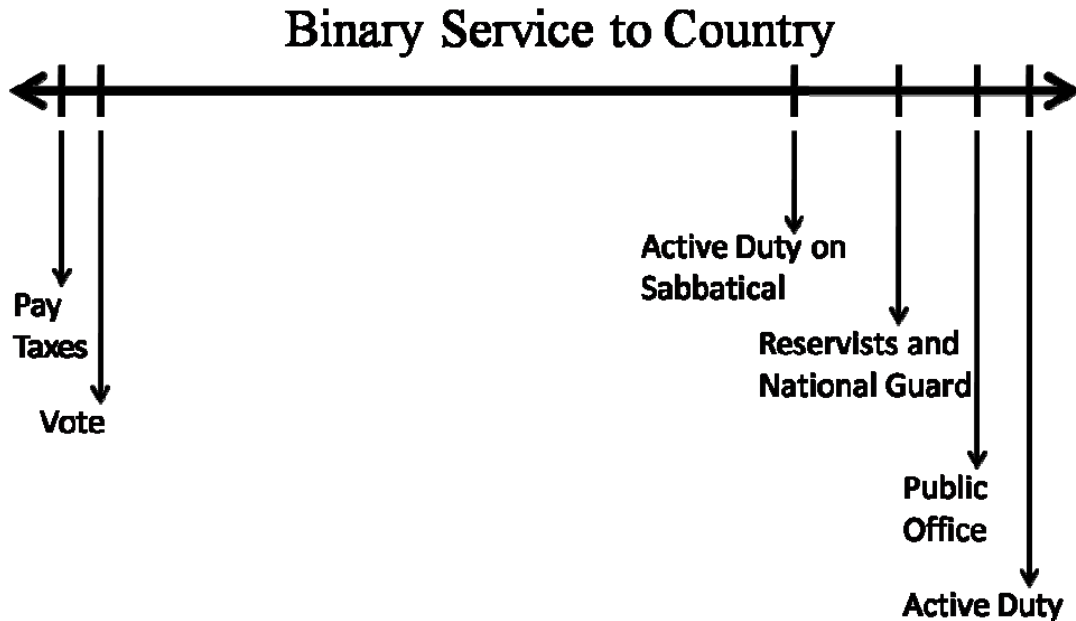


Figure 26. Binary service to country

By examining how most citizens traditionally interact with respect to the support of national interests, a binary picture of national service results, as depicted in Figure 26. Even in a time of limited war, as has been fought by the U.S. since Vietnam, very little is asked of the general public than to vote and pay taxes. (This of course breaks down in the case of World War where millions are dying.) Of course, if they disagree with the course of national action their voice will be heard but of those who support it little if anything is asked. In the networked information economy this does not have to be the case. There are a significant number of individuals with a favorable V/C ratio, who would be willing to contribute to national PP. This creates a continuum of service.

this manner will provide a true force multiplier because the reservist will manage and employ a presently unutilized workforce. When paired with the appropriate PP project, reservists bring with them the subject matter expertise to steer the project, the perspective of the warfighter, and the ability to interface efficiently with the private sector. Reservists also possess a very favorable V/C ratio when employed in this manner. PP does not require travel to a military installation at regular intervals. It promotes utilization of their civilian professional skills and contacts more effectively and it provides a real sense of contribution to the national effort. All of this is accomplished at a cost savings to both the individual and the service.

The remaining contributors will depend on the focus of the project. Sometimes they will be primarily active duty members and other times will be made up of contributions from the general public. It has already been stated in Figure 22 that the point is not to solicit participation from everyone but rather to provide the opportunity to contribute knowing that only those with something to be gained by the reward equation and a favorable V/C ratio will contribute.

It is important to realize that this is a different application of the reward equation than originally proposed by Benkler. Recall the reward equation is:

$$R = M + H + SP \text{ where}$$

R = individual agents reward for performing an action

M = Monetary compensation

H = Hedonistic rewards

SP = Social-psychological rewards

The hedonistic rewards proposed are exemplified by those who contribute to OSSD because they themselves what use of the software program that is created. This is direct hedonistic reward, the individual uses their talents to create a reward directly related to those talents (software programming to get use of a software application) In DoD PP, in more cases than not, the individual will not get direct use of the project to which they are contributing. Their hedonistic value is created through development of their skills and use of the security provided by the military to which they are assisting.

Specifically, these individuals with favorable V/C ratios are:

- Stay at home parents, especially those who were once professionals
- Retirees
- College students
- The perpetually under-utilized or under-fulfilled

All of the above groups have hedonistic rewards associated with utilizing their skills, have an interest in national security, are not driven primarily by monetary rewards and have surplus time. Consequently they all have a V/C ratio significantly greater than 1.

D. INTEGRATION OF DOD HIERARCHY WITH THE PEER PRODUCTION MODEL

Peer production is a methodology that effectively uses intellectual capital and human resources in an enterprise to achieve the desired effect. Most enterprise models today are primarily hierarchical. Consequently, they are constrained into bureaucratic processes which can involve significant cost that result from both using the processes and maintaining the hierarchy. Many traditional hierarchical firms are finding it very beneficial to incorporate PP in their processes. These include Microsoft, Proctor and Gamble and Xerox to name a few.³⁵ The DoD will benefit from PP similarly.

The DoD functions as a traditional hierarchical organization. Many of the contractors that produce our systems and provide our services are also organized and operate in a hierarchical fashion. Therefore the relationships within and between DoD and its contractors can be analyzed with respect to the coordination/transaction costs mentioned in Chapter III of this thesis. To illustrate the DoD contractor relationship(s) several system models are presented below (Figure 28).

³⁵The use of PP by Xerox and Proctor and Gamble is discussed in some detail in the examples of Appendix A. Microsoft has just started using PP in the development in Internet Explorer as was mentioned earlier in this thesis.

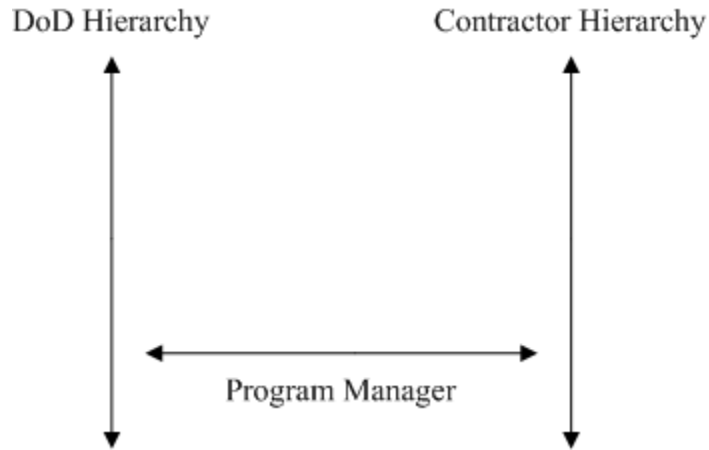


Figure 28. Traditional Organizational Hierarchy for Systems Development (The H Model)

In traditional system acquisition the relationships involved with creating a particular capability can be illustrated by a program manager that serves as a bridge between independent, hierarchical organizations (the H model), Figure 28. Both the DoD and contractor hierarchies have their own associated internal coordination costs. Transaction costs are experienced by the program manager coincident with the operations and functionalities between the two hierarchies. In effect the H model doubles the coordination costs over what it would take an individual company to bring a product to market. Both organizations have duplication of efforts for program accounting, hierarchical control, task implementation and coordination, and communications.

For certain applications, the DoD might make use of the PP model in conjunction with its own coordination hierarchy, to experience significant improvements in cost, time, and quality of its systems.

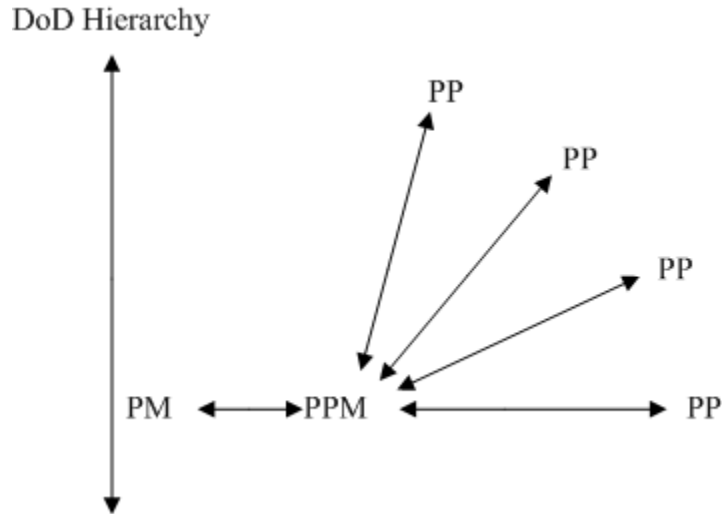


Figure 29. Peer Production Model Married with DoD Hierarchy (The Fan Model)

For certain types of applications the Fan model (Figure 29) is quite appropriate. Here the PM acts as a facilitator and organizer among the individual peer producers. All of the traditional requirements from Needs Analysis through Operational Test and Evaluation (OT&E) and production still apply. The real (and only) difference is the development of the system is accomplished in a PP manner. For example, this model is especially well suited for software development.

In addition to the above situations, there will also be a small number of cases where a pure PP model, outside of the DoD hierarchy can be used.



Figure 30. Pure PP model for DoD

In these cases, a Project Management Office (PMO) manages the flow of information from the DoD organization to the prosumers in the general public. The Pure PP model (Figure 30) can be best used for certain services and development of administrative systems that are required for the DoD organization to function. Examples of these type of applications include advertising, web-hosting, R&D, maintenance, knowledge sharing, and problem solving.

E. PEER PRODUCTION VERSUS FIRM PRODUCTION MODEL SIMULATION COMPARISON

A software design scenario was chosen as the example to model to demonstrate how both the firm and PP models work. Software design fits well into the PP process but is typically accomplished in a firm construct. In that regard it made for an easy comparison. Software projects also tend to be both modular and granular. They fall into the category of knowledge, information, and culture (Benkler, 2006). Also the OSSD movement, which began over 15 years ago, represents the beginning of the PP movement. And there is significant data available to baseline the model.

1. Firm Production Model

In the hierarchical process of firm production there is typically a program manager and an association of workers assigned as subordinates. This structure is repeated for as many levels as necessary to accomplish the task. The structure used in the firm model is seen in Figure 31.

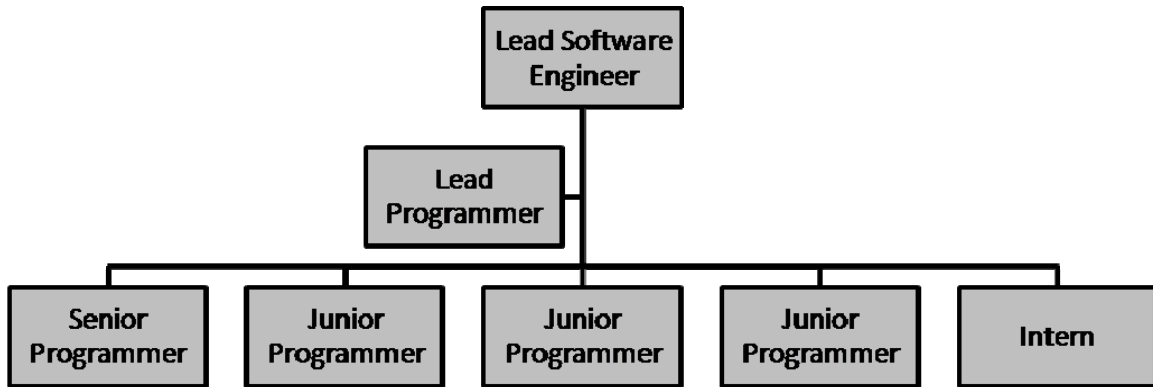


Figure 31. Firm model hierarchy used for simulation

Within one level of the hierarchy, the major role of the manager is task assignment. To accomplish it a manager has to pair an agent with a task from a pool of agents and tasks. The agents have associated with them a respective talent level for performing their required tasks. Likewise, the tasks have a difficulty associated with each of them. The role of the manager is to assess what the talent level and task difficulty is and then to pair each agent and task for the most efficient accomplishment. It is impossible to determine exactly what these values are for talent and difficulty because of incomplete knowledge and specification. Incomplete specification results because the manager cannot know everything about the task to determine exactly how difficult it will be to accomplish. Likewise, the manager does not know everything about every agent to include their education, specific likes and dislikes, personal situation, and any number of other factors that will affect their performance of every task. As a result, the manager assigns a specific task and difficulty to each entity, but there is actually a significant level of variance to this assessment. In the model, this variation is accounted for through a probability distribution around both agent talent and task difficulty (Johnson, 2001). The management personnel also must assess the time it will take the agent to perform the task. There is also a variability distribution associated with required task time but it is a function of the paired agent talent and task difficulty levels.

Two firm production behavior models were built in ARENA³⁶ to demonstrate the effects of variability and incomplete knowledge specification. The generic process flow of these models is seen in Figure 32 and the description of the process flow is in Table 4. The first model represents an ideal firm production process. This model assumes perfect specification for agent talent, task difficulty and duration. Perfect specification means that, on a scale of 1–10, if a task is thought to be an eight in difficulty it is actually an eight when performed. The same goes for agent talent, if an agent is assessed by management to be a six then the agent always performs to the standards of a six in talent. Therefore, the ideal model has no variability associated with it. Once assigned, talent, task difficulty and duration are constant. There is still variability between the results of each simulation replication because of the randomness in assigning the available talent of the pool of agents, along with the difficulty and duration of the tasks. In one replication, there may be easier tasks than another or more talented agents than another replication. The output of the ideal model simulation presents the best case for accomplishing the project with respect to total time taken to accomplish all the tasks. In order to put the output in understandable terms a notional cost is assigned to the project. This is accomplished by assigning a wage rate to each agent based on their position in the model hierarchy. The sum of the wage rates multiplied by the total time taken results in a number equivalent to the labor cost of the simulated project.

The second firm model represents the real case where incomplete specification is considered. The distributions used to assign this variability are described in Table 5. The firm process variables representing talent and difficulty in both firm models were assigned discrete integer values between 1 and 10. These values were used to determine whether a particular agent can accomplish a task. If an agent has a talent equal to or greater than task difficulty then that agent was deemed capable of accomplishing the task. This process of assigning weighting factors was used to mimic the process of assigning personnel to tasks in actual project management. The scale from 1 to 10 was used

³⁶ ARENA is a software application that facilitates the creation of process models that can be run through any number of replications. The replication process generates statistical data about the process so conclusions can be drawn about performance over time. In this case, I used ARENA to statistically compare a firm production process with a peer production process in terms of project time, cost, rework, and number of personnel required.

because it gave sufficient but not excessive contrast from one value to the next. Discrete distributions instead of continuous were used because they are more consistent with the actual mental process used by a manager and the less than exact nature of the assessment being made. Personnel management is more art than science because it relies on making evaluations about people and applying experiences gathered from similar projects and situations. Modeling an inexact process like this is statistically a difficult task. In this case, the 1–10 scale was chosen because it both fit the needs of the modeling process and could be used to collect data in future research through surveys on real world applications.

A constant number of tasks to be completed were used in each simulation. Ten percent of the tasks were front loaded and available in a pool for assignment to an agent. The other 90% of the tasks were introduced into the simulation as it proceeded. Exponential distributions were used to randomly introduce new tasks that were independent of each other. A mean arrival time was picked, that was small enough to ensure that the agents are never idle and waiting for new tasks to arrive.

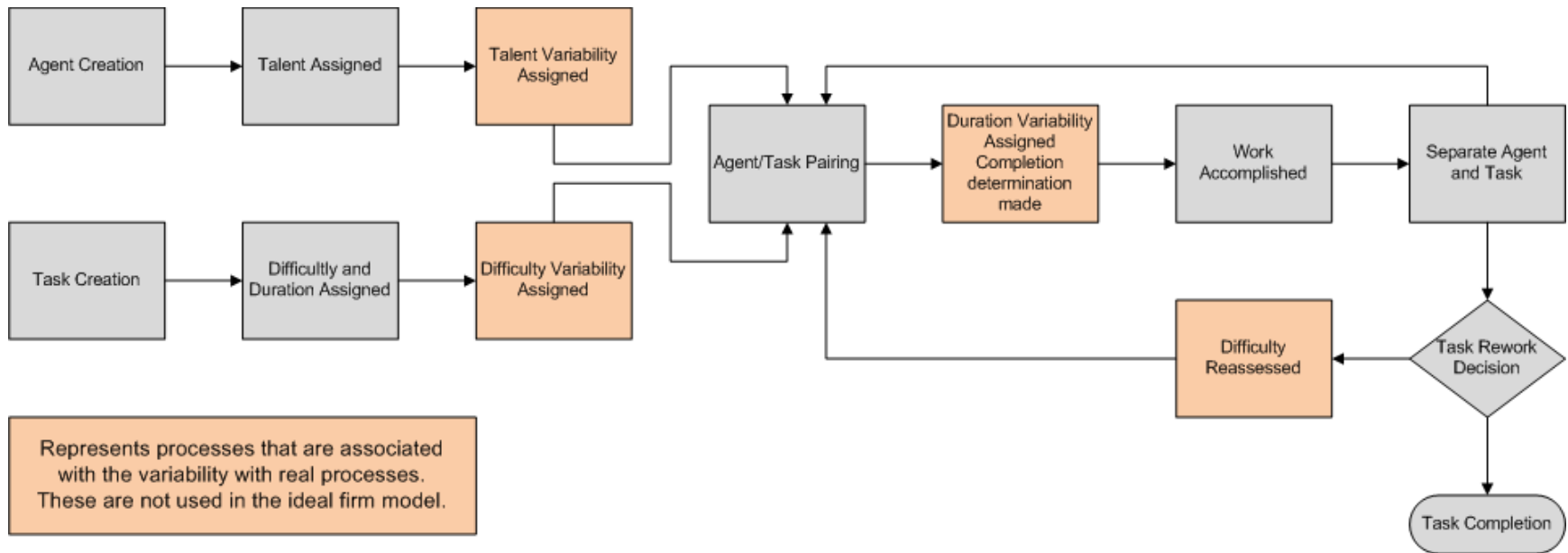


Figure 32. Firm model simulation process flow

Process Flow Point	Description
Agent creation	Entities were created by ARENA to represent the agents (computer programmers) that perform the tasks of the project.
Talent assigned	The first entity created was assigned a talent level of eight. This represents the Lead programmer. Eight is reasonable because it is a relatively high talent level and is consistent with a programmer who has repeatedly proven himself on previous projects. This number could be varied but the key is that this number must be equal to or be greater than the maximum difficulty assigned to any task. Sensitivity analysis on the simulation model found that an endless loop will be created if there is insufficient talent to perform the tasks. The rest of the agent entities were randomly assigned a value between some minimum and maximum talent level.
Talent variability assigned	Talent variability is based on the fact that the agent's talent is being assessed by a third party in real life. Consequently, incomplete specification is a factor. Task assignment is based on the talent assigned but task performance is based on the revised talent after variability is applied.
Task creation	Entities were created by ARENA to represent the tasks that are necessary to complete the project. The number of tasks created can be varied in the simulation to model different project sizes. It was unreasonable to increase this number indefinitely though because this would be inconsistent with real life. It would cause the project simulation time to increase without bound and endless projects are just not feasible or profitable. To model large projects what should be done is to model the number of tasks that one level of the hierarchy would accomplish in the course of the project and then multiple those results for the number of project teams involved in the project.
Difficulty and duration assigned	<p>Task difficulty and duration was assigned in one step. In reality the difficulty is a function of the manager's assessment of the task. In the simulation the difficulty is randomly assigned based on a probability distribution. The distribution is skewed towards easier tasks to be consistent with actual projects. Too many extremely difficult tasks make a project too risky to undertake.</p> <p>Duration was assigned randomly also. To be consistent with the granular requirement of peer produced projects no task was assigned a notional duration greater than ten hours. The minimum assigned is one hour.</p>
Difficulty variability assigned	Difficulty variability is assigned by applying similar logic to that used to assign talent variability. Difficulty variability is also a result of a manager's assessment of an incompletely specified task. Agent assignment was based on task difficulty but task performance was a function of the revised difficulty after variability was applied.
Agent/Task pairing	Agent and task pairing is accomplished by evaluating the difference between an agent talent and the difficulty of all of the tasks in the queue waiting to be accomplished. The most difficult task the agent is deemed capable of accomplishing is assigned.
Duration variability and completion	In real life, actual task duration is a function of the resources available, infrastructure in place, and many more factors. For the purposes of this model, task duration was defined as a function of only two variables—talent and task

Process Flow Point	Description
determination	difficulty. In the simulation a weighting factor was used to adjust the task duration based on the difference between actual talent and actual difficulty. If actual difficulty is two or more units greater than actual talent then the agent will work on the task for the weighted duration but fail to complete it.
Work accomplished	The work accomplished process in the simulation is just a delay mechanism that prevents the task and agent from proceeding until the assigned duration has passed. If the agent had sufficient talent to perform the task then the task is tagged as complete. If the task is too difficult for the agent assigned then it is tagged as a failure.
Agent and Task separation	Agent and Task separation is just a function of the simulation. To permit work accomplishment the task and agent entities are actually combined into one entity. Once the work delay is satisfied the entities must be separated again to permit the task to be evaluated for completion and the agent to return and get another task assigned.
Task rework decision	Task rework decision evaluates the task that had just left work accomplishment for two things. If the task was tagged as complete then nothing further is done and the task exits the system. If it was tagged as failed then the number of times the task was worked on is evaluated. If the task failed twice then it was labeled as an incomplete task and it left the system. At this point the determination is that no agent is capable of completing the task so it is removed from the system. When the simulation is complete the total number of incomplete tasks will be tallied. The idea is that a certain number of these tasks could still be reworked. Possibly the Lead Software Engineer could get involved to complete them directly or an outside contractor can be hired to accomplish the task. Either way, the incomplete task represents a failure of the firm model. In real life this equates to a schedule and cost overruns. As some point the number of failed tasks will be great enough that no amount of rework is feasible and project failure will result.
Difficulty reassessed	Difficulty reassessment permits learning. Once a task is attempted it is much closer to being fully specified. Consequently, a more accurate difficulty assignment can be made. In the simulation this means that difficulty is reassigned to equal the difficulty after variability was applied. This permits reassignment of the task to a more talented agent for the rework.
Task completion	Statistics are taken on the completed and incomplete tasks and then the tasks exit the system.

Table 4. Firm simulation process flow explanation

Variable	Distribution	Reason
Talent	Discrete PDF 5% T = 8 10% T = 7 15% T = 6 25% T = 5 25% T = 4 20% T = 3	T = Talent level assigned For a firm model it seems reasonable that the majority of agents will have an average talent level between four and six. Only a few will have high or low talent levels. High talent costs too much and low talent cannot do enough.
Talent variability	Discrete PDF 20% AT = T - 1 75% AT = T 5% AT = T + 1	AT = Actual talent of agent after variability applied The Probability Distribution Function for talent variability is skewed towards making agents less talented than they are originally assessed. This is done to be consistent with how the firm model operates. There is no incentive for an agent to be more talented than their boss thinks. If an agent can accomplish a task then it is to their benefit to make sure their boss knows it. The converse is not true; an agent will tend to present themselves in the best manner possible. This may lead to a manager inaccurately assessing their talent as being higher than it actually is.
Difficulty	Triangle Distribution D = Triangle(2,5,8)	D = Task difficulty assigned
Difficulty variability	Discrete PDF 5% AD = D - 2 10% AD = D - 1 25% AD = D 40% AD = D + 1 20% AD = D + 2	AD = Actual task difficulty after variability applied It seems to be a reasonable assumption that tasks are often more difficult than expected. Rarely do tasks turn out to be easier than expected. This is also consistent with the number of projects that take longer than scheduled.
Duration	Uniform probability between 1 and 10 hours to complete Dur = Uniform(1,10)	Dur = Task duration assigned
Duration variability	Function of difference between AT and AD AD >= AT + 2, RD = 1.3*Dur and task will fail AD >= AT + 1, RD = 1.3*Dur AD = AT, RD = 1.1*Dur AD < AT, RD = 1.0*Dur	RD = Realized duration after comparison made between AT and AD It is true that it is possible to complete a task in less time than expected but it is unrealistic to plan on this occurrence. There may be disagreement on the weighting factors used to adjust task duration but the same factors were used in both the firm and PP simulation models. Any error introduced by these factors will be consistent across both models.

Table 5. Firm model variability distributions

2. Peer Production Model

The Pure PP model (see Figures 33 and 34) derived describes the peer production process in general. It is the starting point that can be tailored to portray specific projects in later research. In this regard, the model has been verified to mirror the actual process but has not been validated with actual data. For comparison sake, as many of the variability distributions as possible have been held constant between the firm model and PP model simulations. Specifically, the same distributions are used to assign task difficulty and difficulty variability as well as duration variability. Tasks are introduced with the same distribution in the temporal domain as in the firm models. Talent variability is not used in the PP model however. This is one of the characteristics of PP that results in an increase of project success probability over firm models of production. There is no incentive for a contributor in PP to take on a task that they cannot complete (Chapter IV, Section G). No rewards are generated by failed attempts and the failure is directly attributable to the specific agent and not absorbed by the organization. In the model this translated into no variability in the self-assessed talent of an agent. An individual's talent is perfectly specified to herself. This does not mean that a PP contributor is guaranteed to complete every task because the task difficulty is still incompletely specified.

The generic process flow of the PP model is presented in Figures 33 and 34. The process flow description is in Table 6 and Table 7. Table 8 lists the distributions used in the model. In the PP model there are two separate processes that occur. The first represents the overhead associated with using the PP economic model of production. The design and implementation sub-functions in the PP system represent this overhead. The tasks that are performed in the PP process flow are termed "foundation blocks" and those performing them are called "founders". In real life, this process flow corresponds to the work Linus Torvalds did before he released LINUX to the general programming public. It represents the work Jimmy Wales did to build the structure for Wikipedia and it represents the work done by NASA to create the system in which the Clickworkers contributed. The work required to prepare a project for PP may be large or small. It is going to be different for every project but as the above examples have demonstrated, it is

worth it. Because this foundation process happens outside the PP process there is a cost associated with it. This cost will be estimated in a manner similar to the manner in which the labor costs were estimated in the firm model. An assumption will be made that the founders of the PP project are of the same skill level as the Lead Software Engineer in the firm model hierarchy. As a result they will be assigned the same labor rate as the Lead Software Engineer. This rate will be paid during the performance of the foundation blocks and throughout the PP process. The last major characteristic of PP that must be accounted for in the model is the porous nature of the PP community. PP is neither a hierarchical process nor a contractual one. At any time contributors are free to enter and leave the community. Consequently, there is a periodic introduction of agents into the PP process like the periodic introduction of tasks. When a peer agent enters the community there is no way of knowing how long they will remain active and how many tasks they will accomplish during that time. To determine this, information that has been collected about contributions to OSSD projects has been used. Specifically, the work of contributors can be characterized into contribution deciles (Lerner & Tirole, 2002). On average in OSSD, the top decile of contributors account for 72% of all contributions; the bottom decile of contributors contributes less than 1%. The data reported by Lerner and Tirole (2002) was used to randomly assign each PP agent in the model a contribution decile and consequently a number of tasks that they will complete before departing the community. The assignment of number of tasks to be completed was independent of talent level. This is done to be consistent with actual PP processes. An average programmer has just as much likelihood of being a top contributor in volume of work as does an expert programmer. The only difference between them is in the difficulty of tasks they perform.

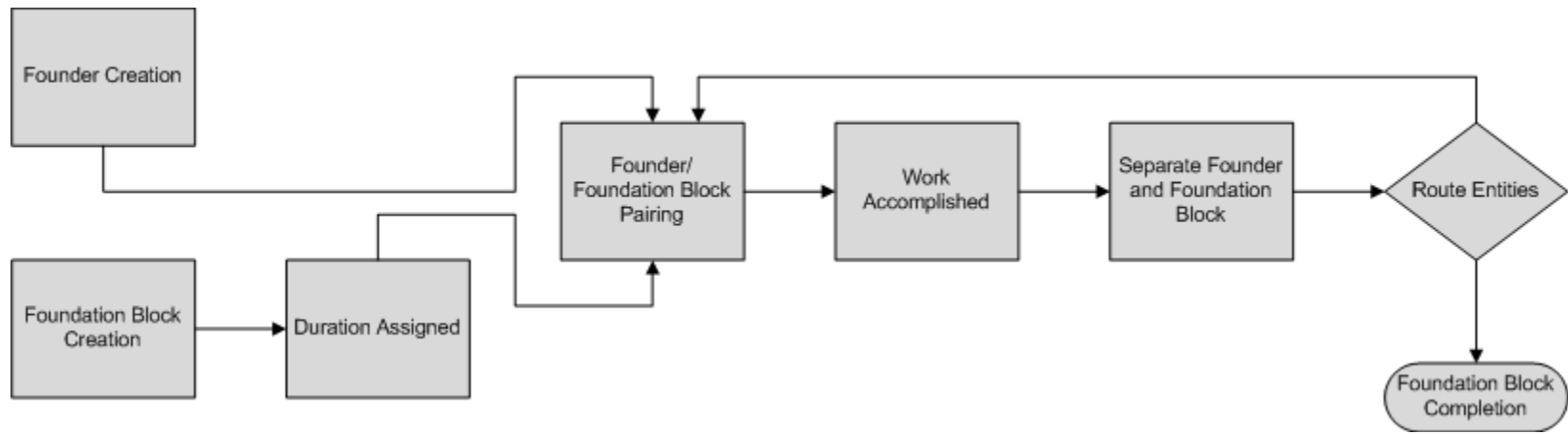


Figure 33. PP model overhead process flow

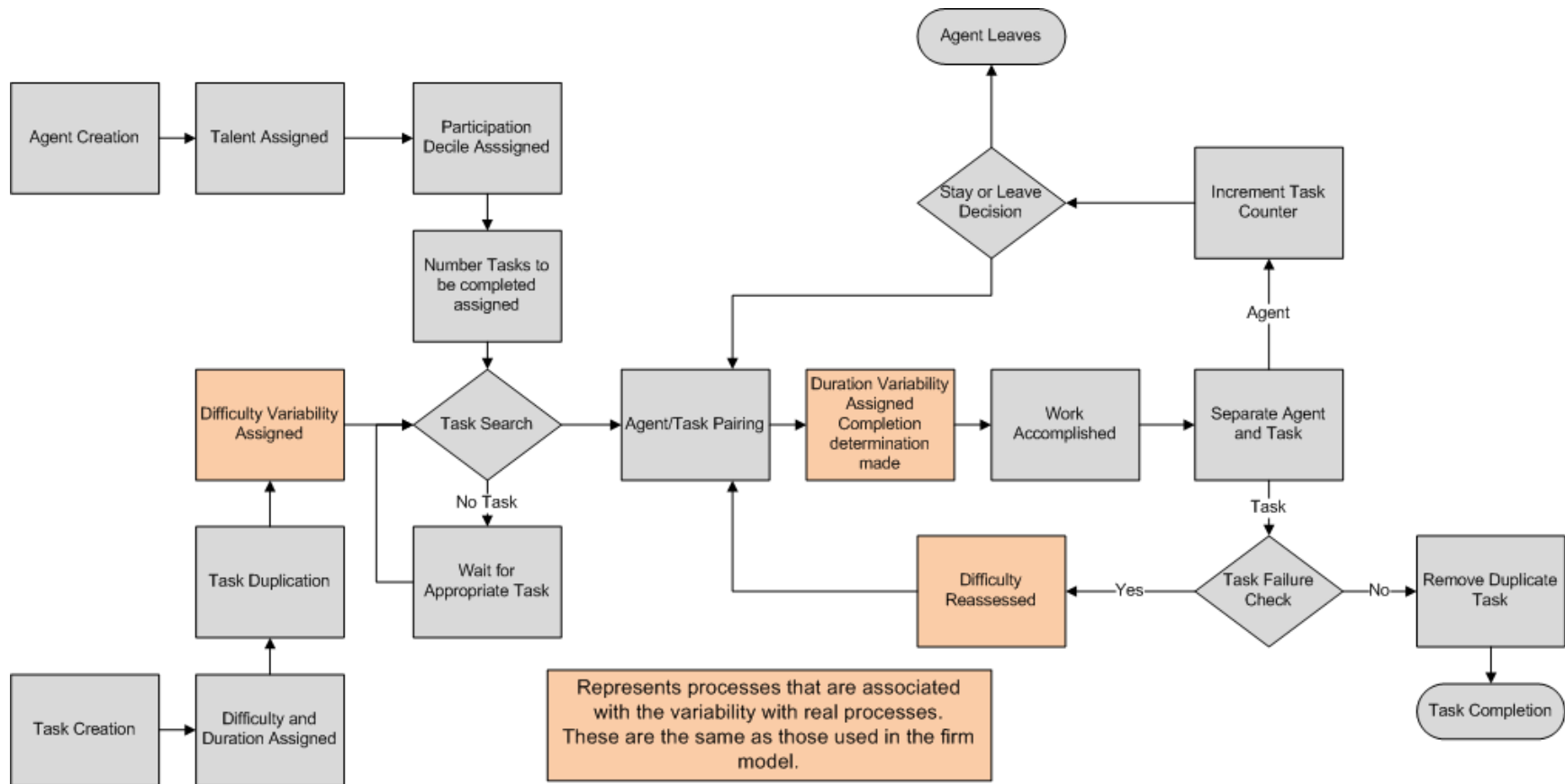


Figure 34. PP model simulation process flows

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Process Flow Point	Description
Founder creation	Entities are created to represent the individuals that will design and implement the PP system.
Foundation block creation	These entities represent the tasks that must be accomplished to field the PP system.
Duration assigned	The same duration distribution is used as in the firm models. Duration of tasks is randomly assigned between one and ten hours.
Founder/ Foundation block pairing	It is assumed that the founders are highly qualified and are capable of performing any task necessary to create the PP system according to specifications. Consequently no variability is used for the completion of the foundation blocks.
Work accomplished	The founder and foundation blocks are delayed until the required duration has passed.
Separate founder and foundation block	This process is a function of how ARENA works. Founder and foundation blocks are separated into two entities again.
Route entities	Founder is routed back to get another task. Foundation block leaves the system
Foundation block completion	Completed foundation blocks exit here. When the last foundation block exits a signal is sent to start the generation of agents and PP begins.

Table 6. PP simulation process flow explanation for overhead work to prepare a project for PP (See Figure 33)

Process Flow Point	Description
Agent creation	Entities are created to represent the PP contributors.
Talent Assigned	Talent is assigned randomly as the agent entity passes through. A value between 2 and 10 will be assigned based on a discrete PDF
Participation decile assigned	Agents are randomly assigned one of ten participation deciles. Their participation decile determines how long they will remain part of the community and how many tasks they will perform during that time. It is based on the results of the study by Lerner and Tirole.
Number of tasks to be completed assigned	The number of tasks to be completed is a function of the number of agents predicted to join the community and the percentage of work the agent's respective decile is predicted to accomplish. In the simulation the number of agents predicted is the number of agent entities that will be created. Number to be completed is equal to: $(\text{Total number of tasks} * \text{decile completion percentage}) / (\text{Total number of contributors})$

Process Flow Point	Description
	* 10%)
Task creation	Entities are created by ARENA to represent the tasks that are necessary to complete the project. The number of tasks created can be varied in the simulation to model different project sizes. It is not reasonable to increase this number indefinitely because this would be inconsistent with real life. It would cause the project simulation time to increase without bound and endless projects are just not feasible.
Difficulty and duration assigned	<p>Task difficulty and duration is assigned in one step. In a real PP process the initial difficulty will either be assessed by a founder, or another member of the community. In the simulation, the difficulty is randomly assigned based on a probability distribution. For comparison sake, the same distribution is used as the one in the firm model simulation.</p> <p>Duration is assigned randomly also in the same manner as in the firm model simulation. The minimum assigned is one hour and the maximum 10.</p>
Task duplication	<p>Task duplication is one of the unique characteristics of PP. In the firm model if a task was assigned to more than one agent it represented a waste of resources. This is not the case in PP. There is nothing preventing a PP agent from working on a task that is already being worked by another. Of course, choosing to do so potentially reduces the reward that the agent may receive but it does nothing to adversely affect the efficiency of the project as a whole.</p> <p>In the simulation, before the task and agent are paired together a duplicate is made of the task is made and sent back the waiting queue to be available for another agent to work on.</p>
Difficulty variability assigned	Same process as the firm model
Task search	Task search represents the self selection process of PP. In the firm model task pairing was done by the manager, In PP it is accomplished by each individual.
Wait for appropriate task	Because tasks are self-selected it is necessary to have a waiting area in the simulation for the agents to queue in while waiting for an appropriate task. In the firm model, if there is no difficulty level-8 tasks for the agent to work on then there will be assigned a 7 or 6 or 5 and so on. It is a loss of efficiency to have them idle when there is still work to be accomplished. In PP this is not a loss of efficiency. Because contributors perform tasks based on their value from the reward equation there is little value to be gained by an expert programmer working on a mundane task. Consequently if there are no tasks available of sufficient difficulty the agent will just wait until one becomes available.
Agent/Task pairing	Just a function of how the simulation works.
Duration variability and completion	<p>Same as the firm model. Restated below for completeness.</p> <p>In real life, actual task duration is a function of actual agent talent and actual task difficulty. In the simulation a weighting factor is used to adjust the task duration based</p>

Process Flow Point	Description
determination	on the different between actual talent and actual difficulty. If actual difficulty is 2 or more units greater than actual talent than the agent will work on the task for the weighted duration but fail to complete it.
Work accomplished	The work accomplished process in the simulation is just a delay mechanism that prevents the task and agent from proceeding until the assigned duration has passed. If the agent has sufficient talent to perform the task then is tagged as complete. If the task is too difficult for the agent assigned then it is tagged as a failure.
Separate agent and task	Agent and Task separation is just a function of the simulation. To permit work accomplishment that task and agent entities are actually combined into one entity. Once the work delay is satisfied the entities must be separated again to permit the task to be evaluated for completion and the agent to continue on.
Increment task counter	This process keeps track of how many tasks each agent has accomplished.
Stay or leave decision	The number on the agent's task counter is compared with the number of task to be completed by that agent. When they are equal the agent leaves the system.
Agent leaves	Statistics are collected and the entity leaves the system.
Task failure check	Task rework decision evaluates the task that just left work accomplishment. If it was tagged as complete then the task proceeds on to duplicate task removal. If the task was tagged as a failure then it proceeds on to difficulty reassessment.
Remove duplicate task	Duplicate task removal symbolizes the process of a contributor updating the community that a task is complete. On the community knows that it has been accomplished agent will cease to select it for accomplishment. In the simulation this is done by removing the duplicate task that was made from the waiting tasks queue.
Task completion	Statistics are taken on the completed and incomplete tasks and then they exit the system.
Difficulty reassessed	Difficulty reassessment permits the community to learn. Once a task is attempted it is much closer to being fully specified. If a contributor fails yes shares the problem with the community so a more accurate assessment of the difficulty involved can be made. In the simulation this means that difficulty is reassigned to equal the difficulty after variability was applied. This permits the task to be self-selected by a more talented contributor.

Table 7. PP simulation process flow explanation for the process of producing a product with PP (See Figure 34)

Variable	Distribution	Reason
Talent	Discrete PDF 5% T = 2 10% T = 3 25% T = 4 30% T = 5 20% T = 6 5% T = 7 2% T = 8 2% T = 9 1% T = 10	T = Talent level assigned Talent is assigned based a PDF that represents the probability that a person interested in this type of project will have a given talent for performing tasks to support it. The distribution is centered on the mid level talents. 40% of contributors will be assigned a talent less than or equal to four, 55% will be assigned a talent between five and seven, and 5% will be given talent greater than or equal to eight. This is consistent with the reward equation. It is the mid skill levels that have the most to benefit from contributing. They will typically be the ones whose profession is in the field for which they are participating, consequently they can experience the most gain from increased exposure to the field and their peers. Since they have the most to gain it makes sense that they would be in the majority.
Contribution decile	Constant Probability = 10%	Entities have a 10% chance of being assigned to each of the ten contribution deciles.
Number of task to be completed	Top decile 72% 2nd decile 9.0% 3rd 6.0% 4th 4.0% 5th 3.5% 6th 3.0% 7th 1.5% 8th 0.5% 9th 0.4% 10th 0.1%	Based on the research presented in <i>Some simple economics of Open Source</i> , Lerner and Tirole (2002).
Difficulty	Triangle Distribution D = Triangle(2,5,8)	D = Task difficulty assigned
Difficulty variability	Discrete PDF 5% AD = D - 2 10% AD = D - 1 25% AD = D 40% AD = D + 1 20% AD = D + 2	AD = Actual task difficulty after variability applied It seems to be a reasonable assumption that tasks are more often harder than they are easier. This is also consistent with the number of projects that take longer than scheduled.
Duration	Uniform probability between 1 and 10 hours to complete Dur = Uniform(1,10)	Dur = Task duration assigned

Variable	Distribution	Reason
Duration variability	Function of difference between AT and AD $AD \geq AT + 2,$ RD $= 1.3 * Dur$ and task will fail $AD \geq AT + 1,$ RD $= 1.3 * Dur$ $AD = AT,$ RD $= 1.1 * Dur$ $AD < AT,$ RD $= 1.0 * Dur$	RD = Realized duration after comparison made between AT and AD It is true that it is possible to complete a task in less time than expected but it is unrealistic to plan on this occurrence. There may be disagreement on the weighting factors used to adjust task duration but the same factors were used in both the firm and PP simulation models. Any error introduced by these factors will be consistent across both models.

Table 8. PP model variability distributions

3. Simulation Results

Two simulation runs were conducted. The first was to demonstrate the effects of incomplete specification of agent talent and task difficulty on the firm model of production. In this trial, the real and ideal Firm Models were compared. A second set of 1000 replications was conducted to compare the real Firm Model with the Peer Production Model. In this trial the incomplete specification of the tasks was the same for both models. The PP Model however does not succumb to incomplete talent specification due to agent self-selection. The results of both trials are below.

a. Firm Simulation Results

Simulation runs using six and twelve agents were conducted to see the effects of team size on project time and cost. Six and twelve agents were used, because they represent the opposite ends of what is typically viewed in industry as an effective team size. Less than six and managers are underutilized. Over twelve and performance suffers because managers are overburdened.

A 30% increase in time to complete all tasks was seen when variability was added to the firm model. This was consistent across both the six and twelve agent trials. See Figure 35. Variability in talent and difficulty also produced a rework rate of 5–8% and a failure rate of 1–3% for tasks. Rework occurred when a task "failed" the first time because task difficulty was greater than the agent talent. A task was deemed

"incomplete" after it was worked twice and still was not completed successfully. Failure rate is discussed in conjunction with the PP model results (Figure 37).

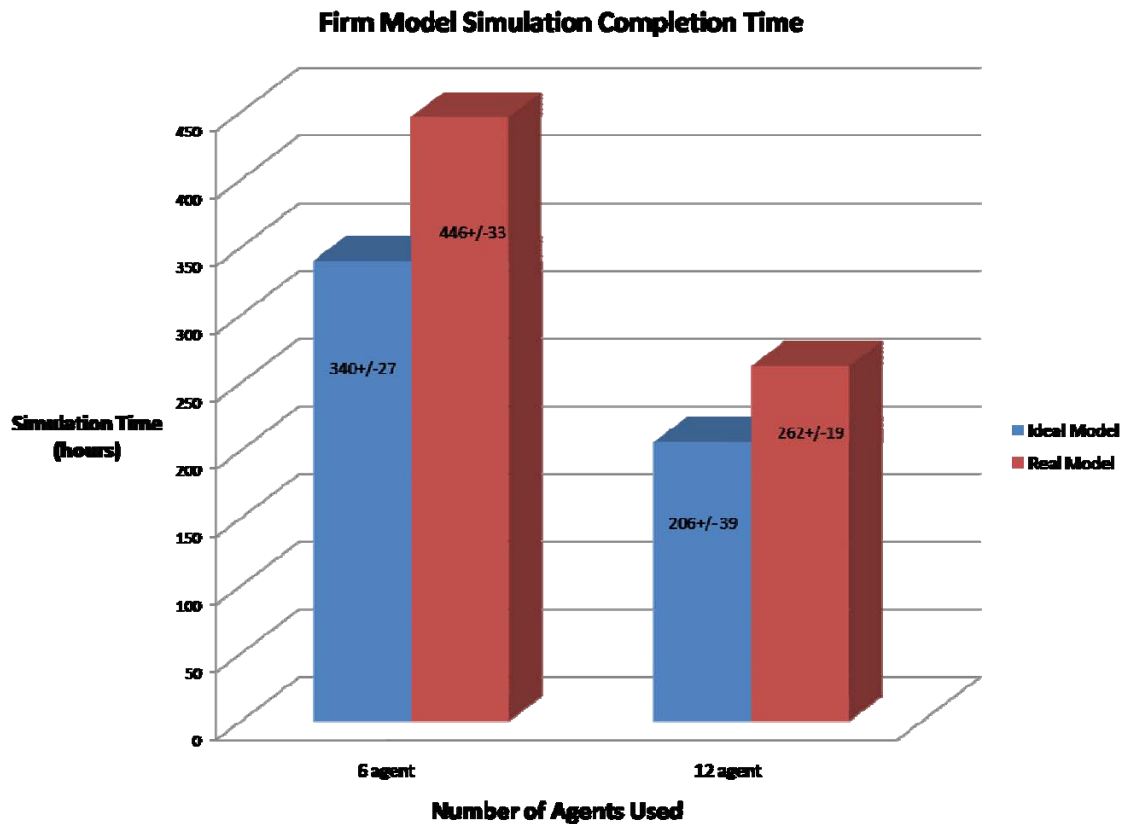


Figure 35. Firm Model Simulation Average Trial Completion Time

Simulation time represents continuous work time or the amount of productive work time necessary to complete the project. To relate simulation time to actual project duration, the simulation time was divided by some average number of effective hours per week. Thirty hours of a 40-hour workweek was used as productive time. The rest is “lost” time for meetings, breaks, email, etc. The project time in weeks (sim time/30) does not take into account long weekends, vacations, sick-time, employee turnover, and holidays. As a result, the actual project time will be even longer than simulated. To get the labor cost, the average weekly salary * number of agents * number of weeks was calculated.

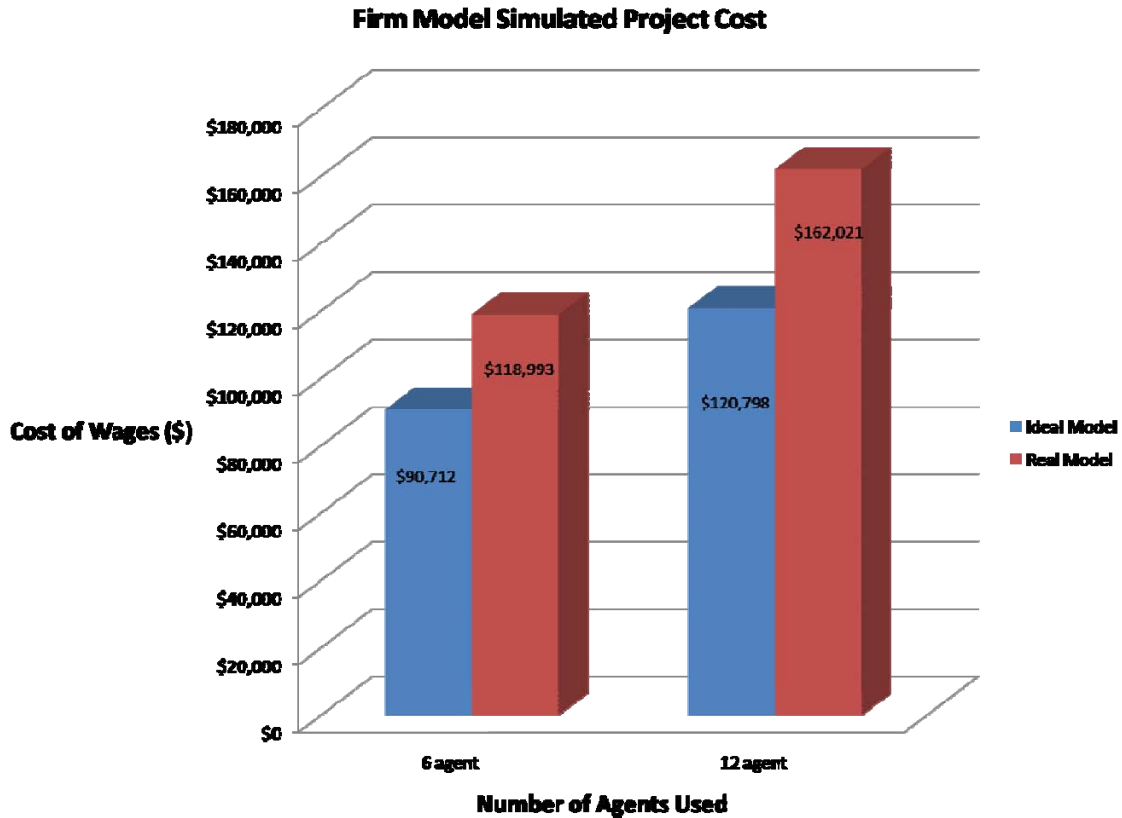


Figure 36. Firm Model Simulation Average Trial Completion Cost

To calculate project cost a notional salary was assigned to each agent based on talent level. For simplicity sake, a salary of \$10,000 per year was awarded for each talent point. Therefore, an agent with a talent of eight would earn \$80,000 and an intern with a three for talent would earn \$30,000. For the firm models, project cost was equal to:

$$\text{Average Talent} * \text{Number of Agents} * \$10,000 * (\text{sim tim}/30) * .02$$

The average talent in the simulation trials was 6.67 for the six-agent trial and 7.33 for the 12-agent trial. This average was a result of the random talent distribution used by ARENA. As seen in Figure 36, there was a 30% increase in project cost due to incomplete specification of agent talent and task difficulty.

b. PP Simulation Results

The PP model simulation provided more information about the PP process that initially expected. There was a need for 20–50 PP agents for every firm agent to complete all tasks of the project. This was a result of the porous nature of the PP community. None of the contributors entered that community at the start of the project, nor did they necessarily stay until the project was completed.

The time to complete the project did not seem to be a function of the number of agents but rather a function of the rate at which the agents joined the community. The Clickworkers project showed that the rate of joining was a function of publicity for the project and as a result could be influenced. This influence was beyond the scope of this research.

The other result of the PP simulation was that 1/3 to 1/2 of the contributors were left in the system when all of the tasks were completed. This meant they had not yet reached the limit of their contribution decile. In a real PP system this is the source of the increased rate of innovation. In actual PP projects, individuals will do one of two things when there is a shortage of tasks. They will either come up with their own task to do to make the project better or they will wait in standby until a new bug or idea arises. There is simply no way to accomplish this in the firm model. Firm agents are always busy just doing the required tasks.

c. Firm and PP Simulations Compared

Comparisons were made between the real firm model and the PP model in the following areas: average number of incomplete tasks per trial (Figure 37), task duplication factor (Figure 38), simulation time (Figure 39), and project cost (Figure 40). The results supported all claims about the benefits of PP.

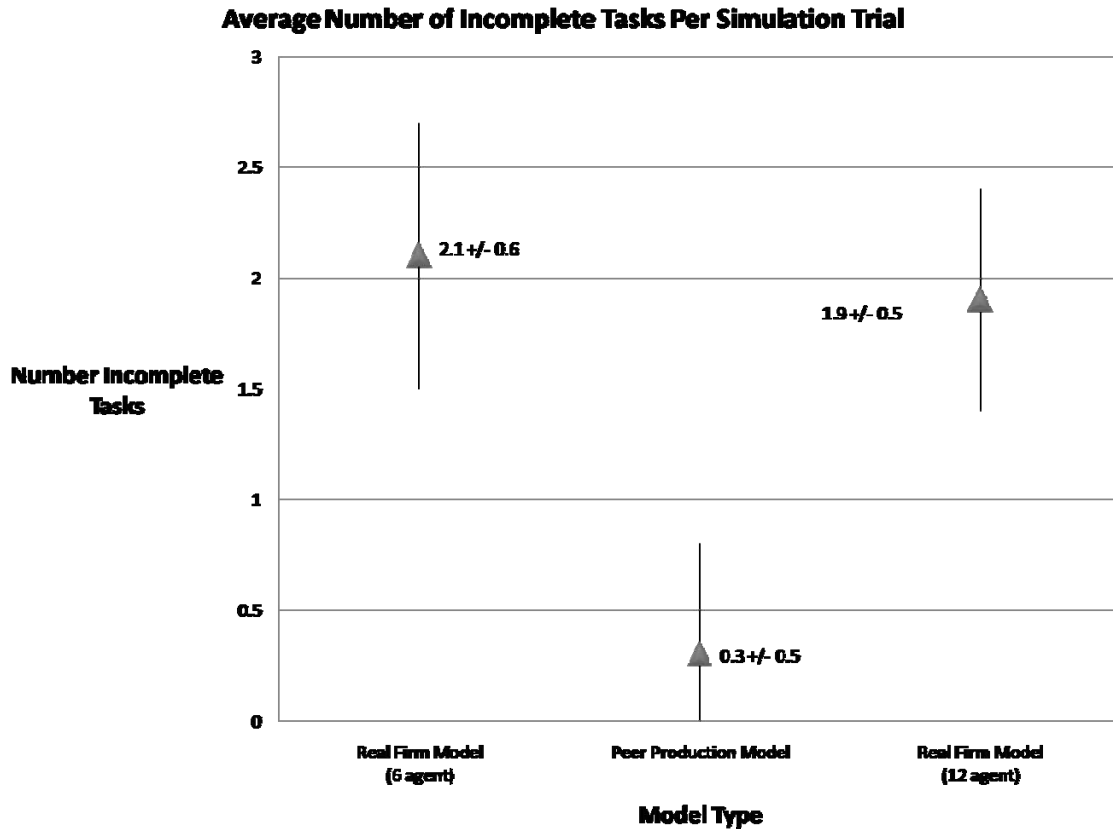


Figure 37. Average Number of Incomplete Tasks Per Simulation Trial (variance depicted is for 95% confidence interval)

Figure 37 provides the evidence for the claim that PP can increase the success probability of a project as a whole. This is done by significantly reducing the number of individual tasks that cannot be accomplished. The real world example that validates this claim is the InnoCentive model.

The underlying benefits to a reduced task failure rate are also significant. The evaluation criteria to characterize a task as "failed" after two unsuccessful completion attempts was incorporated into the PP simulation to provide a comparison point with the Firm model. In the PP model there was no need to designate a task as failed. Rather the task would just stay in the queue until it is completed successfully.

The 0.3 failed tasks per simulation trial could be eliminated completely because of two attributes of the PP process. First, there is no labor cost associated with repeating the task over and over again. Second, and more importantly, the labor pool is

under continuous renewal so there is always new talent that can try the task again. After enough attempts the task will either be completed or deemed "unsolvable" (which is different than "failed").

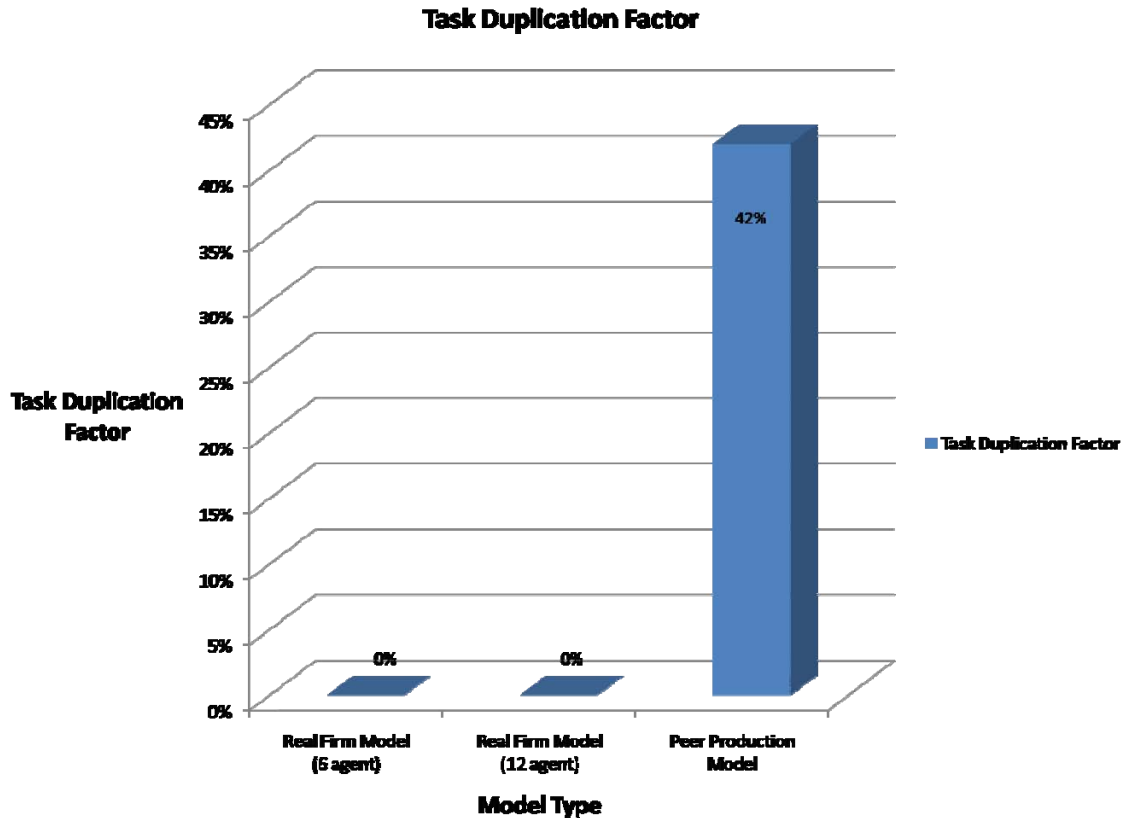


Figure 38. Task Duplication Factor Compared

A corollary to reduced task failure is seen in Figure 38. Task duplication is defined as completing a task multiple times regardless of successful completion. Task duplication is not automatically built into the Firm model as it is in the PP model. To get task duplication in the Firm model resources must be allocated to do the completion check. This does not always mean that the task is completed independently all over again although this is sometimes true. Other times task duplication may just be checking the work over and "signing it off". In either case, resources are expended and in the Firm model this means cost is added to the bottom line. As shown in Figure 38, no task duplication was built into the Firm model simulation and consequently none occurred.

No task duplication was built into the PP model either but, on average, 42% of the tasks in each simulation were completed successfully more than once. This is a natural duplication that results from a subtle difference between the Firm and PP processes. This subtle difference however leads to profound differences in the outcome of the models.

In the Firm model a task comes out of the "waiting to be done" queue when it is assigned to an agent to accomplish. This is consistent with how real firms operate (unless they are willing to pay for duplication factor). Typically, when a task is assigned to one person it is not assigned to another until the first proves incapable. In the PP process tasks are not removed from the "waiting to be done" queue until they are reported as completed. The 42% duplication factor is "natural" because it represents the percentage of tasks that were self-selected by multiple agents before the first successful accomplishment of that particular task was reported. Duplication factor can be increased to essentially any degree. One hundred percent duplication (i.e., every task completed twice) can easily be achieved by not removing the task from the queue until it is completed twice. Of course something greater than 100% duplication will actually be experienced because agents will continue to work on the task to completion even after the duplication factor quota is met. The Clickworkers experiment is an example of duplication factor in practice. The Clickworkers process achieved confidence in the PP result by never removing the task from the queue. As more and more agents identified a crater in a particular location during the Clickworkers experiment; the probability that there was a crater in that location increased. Eventually, the Clickworkers model produced results with equivalent certainty as if the work was performed by a trained expert.

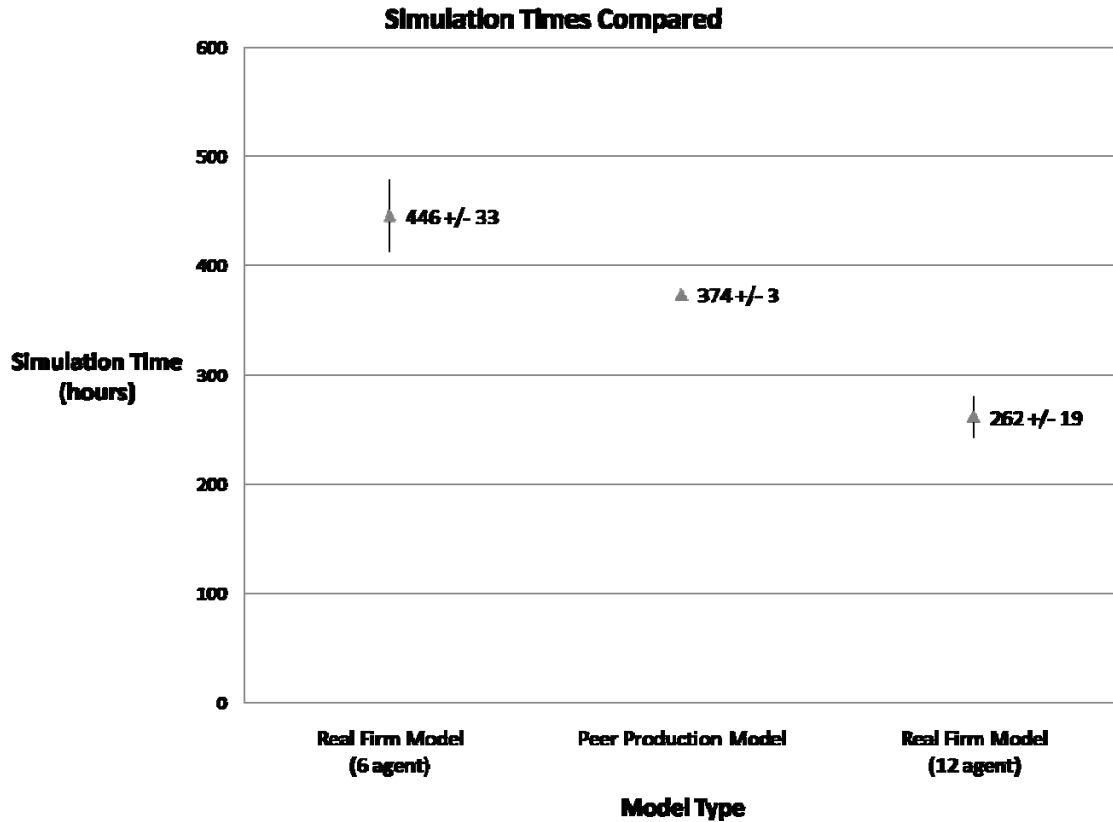


Figure 39. Average Trial Simulation Times Compared (variance depicted is for a 95% confidence interval)

It has been shown that the PP model provides both a higher probability of success and higher duplication factor than the firm model. Figure 39 shows that these benefits are obtained without increase in overall project completion time. Figure 39 is somewhat arbitrary however. As was previously stated, PP project completion is dependent more on the peer contributor introduction rate and appears to be independent of the particular project being completed. As a result, completion time is directly related to a successful publicity plan and a technically capable communication medium to compile contributions. Statistically these claims are supported by the relatively small dispersion seen around the PP simulation trial completion time. Over all the trials, the agent introduction function was unchanged. As a result the completion time was also unchanged.

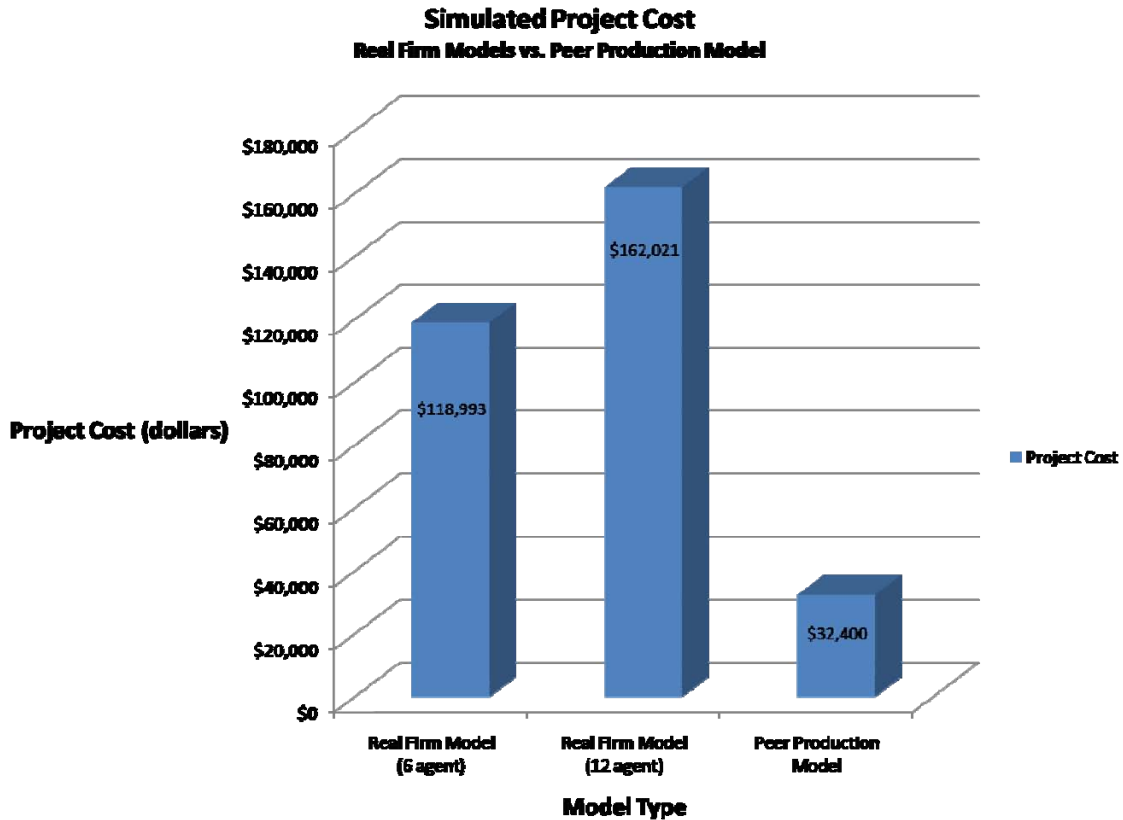


Figure 40. Real Firm Model Vs. PP Model Average Trial Simulated Cost

The last item to compare is simulated project cost. Figure 40 shows that the PP model is also highly cost effective. This should not be surprising. The Firm models had six and 12 individuals on the payroll for the duration of the project. The PP model had only two. The two individuals in the PP model simulation were assumed to be super experts and given a salary commiserate with a talent equal to ten (\$100,000/year). The highest paid agent in either Firm model earned \$80,000/yr, commensurate with a talent equal to eight. So, even with a significantly higher average salary the PP model still cost significantly less to complete the same work in the Firm model.

The process of simulating the PP process provides great insight into how the process works. In doing so it also provided objective evidence to correlate with the subjective evidence of real world examples. It has shown that the PP model, when applied to a properly structured project, has a higher probability of success, a higher duplication factor, a comparable project completion time, and a lower project cost.

Consequently, little valid argument can be made against making the necessary organizational changes necessary to adapt and apply the PP process when appropriate.

F. APPLYING THE PP MODEL

1. Three Classes of PP

The application of peer production is divided into four categories of which three are relevant to the DoD application of PP. The omitted class of PP is independent PP. It is the PP that involves a peer community that has no relationship with a traditional hierarchical organization. The differences between the remaining three categories revolve around the location of the peer contributors with respect to the firm boundary and the direction of flow of the project output.

a. Internal PP

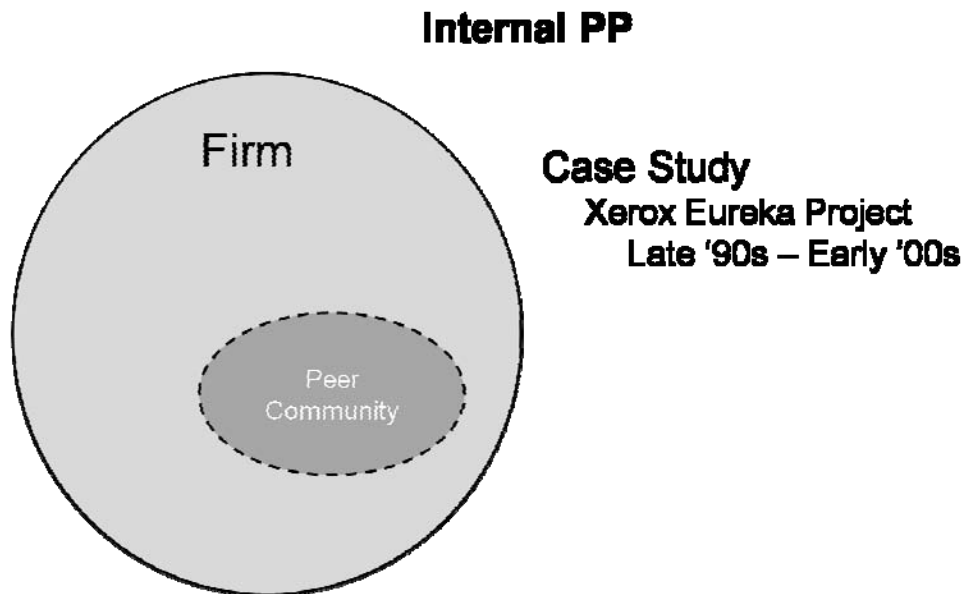


Figure 41. Internal PP

Internal PP, Figure 41, has the peer community inside the boundaries of the larger firm. Xerox's Eureka project is an example of this and is discussed in Appendix A. Many of the applications for the DoD fall into this class of PP, particularly those involving maintenance, logistics and supply, and fleet support. The biggest

challenge to implementing this class is permitting voluntary participation in the peer community. In order for PP to work the process cannot be mandated by the external firm hierarchy.

b. Outside-In PP

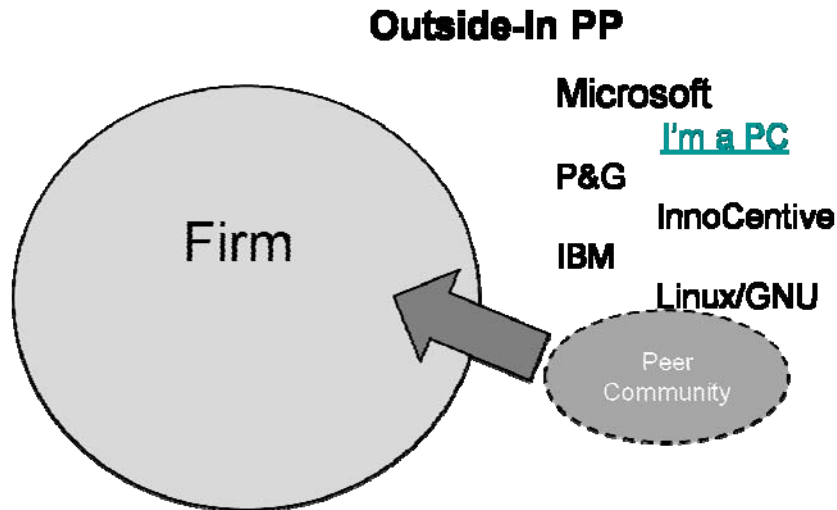


Figure 42. Outside-In PP

Outside-In PP, Figure 42, is the type of PP that is most visible in today's marketplace. Here the peer community is comprised of individuals that exist outside the firm boundary. Although the individual peers receive some reward for their contribution the specific output of the project is directed at benefiting the firm. Utilization of this class of PP will afford the DoD the greatest return on investment. It involves permitting individual to voluntarily perform tasks the DoD traditionally contracts.. The area to look for these types of applications is not in the core tasks of the military but in the fringe activities must be performed to sustain performance of the core tasks. These activities include things like family support, health care, and advertising.

c. *Inside-Out PP*

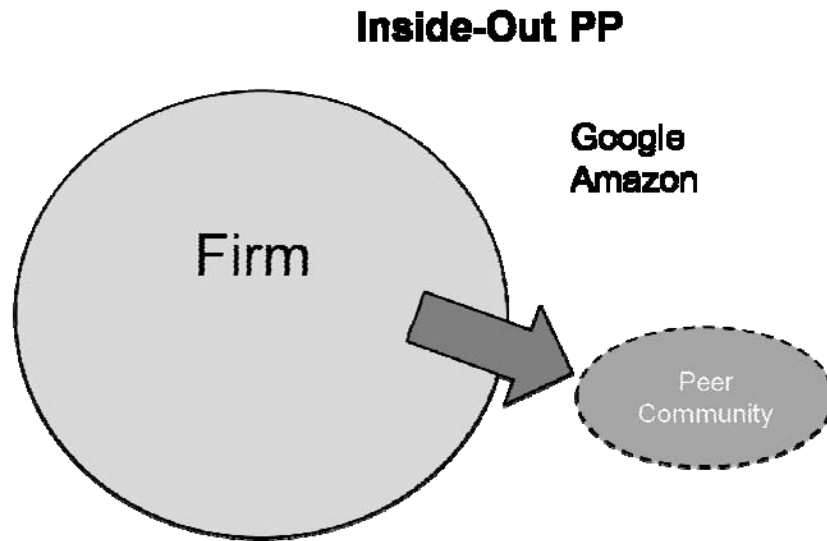


Figure 43. Inside-Out PP

Inside-Out PP, as seen in Figure 43, can be thought of as service oriented PP. Here the firm is compiling and integrating the contributions of a peer community and returns some product to that community from which they receive a benefit. The firm derives reward from this integration activity through some complementary process. Wikipedia and Google are the best examples of this class. Wikipedia takes explicit contributions from peers and returns a unified Web-based encyclopedia to them for their use. Google takes implicit contributions in the form of Web page links and compiles them into an effective Web search engine. If you consider national defense the service that is provided to the peer community, DoD sponsored PP could be broadly placed into this category, although the application of individual projects will look more like the other classes.

2. The Big Picture

The beauty of implementing PP within the DoD is that it does not require an explicit statement of a change in policy like was seen with the pursuit of network-centric warfare. What is necessary is an internal commitment to seek out the benefits of PP and apply it in a manner consistent with the principle of PP. After that, each individual

application of PP is a stand-alone system that is independent of other PP systems. This permits a very low risk, gradual application of PP techniques that begins with the obvious applications. It can proceed to other applications as more comfort and experience is gained with applying the methodology and after success has been demonstrated.

Over time, after repeated application of PP to the point where it is fully integrated into the manner in which the DoD operates, a sweeping organization change will occur. This can best be seen in Figure 44, where the individual peer networks represent specific independent applications of the PP methodology.

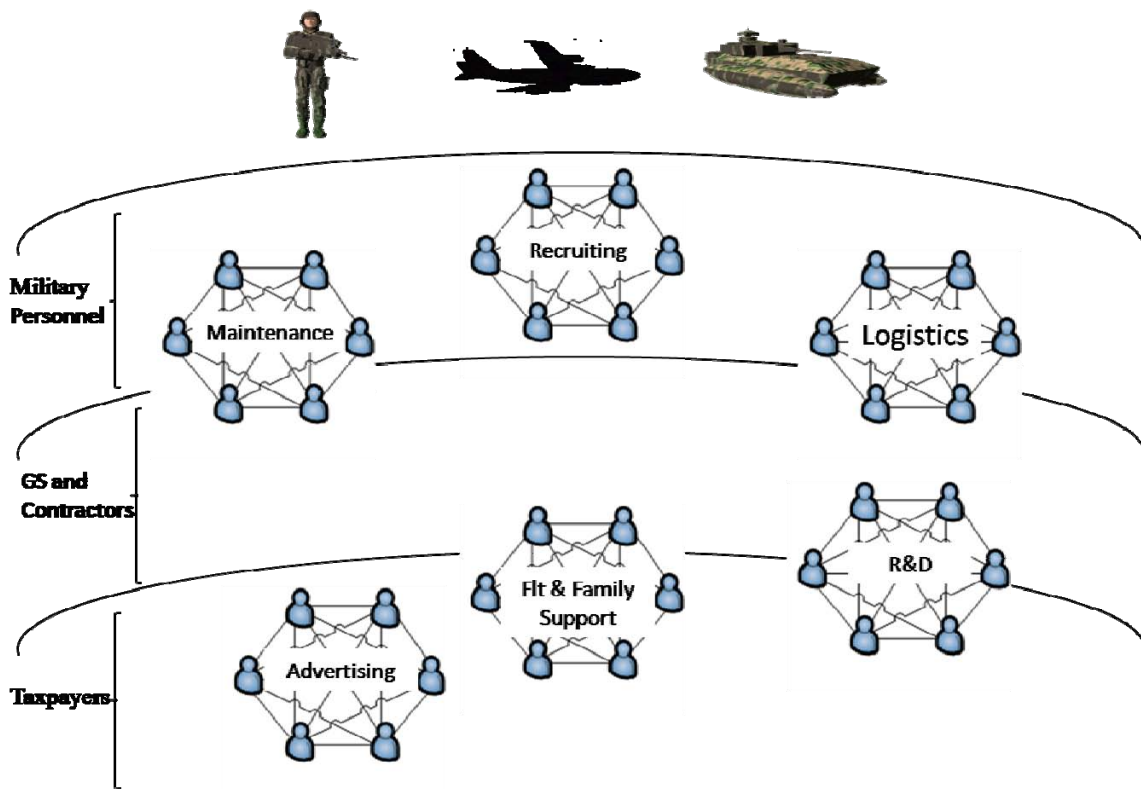


Figure 44. Cumulative picture of DoD PP

With fully integrated PP, the "tip of the spear" functions the same way, but the waves of support that are behind that warfighter is fully infiltrated with PP processes. The operational picture presented in Figure 44, can then be expanded to support concepts like the 1,000 Ship Navy and the Global Maritime Partnership. To meet this need simply add another wave of support behind the taxpayer and label it "international community".

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VIII. CONCLUSIONS

A. REVIEW AND SUMMARY

PP is an economic model of production where individual peer contributions are integrated into a unified intelligible whole. It functions within the networked information economy, and is fueled by the presence of a ubiquitous personal computing power. The emergence of this new economic model is consistent with the accepted principles of transaction cost economics. It takes advantage of greatly reduced transaction costs for the exchange of knowledge, information, and culture.

Peer contributions are regulated by the reward equation:

$R = M + H + SP$ where

R = individual agents reward for performing an action

M = Monetary compensation

H = Hedonistic rewards

SP = Social-psychological rewards

The driving force for these contributions is primarily based on the H and SP reward components. From these potential rewards, would-be contributors assess a value of participation and weigh it against the cost of contributing. The cost for most participation is typically a function of the time it takes. The ideal candidate has a surplus of time and consequently will have a V/C ratio significantly greater than one. As long as the V/C remains greater than one, participation is likely to occur.

In order to be eligible for PP, there are characteristics which a potential project must have. It must be modular. Modularity refers to the degree which a project can be divided into smaller independent tasks that can be distributed for completion. It must also have a granularity that is consistent with the characteristics of the peer community. Granularity refers to the size of the modules in terms of the effort required to complete them. In most cases a project should be comprised on non-uniform granularity. This will enable tasks to be accomplished by a broad base of peers with different individual characteristics.

Organizationally, PP requires a hands-off approach from the sponsoring organization. Peer contributions require self-selection. A contributor must be able to decide for themselves which tasks provide the best V/C ratio. This means that no hierarchical control can be exerted from outside or inside the peer community. This requirement presents a significant challenge to the traditional organization within the military-industrial complex.

It is self-selection that facilitates many of the gains experienced through PP. It allows many of the costs of personnel management to be eliminated and efficiency gains are experienced because of it. It also permits task duplication, which increases the probability of success for both the individual task and the project as a whole. Finally, self-selection enables a larger rate of innovation because advances can be developed and implemented as soon as they are identified. By modeling the PP process these potential benefits of PP have been notionally quantified.

Until this research, the work on PP has been to describe the economic model and why it is used. This work represents the first look at developing a systematic approach for applying PP routinely. To accomplish this task a functional decomposition of PP was presented. It was comprised of six top level functions which included: project preparation, PP system design, PP system implementation, community cultivation, rewards propagation, and results integration. Using that functional decomposition as a template, permit PP to be customized for a variety of applications within the DoD.

These applications fall into three broad categories of PP. They are internal, outside-in and inside-out PP. Internal applications will utilize a peer community that exists within the larger military hierarchy. Outside-In PP will use an external PP to produce results that both directly and indirectly help the warfighter. All DoD sponsored PP projects together can be broadly viewed as Inside-Out PP because the peer community is benefitting for the collective gains of PP applied within the military.

APPENDIX A: REAL WORLD EXAMPLES

The examples presented below step through the functional decomposition of implementing PP within the scope of real world applications.

A. NASA CLICKWORKERS

The NASA Clickworkers case is a good example of how it is necessary to understand the need to be met, and also that it sometimes requires some significant creativity to identify a PP opportunity. NASA's initial need analysis was to analyze the high resolution images of the surface of Mars. Responding to this need, NASA initially hired experts, namely geologists with advanced degrees, to review each image of Mars and characterize the topography. In practice this task amounted to simply identifying, classifying, and labeling craters. After this task was accomplish a few thousand times and it was discovered to be an extremely tedious and time consuming process a new need was formulated.

A faster way to characterize the Mars topography was needed. To meet this need, NASA researchers turned to a distributed network of human processing power to accomplish the massive data analysis task. The initial Clickworkers pilot sought to answer two questions: (1) Are people willing to volunteer their free time for routine scientific work? (2) Does an unspecified, anonymous public have the motivation and training to produce accurate results in a scientifically important task? (Kanefsky, Barlow, & Gulick, 2001) This process of need identification and research question specification is consistent with top-level function 1.0 - Prepare the PP project. Because it was not known if the public would be technically capable of producing the required quality the pilot program used previously cataloged data. Specifically, image maps containing 42,284 already classified craters were used. This inventory was an example of "a data product that is time-consuming to produce, difficult to automate, and scientifically important" (Kanefsky, Barlow, & Gulick, 2001).

Execution of peer produced topography classification began by establishing an interactive Website to host the Mars lunar images and collect individual classification contributions. A portion of the Website was devoted to training the analytical workforce. The training supplied directions for making two different types of contributions, crater identification and crater classification. To identify a crater, would be contributors were instructed to mark with a mouse click four points on a crater rim. After the fourth point was inputted a circle outlining the crater was drawn automatically. If the contributor agreed with the crater position then a "submit" button was pressed and the latitude, longitude, and diameter of the crater were recorded in the project database. A training program with seven known craters gave accuracy feedback, as each was identified and marked. If desired by the contributor, hints and/or a demonstration were available on where to find the next crater.

The second task of crater classification was presented as an additional task that required more judgment. To accomplish this task a contributor was presented an image with a single crater already identified and asked to fit the crater into one of three age classes. A description and example of each age class was supplied and an additional animation of crater erosion was available. The process of Website design, contributor training, database integration are all tasks that are part of top-level function 2.0, Design of the peer production system. The key to the system success however is what happens to the individual contribution. Through automated database manipulations, individual contributions are combined into a weighted average for actual crater location. It was these weighted averages that were compared to the predetermined crater locations. This automated integration function is the key to this successful PP application. This is ultimately what permitted crater identification to be accomplished rigorously and quicker in a distributed fashion than in the more traditional expert conducted analysis.

The design of this PP system highlights the requirement for the requested tasks to be both granular and modular. Clickworkers met both requirements in the simplest manner. Both the tasks of identification and classification of craters are of the finest granularity. This granularity allows an individual contributor with a lot or a little bit of spare time to contribute. Modularity is achieved by offering two types of tasks to the

contributor. One task is simple and the other requires slightly more effort and thought. This modularity promotes continued contributions from the peers by providing a varied experience.

The effectiveness of the Clickworkers experiment in accomplishing the desired task is best evaluated by considering the quantity and quality of the results. After the initial wave of targeted publicity for the project, 800 contributors participated over the first four days and marked over 30,000 craters. Within the first three weeks 90,000 craters were identified. The classification task returned 8,000 entries in four days and 21,000 within three weeks. Both results were achieved faster than a single graduate student could have accomplished. It is also worth noting that one time visitors to the site accomplished 37% of the work (Kanefsky, Barlow & Gulick, 2001). In terms of quality, a systematic comparison of thousands of Clickworker identified craters shown the peer produced results to be within a few pixels of the accepted catalog positions. The differences that did result between Clickworker and accepted positions were consistent in size to errors seen by comparing craters evaluated by Barlow on independent occasions.

The Clickworkers experiment represents the simplest of PP systems. This example also demonstrates the effectiveness of PP for certain tasks while highlighting some of the necessary design features of a successful PP system.

B. INNOCENTIVE

InnoCentive, a Web-based company, that matches problems with would-be solvers in an example of a successful reward system employed inside a PP construct. InnoCentive provides a forum for "seekers" to post problems to which they need solutions. The Website, www.InnoCentive.com, categorizes the problems into disciplines and enables solvers to search for a problem to which they may know the answer. In return for a viable solution the solver receives professional recognition and financial awards.

Seekers are typically corporations with an R & D need that they either cannot or choose not to solve using "in-house" resources. In return for the solution the companies offer a pre-determined monetary reward for an acceptable solution. The seeking

company determines both the amount of reward and definition of an acceptable solution. InnoCentive handles the solicitation and collection of potential solutions. One of the largest corporate users of InnoCentive is Proctor and Gamble. Once the problem, associated reward and required deadline are posted on InnoCentive potential solvers compete for the reward. The InnoCentive process exemplifies two of the most essential characteristics of a PP system perfectly. They are self-selection and anonymity.

Self-selection is the most important characteristic from the perspective of the peer contributor; self-selection is what permits a contributor to maximize their return on investment. Anonymity is what results when control is relinquished by the firm. Anonymity requires the firm to focus on the task and not the performer of the task. This is what Proctor and Gamble has successfully done through their use of InnoCentive. As a result P & G obtains more than 50% of its new product ideas from outside the firm boundaries.

C. XEROX EUREKA

Eureka is a system designed, developed, and deployed by the Xerox Corporation in the early 1990's to support the Customer Service Engineers (CSEs) who repaired the copiers and printers at customer locations. The need for this system arose from a shortfall in the technically skilled workforce. Xerox was forced to hire less skilled, less experienced workers. Because the new employees were less technically competent upon hire Xerox moved away from documentation and training that described the principles of product operation. This type of documentation required technicians to diagnose and repair the equipment on their own. Instead directive repair and adjustment procedures in the form of decision trees were substituted. The CSEs quickly discovered that the documentation was never complete enough to encompass even a majority of the problems encountered in the field. As a result, repair time and cost went up drastically and customer satisfaction plummeted. A better way of supporting the CSE had to be found.

By observing how the CSEs actually performed their jobs, researchers Daniel Bobrow and Jack Whalen from the Xerox Palo Alto Research Center found that it was local communities of repair technicians that facilitated the repairs in the field. Because

the corporately supplied documentation was incomplete and the technical background of many CSEs was insufficient, repairs were often accomplished through trial and error. (This is what drove average repair time and cost up.) Once a solution was found to a "never before seen" problem the solutions were shared informally among local communities of CSEs. Some groups even formalized the process by creating and sharing cheat sheets. After witnessing this, Bobrow and Whalen set out to create a system that would allow these communities to share their solutions across the entire enterprise. The system that resulted was called Eureka.

As developers worked with CSEs to create Eureka four questions were posed that get at the heart of the development of a PP system. They were:

- If a CSE submitted a tip, would it disappear into a black hole?
- Would the CSE get credit?
- How would they know they could trust all the tips?
- How would they get the right tips at the right time?

The first question pertains directly to the development of the peer community and an individual's V/C ratio. Submitting a tip to the system is only worth a person's time (Cost) if he can see the results (Value). Question 2 relates directly to the Reward Equation. Hedonistic (H) and Social-Psychological (SP) rewards are only possible when contributions are documented with who contributed them. It is important to note the CSEs that tested the pilot program communicated that there should be no monetary reward for contributing tips to the database. Monetary rewards would put the focus on the number of tips produced and not the quality and would also create unnecessary competition that would be counter to the goals of the community.

Questions 3 and 4 above relate to the design and implementation of a PP system. Validation of peer contributions needs to be accomplished in any PP system. In the case of the Eureka project, a "validator" known for expertise on the particular product line certifies each tip before it is released to the wider peer community. Getting the right tips at the right time is a usability issue. It does no good to save 20 minutes on a repair if it takes 30 minutes to find the shortcut. With Eureka this was taken into account by addressing both a hardware and software issue. A multi-input search function was used

to get the CSE to the correct information quickly and the program was loaded onto communication equipment that the CSE already carried thereby eliminating the need for new gear and training. The design features were vital to the success of the project and they highlight the necessity to make the peer community the central focus of system design and implementation.

The pilot program was run across Xerox's French market. The tip database started with support for three products. By the end of the first year the database had grown to more than 40 products. Also by the end of the first year, more than one tip was being added each day, more than 20% of the CSEs had submitted a tip and CSEs were consulting the tip database an average of two or more times a week. In that same year the French service metrics went from below average when compared to the rest of Europe to a benchmark performer. Metrics were soon better than the European average by 5–20%, depending on the product.

The results experienced through Eureka far exceeded anyone's expectations at Xerox. Customer satisfaction rose and repair cost dropped because of it. Secondary effects seen were increased employee job satisfaction and retention. These were also unexpected. Today, the Eureka story is an excellent example of Internal PP and the power of PP in general.

APPENDIX B: COMPLETE PEER PRODUCTION SYSTEM FUNCTIONAL DECOMPOSITION

1. Prepare the project
 - 1.1. Conduct need analysis
 - 1.1.1. Determine the process to which improvement is sought
 - 1.1.1.1. Research current conditions
 - 1.1.1.2. Determine where improvements are necessary
 - 1.1.2. Specify Objectives
 - 1.1.2.1. Determine the beginning state
 - 1.1.2.2. Identify the desired end state
 - 1.1.2.3. Identify possible ripple effects from desired end state
 - 1.2. Determine if portion of need can be met through PP methodology
 - 1.2.1. Determine if community of peers is possible
 - 1.2.1.1. Consider anyone who is capable of performing tasks
 - 1.2.1.2. Determine if community already exists
 - 1.2.1.3. Consider availability of individuals with skills required
 - 1.2.1.4. Determine V/C ration of potential peer producers
 - 1.2.1.5. Evaluate reward characteristics for performing required tasks
 - 1.2.2. Determine granularity of project tasks
 - 1.2.2.1. Determine if project requirements can be redefined to increase granularity
 - 1.2.2.2. Group tasks into up to three granularity groups
 - 1.2.2.3. Subdivide granularity groups into talent requirements
 - 1.2.3. Determine modularity of project tasks
 - 1.2.3.1. Determine if project requirements can be adjusted to increase modularity
 - 1.2.3.2. Determine if project has uniform or disparate modularity size
 - 1.2.3.3. Determine the fidelity to which the module requirements are known

- 1.2.3.4. Determine if peer innovation is acceptable
- 1.2.3.5. Determine number of initial modules
- 1.2.3.6. Determine number of total modules to complete system
- 1.2.4. Determine integration methodology
 - 1.2.4.1. Determine degree of task duplication necessary to provide necessary confidence
 - 1.2.4.2. Automate integration if possible
 - 1.2.4.3. Estimate integration complexity
 - 1.2.4.4. Determine manning requirements for non-automated integration
 - 1.2.4.5. Determine if project is discrete or continuous
- 1.2.5. Model project
 - 1.2.5.1. Evaluate community size required
 - 1.2.5.2. Estimate project duration
 - 1.2.5.3. Estimate cost
- 1.3. Outline the application of PP to problem
 - 1.3.1. State reason for applying PP
 - 1.3.2. Define operational model
 - 1.3.3. Define business model
 - 1.3.4. Identify possible ripple effects from applying PP in this manner
 - 1.3.4.1. Identify good effects
 - 1.3.4.1.1. Potential future applications of same system
 - 1.3.4.1.2. Secondary effects of system
 - 1.3.4.2. Identify potential negative effects
 - 1.3.4.2.1. Security risks
 - 1.3.4.2.2. Legal issues
 - 1.3.4.2.3. Negative publicity
 - 1.3.4.2.4. Malevolent agents
- 2. Design the peer system
 - 2.1. Determine Requirements of PP system
 - 2.1.1. Functional

- 2.1.1.1. Suitability
 - 2.1.2. Customer
 - 2.1.2.1. Training
 - 2.1.2.2. Format
 - 2.1.2.3. Cost
 - 2.1.3. Performance
 - 2.1.3.1. Availability
 - 2.1.3.2. Reliability
 - 2.1.4. Design
 - 2.1.4.1. Technology compatibility
 - 2.1.4.2. Security
 - 2.1.4.3. Authentication
- 2.2. Determine necessary technologies to meet requirements
 - 2.2.1. Consider what is necessary for peer community to be successful
 - 2.2.1.1. Identify peer needs to perform tasks
 - 2.2.1.2. Identify peer needs to experience rewards
 - 2.2.1.3. Identify peer needs to promote active community
 - 2.2.2. Determine what information format is necessary for project success
 - 2.2.3. Determine suspected communication volume
 - 2.2.4. Determine required community size
- 2.3. Determine course of action
 - 2.3.1. Identify work packages
 - 2.3.2. Determine schedule
 - 2.3.3. Determine budget
- 2.4. Identify Stakeholders
 - 2.4.1. Contributors
 - 2.4.2. Funding sources
 - 2.4.3. Users
 - 2.4.4. Suppliers
 - 2.4.5. Builders

- 2.4.6. Benefactors
- 2.4.7. Reporting seniors
- 2.4.8. Concerned parties
- 2.4.9. Inspectors
- 2.5. Estimate needed resources
 - 2.5.1. Estimate personnel requirements both in quantity and specialty
 - 2.5.1.1. Engineering
 - 2.5.1.2. Administration
 - 2.5.1.3. Computer
 - 2.5.1.4. Human Resources
 - 2.5.1.5. Financial
 - 2.5.2. Estimate funds to field the PP system
 - 2.5.2.1. Equipment funds
 - 2.5.2.2. Travel funds
 - 2.5.2.3. Training funds
 - 2.5.3. List equipment necessary to field PP system
 - 2.5.3.1. System equipment
 - 2.5.3.2. Testing equipment
 - 2.5.3.3. Training equipment
 - 2.5.3.4. Repair equipment
 - 2.5.4. Determine project process flow
 - 2.5.4.1. Work Flow
 - 2.5.4.2. Communication Flow
 - 2.5.4.3. Compensation Flow
 - 2.5.4.4. Information Flow
 - 2.5.5. Conduct risk mitigation
 - 2.5.5.1. Define "risks"
 - 2.5.5.1.1. Technical risks
 - 2.5.5.1.2. Schedule risks
 - 2.5.5.1.3. Cost risks

- 2.5.5.2. Implement identification techniques
 - 2.5.5.2.1. Establish Risk Management Board
 - 2.5.5.2.2. Utilize lessons learned from previous projects
 - 2.5.5.2.3. Identify shortfalls between needs and resources
 - 2.5.5.2.4. Peer review of project plans
- 2.5.5.3. Document all risks captured during identification
- 2.5.5.4. Assess risks
 - 2.5.5.4.1. Probability of occurrence
 - 2.5.5.4.2. Consequences of occurrence
 - 2.5.5.4.3. Categorize assessments
- 2.5.5.5. Mitigate risks
 - 2.5.5.5.1. Develop contingency plans
 - 2.5.5.5.2. Monitor risks
 - 2.5.5.5.3. Implement contingency plans as necessary
 - 2.5.5.5.4. Monitor success of contingency plan
- 2.5.6. Identify external information needed
 - 2.5.6.1. Schedule information
 - 2.5.6.2. Data feeds
- 2.5.7. Identify external support needed
 - 2.5.7.1. Personnel
 - 2.5.7.2. Access
 - 2.5.7.3. Equipment
- 2.6. Design communication flow
 - 2.6.1. Design communication system from founders to peer community
 - 2.6.1.1. Provide mass distributions capability
 - 2.6.1.2. Provide subgroup distribution capability
 - 2.6.1.3. Permit individual communication
 - 2.6.2. Design communication system between peers
 - 2.6.2.1. Provide social network tools
 - 2.6.2.2. Provide asynchronous collaboration tools

- 2.6.2.3. Provide synchronous collaboration tools
 - 2.6.3. Design communication system from peers to founders
 - 2.6.4. Design communications from peer community to public
 - 2.6.5. Design communications from founders to public
 - 2.6.6. Design communications from public to founders
- 2.7. Design integration subsystem
 - 2.7.1. Track changes to project
 - 2.7.2. Track contributors
 - 2.7.3. Collect contributions
 - 2.7.4. Combine contributions into intelligible whole
 - 2.7.5. Validate contributions
- 2.8. Test system
 - 2.8.1. Define test objectives
 - 2.8.2. Develop test
 - 2.8.2.1. Measures of effectiveness
 - 2.8.2.2. Measures of performance
 - 2.8.3. Plan test
 - 2.8.3.1. Data collection plan
 - 2.8.3.2. Data analysis plan
 - 2.8.3.3. Reports plan
 - 2.8.4. Execute test
 - 2.8.4.1. Safety
 - 2.8.4.2. Variability from design
 - 2.8.4.3. Collect data
 - 2.8.5. Analyze test results
 - 2.8.6. Report results
- 3. Implement PP system
 - 3.1. Field system
 - 3.1.1. Determine implementation schedule
 - 3.1.1.1. Coverage area sequencing

- 3.1.1.2. Maximize initial effectiveness
 - 3.1.1.3. Minimize operational disruptions
 - 3.1.2. Install first increment
 - 3.1.2.1. Conduct training
 - 3.1.2.2. Answer questions
 - 3.1.2.3. Fix bugs
 - 3.1.2.4. Gather data
 - 3.1.2.5. Compile lessons learned
 - 3.1.2.6. Report performance
 - 3.1.2.7. Repeat as necessary
 - 3.1.3. Monitor performance continuously
 - 3.1.4. Expand capability as necessary
- 4. Cultivate the community
 - 4.1. Publicize the project
 - 4.1.1. Use immediately available spheres of influence
 - 4.1.2. Account for network externalities to spread project awareness
 - 4.1.3. Prevent over publicizing to point of overloading system.
 - 4.1.4. Track interest
 - 4.1.5. Broaden publicity if necessary
 - 4.2. Explain objectives, operating practices and procedures
 - 4.2.1. Define processes
 - 4.2.2. Define interactions between processes
 - 4.3. Establish benefits of contributing
 - 4.3.1. Individual benefits
 - 4.3.1.1. Learning
 - 4.3.1.2. Immediate monetary compensation
 - 4.3.1.3. Future employment
 - 4.3.1.4. Increased skills
 - 4.3.1.5. Documents performance
 - 4.3.1.6. Social rewards

- 4.3.1.7. Psychological rewards
 - 4.3.1.8. Hedonistic rewards
 - 4.3.2. Peer community benefits
 - 4.3.2.1. Learning
 - 4.3.2.2. Social
 - 4.3.2.3. Stimulate other businesses
 - 4.3.3. Project sponsor benefits
 - 4.3.3.1. Cost savings
 - 4.3.3.2. Increased efficiency
 - 4.3.3.3. Better product
 - 4.3.3.4. More satisfied employees
 - 4.3.3.5. Lower personnel turnover
- 4.4. Synchronize with project implementation
 - 4.4.1. Project needs are consistent with anticipated community size
 - 4.4.2. Target community is consistent with project requirements
 - 4.4.3. Implementation promotes peer participation
 - 4.4.4. Implementation devalues hierarchical processes
- 5. Propagate rewards
 - 5.1. Track contributions
 - 5.1.1. Who
 - 5.1.2. When
 - 5.1.3. Significance
 - 5.1.4. Effectiveness
 - 5.1.5. Creativity
 - 5.2. Publicize contributions
 - 5.2.1. Within community
 - 5.2.2. To public
 - 5.2.3. To sponsors
 - 5.3. Facilitate job placement
 - 5.3.1. In future projects

- 5.3.2. Maintaining current project
- 5.3.3. Recommendations for future employment
- 5.3.4. Referral to hiring employers
- 5.4. Distribute monetary rewards
 - 5.4.1. Payment
 - 5.4.2. Reimbursement
 - 5.4.3. Credit
 - 5.4.4. Right-off
- 6. Integrate the results
 - 6.1. Validate each contribution
 - 6.1.1. Check for correctness
 - 6.1.1.1. Average out incorrect responses
 - 6.1.1.2. Manual expert check
 - 6.1.1.3. Test
 - 6.1.1.4. Peer review
 - 6.1.2. Check for appropriateness
 - 6.1.2.1. Solves a relevant problem
 - 6.1.2.2. Suggests a new innovation
 - 6.1.2.3. Addresses stated needs
 - 6.1.2.4. Addresses implied needs
 - 6.2. Incorporate contribution into whole
 - 6.2.1. Automatically through algorithm application
 - 6.2.2. Manually
 - 6.3. Distribute new whole to stakeholders as appropriate
 - 6.3.1. Make new version available
 - 6.3.2. Notify of its existence
 - 6.3.3. Publicize benefits
 - 6.3.4. Train on changes
 - 6.4. Distribute new whole to community as appropriate
 - 6.4.1. Make new version available

6.4.2. Notify of its existence

6.4.3. Publicize changes

6.4.4. State new problems

6.4.5. Highlight contributors

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