Enabling Information Technology for the Emancipation of Physical and Natural Capital

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Abstract. The paper proposes decision support information technology that directly and indirectly sustains the natural environment thereby advancing a key dimension of sustainable development. Recognizing that physical or man-made capital in industrial societies is drawn from and depletes natural capital stocks, Free/Open Source Software (F/OSS) is proposed that allows for reconceptualizing and sharing physical capital to increase its efficient and productive use within communities. The technology envisioned would provide for an overall reduction in natural capital inputs to the development of physical capital through a psychological shift on the part of users. This builds on periodic historic shifts in identities between living and non-living objects, and viewing physical capital as having its own intrinsic worth and dignity akin to citizens (analogous to the extension of moral rights in deep ecology to include non-human sentient beings and other non-sentient natural objects). While the software under development by the Regional Centre of Expertise on Education for Sustainable Development in Saskatchewan (www.saskrce.ca) is intended to advance new productive arrangements and possibilities through the extension of freedoms to tools, machines, vehicles, and buildings, possibilities exist for encoding a similar culture of freedom with respect to emancipating natural capital (e.g., seeds, forests, land and water resources). An extension of the concept of autonomy to both physical and natural capital is seen as enabling the creative self-expression of these systems expanding their production and productive possibilities while respecting and nurturing the underlying systems on which these depend. Developments in the technology to date will be highlighted including the technology's implementation strategy for the town of Craik, Saskatchewan, Canada, and other communities.

Key Words: sustainable development technology, Free/Open Source Software, autonomy, RCE Saskatchewan, sharing productive capital

1. Introduction

There is an urgent need to discover ways to sustain our natural environment including stocks of various forms of natural capital and key ecological structures and processes. As we approach, and now in many cases exceed, critical thresholds we prepare a poisoned bequest for future generations. If we are to avoid creating harmful situations that are both irreversible and potentially catastrophic, rapid changes in our human relationships with the natural world as expressed through our dominant market production system is required. In examining possible drivers for change,[1] the development of new technology holds most promise for strategic interventions at small scales that, if generally adapted and adopted, may turn the tide. This paper outlines a potentially disruptive technology of this sort using Free/Open Source Software (F/OSS) for the sharing of productive physical capital within communities. It builds on insights related to historic shifts in identities between living organisms (particularly humans) and inanimate objects (particularly machines). In so doing, it grounds technology

1 The Millennium Ecosystem Assessment identifies 6 drivers of change in relation to natural systems: others in addition to science and technology include demographic; economic; sociopolitical; cultural and religious; and physical, biological, and chemical drivers of change (Millennium Ecosystem Assessment, 2003, p. 91).

development in social processes of change taking place over historically lengthy time scales involving human re-conceptualization of each other and non-human objects. The proposed technology makes use of untapped capacities in our social institutions and relies on a critical insight reflected in these historic transformations, namely, that we are not the first human population to confront serious resource limits as a result of our dominant production systems. Indeed, in prognosticating our own demise as a species and claiming this to be unprecedented we thankfully display a kind of hubris. The technology being developed through the Regional Centre of Expertise on Education for Sustainable Development in Saskatchewan (RCE Saskatchewan) in the town of Craik, in the prairie region of Saskatchewan, Canada, provides the potential for a highly effective and efficient use of various forms of physical capital (including machines, vehicles, and buildings) where these are understood as autonomous citizens. The grounded methodology used for developing this software withing various types of communities beginning with Craik provides for a further efficiency in both the conceptualization, development, and deployment of the *Sharing Productive Capital* software technology. The potential to incorporate natural capital into this kind of software is briefly explored in the concluding remarks.

2. Physical Capital and the Depletion of Natural Capital

Attempts to reduce the stresses on the natural resources and habitats can be accomplished by developing alternative production systems that reduce the overall amounts of physical capital required. Physical capital can be understood to include various human made artifacts such as machines, buildings, and vehicles owned by enterprises in market systems along with those held by non-market firms. Because human-made physical capital is always derived from natural resources, an increase in stocks of physical capital (and the energy and other inputs needed to sustain these) lead to a depletion of various forms of natural capital (see Newton, 2003). This connection is viewed as sufficiently strong in a traditional development paradigms that advancing industrial development is seen to require a necessary trade-off with natural capital. However, attempts have been made to conceptually and technologically uncouple the idea of development expressed as economic growth and degradation of natural resources. Conceptually economic growth (understood as the monetary value of all final goods and services produced in a given economy over a specific time period) need not entail greater depletion of natural capital as this is an aggregate monetary measure (vs. a measure of actual physical resources consumed). Technologically, one can devise ways to produce the same quantity of physical goods with fewer resource inputs supposedly enabling economic growth without depletion of natural capital. In addition, economic growth also includes the sale of services and goods with high market values yet only a limited physical component (for example, software). The last two decades have also witnessed the rise of businesses employing forms of capital in their business models that rely on forms of capital other than traditional physical capital (see Table 1).

Table 1: Economic Enterprises Not Primarily Relying on Physical Capital	
Form of Capital	**Recent Business Models Exploiting Alternative Capital Form**
Natural capital	Intensive agricultural operations, biofuels, genetically modified organisms
Financial capital	Currency speculation, new financial products, alternative currencies (e.g. airline point systems)
Human capital	Service industry, skilled workers in knowledge-intensive industries
Social capital	Commercialization of intellectual property, businesses built on social networking

There are a number of reasons to doubt the claim that we have successfully uncoupled economic activity as expressed in economic growth measures from increases in physical capital production. In response to the idea that businesses are diversifying to other forms of capital, it could be argued that this need to diversify merely proves that the levels of natural resource depletion associated with growth in traditional industrial development is unsustainable and has reached tangible limits. Furthermore, the ongoing empirical depletion of both renewable and non-renewable resources is also indicative of our inability to uncouple economic growth from growth in inputs of natural capital. While some developed countries no longer have a significant industrial base, much of this can be attributed to outsourcing of industrial production to developed countries which, in turn, still leads to a global depletion of natural capital. In this case, global efficiencies related to cost are as likely to have been found in reduced labour and regulatory costs as opposed to efficiencies in physical capital design and use. Our economy also remains stubbornly wedded to forms of production that maximize physical capital and energy use relative to inputs of human capital. Michael Renner identifies five manufacturing industries noted for their high energy and physical capital use and relatively low labour inputs. These industry clusters include primary metals; paper; oil refining and coal products; chemicals; and stone, clay, & glass (Renner, 1991, p. 11). While these industries accounted for only a small proportion of the jobs created in the United States in the 1960's, 1970's, and 1980's, Renner notes they were the biggest polluters. The inability of our current economy to shift away from these forms of production despite impending shortages as evidenced with peak oil, suggest an underlying dependence on these industries tied to social structures. Within a market economy where investments in production are determined principally with a view to maximizing return for the investor, it is not a surprise that our market economy has self-selected for those industries that maximize returns on ownable physical capital assets as opposed to human capital. In the latter case, individuals in modern democratic societies own their own labour with slavery and other forms of servitude having been abolished. Under these conditions of self-ownership, greater returns for investors are available, all things being equal, to those industries maximizing physical capital use relative to human capital use (the latter form of capital being one that cannot legally be owned by another—only contracted). Payments to labour are a cost of doing business while owning a piece of equipment can be an ongoing source of revenue. This explains the historic preoccupation with labour efficiency as compared to a noticeable disregard for the efficiency of physical capital (see Renner, 1991). It also explains historic attempts to substitute machines for human labour, where profitable and practical, in industrial production.

The previous discussion points to a strategic point of intervention in seeking to address declining stocks of natural capital and other forms of environmental degradation. This intervention involves increasing the efficient and effective use of existing forms of physical capital and minimizing the need for new

forms of physical capital (and their corresponding natural capital inputs). Increases in physical capital would be limited to cases where there were substantial improvements to be had in human quality of life and well-being unavailable through other means. The structural ties of an investment-driven economy to accumulation of physical capital and a preference for physical capital intensive production places a further constraint on technological innovation. A technology aimed at reducing dependence on physical capital accumulation needs to be transformative or disruptive to the extent it seeks to challenge these preferences of the market system. First, such a technology should not be ownable and, hence, controllable by dominant market players, save where this ownership seeks to advance the technology's accessibility and rapidity of diffusion and prevents dominant market players from intervening to prevent its uptake. Second, the rapid advancement of such a technology is further made possible where the technology is both non-rival (i.e., one's use of the technology does not prevent another from simultaneously using it) and non-excludable (i.e., one is unable to prevent its use by others save with great difficulty). The first concern points to licensing the technology with a Free/Open Source License in relation to the underlying intellectual property associated with the technology. Such a license with copyleft or share-and-share alike provisions (such as the General Public License (GPL)) is likely most resilient in such a context (see Free Software Federation, 2007). Secondly, the technological use of software employing such a license meets the conditions for both a non-rival and non-excludable good.

3. Disruptive Technology Built on Shifting Identities: Physical Capital and Citizenship

How might one develop Free Software that allows for the every increasing efficient and effective use of physical capital? One approach relies on identifying underlying capacities within the existing social and production systems that might enable movement to a new production system. Here the very social institutions and productive processes that shape existing identities and social relationships can be applied creatively to advance a new production system. Not only might a new production system mitigate the deficiencies of the earlier system, it can also allow for new productive possibilities as previously underutilized resources are used more effectively and new resources emerge that could not be used (or perhaps event conceptualized) under the previous system. Analogous to Christopher Columbus's key discovery of trade winds that would enable his voyaging to and from the New World, here we can build on the critical insight of shifting identities between animate or living organisms (especially human beings) and inanimate or non-living objects (especially tools or machines) between major shifts in production (see Table 2). For example, during feudal society, people's primary identity was associated with their specialization (whether in a particular craft, trade, or profession; see Zacour, 1976). A person might have been known as a barrel maker, a fletcher, a miller, etc. At the same time, with the dominance of state institutions during feudal society and the application of formal legal rules enabling markets, the idea of a full private property ownership allowing for alienability and transmissibility of property in physical objects emerges (see Becker, 1980, pp. 207-209). With the move to industrialization and modern democratic societies we observe an interesting shift. In this case the identity associated with a specialized craftsperson of feudal society gets applied to physical tools and we have the emergence of the specialized machines. These machines now are seen to do the specialized work and with human labour organized around their production. This specialized equipment is called capital. At the same time, ownership is applied to humans and how they understand themselves. Human beings become owners of themselves. The concept of self-ownership is in turn instrumental to the formation of the identity of citizenship and the ability for individuals to freely contract their own labour in a market economy. Under our current system in crisis we again see our social system embracing a shift in identities from machines to human beings and other living organisms. Over the last two decades through the concept of sustainable development, the idea of *capital* is now being applied to human beings and natural objects (what is termed *human capital* and

natural capital). This shift has been sufficiently pronounced that we now must specify traditional industrial capital as either *physical* or *financial* capital. Yet if we can meaningfully apply the concept of capital to living things, this suggest an underutilized capacity latent within our social setting, namely, the ability to apply our current understanding of human beings as *free citizens* owning their own labour to physical capital. Drawing on this latent capacity within our current social setting, the proposed transformative technology involves the development of Free/Open Source Software that enables the treatment of physical capital as *citizens*, and provides for the emancipation of such capital.

Table 2: Historic Shifts in Identity with Changing Production Systems

Production System	Identity of Living Organisms (Especially Human Beings)	Identity of Non-Living Objects (Especially Tools/Machines)
Feudal Society with State/Tributary Production System	Specialized Craftspeople/Tradespeople/ Professions	Private Property/Ownership
Democratic State with Market/Industrial Production System	Self-Ownership	Specialized Machines Engaged in Work
	Citizenship (and Free Labourer)	Capital
Global Community with a Sustainable Production System	Human Capital and Natural Capital (= Sustainable Dev't)	Emancipated Capital/Capital as Citizen (Capital as Free Labourer)
	Sustainable Livelihood	

In understanding what it might mean to treat physical capital with the identity of citizen (and its correlate, a free labourer), a useful approach is to identify ethical principles that underly the concept of citizenship. One can subsequently reflect on what these principles might mean for physical capital. In general, the proposed ethical shift involves viewing physical capital as having a kind of intrinsic moral worth and dignity akin to that of citizens. The extension of ethical worth to physical capital in this way is analogous to the extension of moral rights to non-human sentient beings and other non-sentient natural objects found in deep ecology. A key ethical principle underlying the concept of citizenship is *autonomy*. In this case one would be interested in providing physical equipment with those conditions that allow for its "self-govenment" or "self-rule". Philosophically the concept of autonomy has been broken down to include various components needed for its development and exercise. At one level, these include respect for basic negative liberties—the classical freedoms from restraint. These include, for example, freedom from interference by others that undermine one's basic security, restrict one's mobility, or restrict one's freedom to associate with others. On the other hand, an absence of interference is not sufficient for autonomy. One also needs to have meaningful choices from which to

choose, choices that fulfill one's desires. Here one is concerned with the range of one's choices, their quality and quantity (see Cohen, 1995, p. 236). One also needs the capacity to evaluate these choices and the desires that inform these choices. Finally one needs the capacity to form and act on higher-order life plans such that a person "chose[s] to be in the condition she is in or to lead the life that she leads" (Christman 1994, p. 176). All of these conditions for the *exercise of autonomy* require that further preconditions are met for the development of autonomy, such as satisfying one's essential needs, having a breadth of experience, and having an education that develops one's abilities at critical reflection.

Attempts to treat physical capital (whether machines, buildings, or vehicles) as autonomous agents impacts traditional understandings related to their ownership. To the extent one continues legally to own a piece of equipment one does so, in this case, as a steward or guardian on the object's behalf as opposed to being a master over a slave. As a guardian, one seeks to enable the equipment to have a long and "productive" life, fulfilling what it "wants to do" when optimally informed. In this case, to the extent machines are designed with purposes in mind (for example, a saw is designed to cut), one can readily ascribe purposes to the object despite its lack of rationality (or even sentience). In addition, new purposes can be discovered by those using the equipment. Historically legal ownership was used to prevent others from using one's property. With physical capital understood as autonomous citizens, this traditional form of ownership is viewed as a restraint violating the object's negative liberties. Where non-owners propose to put the equipment to good use, particularly where it is underutilized or improperly used by a current owner, respect for the autonomy of the object legitimizes such an alternative use. As such, software enabling physical capital to be treated akin to a citizens is one that enables *a kind of sharing*. The determination of who ought to be able to use the equipment occurs on the basis of conditions other than ownership, namely what promotes the autonomy of the object. At the same time, a requirement for a kind of sharing differs from a traditional understanding of sharing. Those making use of a shared piece of equipment are not able to do anything they would want with the equipment. Activities by owners and non-owners alike are ruled out that undermine the dignity of the physical object, that degrade it, that harm its autonomy. Free Software is thus proposed that enables the sharing of physical capital within a community in a way that respects its autonomy. The following table (Table 3) highlights possible functional features of such software in relation to the elements of autonomy previously discussed.

Table 3: Software Functionality Promoting Autonomous Physical Capital	
Component of Autonomy	**Sample Software Functionality**
1. Freedom from interference	Enabling the cataloging and lending of a machine to optimize its use by all in a community (vs. just owners) in association with other free machines
2. Range of choice (quantity and quality of choices)	Capacity for users to identify and tag existing range of uses for equipment in a given setting
3. Awareness of and capacity to judge range and quality of choices	Capacity for software to promote possible uses and assist in determining best usage where multiple conflicting demands
4. Capacity to judge one's own desires informing what is viewed as a choice	Capacity to evaluate existing purposes of equipment and experiment to identify new, alternative purposes to which it might be put
5. Capacity to form and act on higher-order life plans	Capacity for dedicated equipment time to higher-order community or inter-community projects (e.g., building a community recreation centre, other uses linked to sustainable development)
6. Fulfillment of preconditions needed for the exercise of autonomy outlined in #1-#5	Monitoring and providing the supply of energy needed for the equipment; trackinging its location and proper storage; cataloging existing replacement parts or suppliers to maintain "health" of object

4. Proposed Technology's Efficiency and Effectiveness in Sustaining Natural Capital

The Free/Open Source Software under development that enables physical capital to treated as autonomous within communities is entitled "Sharing Productive Capital" software. This software allows for both an *effective* means for sustaining natural capital as well as an *efficient* means. In terms of effectiveness, with this software a variety of new forms of production that advance human well-being can take place that are not otherwise possible where machines and other forms of physical capital are treated as not having autonomy. For example, ownable physical capital is restricted to market applications under our current system. Once machines are treated as autonomous citizens, they are able to freely choose other productive activities in which they might engage. Importantly, they are able to participate in voluntary modes of production associated with the non-profit or voluntary sector. This is analogous to the ability of non-profit organizations to mobilize citizens as volunteers, freely donating their time towards worthwhile causes. With Sharing Productive Capital software, the voluntary sector now has a means of using productive physical capital without having to find funds to purchase equipment. Such a shift in increasingly important as finances of non-profit agencies becomes increasingly constrained. In addition to the voluntary sector, physical capital can also participate in other production systems, such as engaging in research or discovery on the basis of "curiosity", engaging in gift economies or barter economies, or offering direct service to governments. In addition, to the extent physical capital acquires the status of self-ownership, it can now act as a kind of labourer, earning "wages" not for its owner, but rather to enhance the physical capital's own productive capacity and that of its community. These earnings can also be used to pay taxes (or tribute) to the state

alongside what is expected of traditional human citizens and their governments. The ability of physical capital to now actively participate in non-market systems of production provides new opportunities for meeting human needs and those of our supporting ecosystems that previously were not possible.

In addition to physical capital's new ability to participate in a diversity of production systems, the emancipation of physical capital also allows for a re-balancing of market economies. As previously mentioned, our current market system seeks to maximize the use of ownable physical capital relative to labour inputs. Where physical capital is shared to advance useful ends (whether market or non-market activities), there is no longer an interest in private companies accumulating physical capital that is likely to be shared freely. Where businesses do invest in traditional physical capital that is otherwise being shared, they incur a cost of doing business that is not borne by their competitors. This makes any resulting good or service that much more expensive, all other things being equal, and, hence, that much less price competitive. For example, one can imagine a traditional restaurant owning ovens and various other kitchen equipment having to compete with an individual using autonomous solar ovens and cooking equipment shared in a common community repository, The former will need to charge that much more for its restaurant items to pay for its equipment costs. Businesses would also need to be wary of building up physical capital where communities shift (or are likely to shift) to providing goods and services in a voluntary way, eliminating the traditional market for the good entirely. Parallels could be drawn between information and communication technology companies relying on a software product (and ownership of the underlying intellectual property) finding this software increasingly worth less (or possibly worthless) where Free/Open Source software emerges fulfilling the same market niche. As autonomous physical capital is also able to “learn” from its uses in non-market settings, there is also a greater likelihood over time that products it produces in a market setting will have features that are distinctive and valued relative to goods generated by traditional market production.

Sharing Productive Capital is effective at advancing human well-being and reducing impacts on natural capital in several further ways. Sharing Productive Capital no longer provides economic advantage to owners relative to non-owners. This will cause an economy to minimize physical capital use which, on its own, should reduce the draw-down of natural capital stocks traditionally converted into physical capital. It also allows for new types of resource inputs to be used. Instead of needing to rely on increasingly scarce oil, coal, glass, metals, and wood that our economy has self-selected based on the minimal inputs of human labour required relative to physical capital, one can begin to use other resource inputs that require slightly more human labour relative to physical capital. These can include shifting to more accessible renewable resources (as opposed to a reliance on the previous list of principally non-renewable resources that are typically inaccessible without extensive infrastructure and energy). New kinds of production can also take place where one seeks to maximize participation. With software aimed at sharing productive capital, it is in each person's interests to share the costs associated with the manufacture and/or purchase of equipment, its upkeep, and disposal or reuse. An interest in increasing participation, however, alters dynamics around specialization in a market economy. In this case, the specialized production and skills associated with our current system focused on high technology (presumably as a way of differentiating companies from competitors through production of specialized products in specialized markets) gives way to what to date has been the elusive grail of intermediate or appropriate technology. In the case of shared physical capital, one has incentive to maximize the participation of human beings which influences one's technology choices. Appropriate technology encourages participation to the extent the degree of technical literacy or know-how required is bridgeable from a low level of technical competence to an intermediate competence (versus working with high technology that is designed to require many years of specialized or professional instruction). Effectiveness at preserving and enhancing natural capital is further enhanced as a community seeks to make use of natural resources with which people are familiar and are locally

available, accessible, and abundant. In this sense, a local ecosystem is also viewed as a potential participant seeking to share in the construction, upkeep, and disposal/reuse of the physical capital, again minimizing costs. As such, under a shared productive capital model one will likely see a shift to local production systems that are adapted to the productive capacities of local ecosystems.

A shift to autonomous and shared productive capital also advances the efficient use of this capital and, indirectly, the natural capital from which it is derived. At one level, one can expect that where physical capital is treated as a citizen under conditions of self-ownership, one has the same interest in its productive efficiency as that traditionally associated with labour efficiency or labour productivity. In our current market system there is a disincentive for owners of physical capital to innovate too quickly in relation to their physical capital to the extent this might undermine the value of the asset on the books before the end of its useful life. By innovating too quickly, one could make one's physical capital obsolete before it had been fully depreciated, thus incurring a loss in profitability. Where the productive capital one is using is not on one's own balance sheet, one no longer has a disincentive to rapidly innovate. Furthermore, a community will seek to manufacture equipment that has a multiplicity of functions (versus a single specialized use in relation to a given market niche) precisely to take account of this potential for a machine needing to flexible and able to "switch jobs" as needed from time to time. In fact one would expect a machine to diversify its productive possibilities given this likely need to switch functionalities over the course of its lifetime.

Further efficiency also occurs to the extent equipment no longer sits idle. Currently this occurs where an owner of equipment is unable to find a profitable return in relation to his or her area of business. In this case, a concern for the equipment's autonomy and well-being leads one to seek other ways in which the equipment might be active, either by working with another business or taking part in non-market production systems (e.g., volunteering within the community in a variety of ways when not working for an enterprise).

5. Sharing Productive Capital Software Development

Software that enables people to treat physical capital with autonomous agency is being developed under the "Sharing Productive Capital" project in Saskatchewan, Canada. This project has been led by the authors of this paper, Dr. Roger Petry and Dr. Daryl Hepting along with Glenn Hymers of the Craik Sustainable Living Project (CSLP) and student research support from Arlin Daniel and Warren Butt at the University of Regina. The project has been financially supported by the President's Research Fund of Luther College at the University of Regina and the Regional Centre of Expertise on Education for Sustainable Development in Saskatchewan (RCE Saskatchewan; see www.saskrce.ca). RCE Saskatchewan is mandated to promote education for sustainable development in the prairie region of Saskatchewan, Canada, as part of a network of 62 RCEs globally acknowledged by the United Nations University in support of the U.N. Decade of Education for Sustainable Development (DESD 2005-2014).

The project initially examined philosophical theories related to human autonomy and the ethical treatment of objects, more specifically machines. In addition, an inventory was made of possible Free/Open Source technologies that might be adapted to be used for sharing productive capital. Some of the more promising software takes advantage of the shift to viewing physical capital as free agents capable of volunteering. In this case, F/OSS used to mobilize volunteers, such as Drupal and CivicSpace, have promise. The town of Craik in Saskatchewan, Canada, is a leader in innovation related to sustainable development and is at the geographic centre of RCE Saskatchewan (see

http://www.craikecovillage.ca/). As such, it was a natural choice for developing and piloting this software. Because it is a small town, it, by definition, lacks a significant amount of industrial production. Productive capital that does exist exists at a relatively small scale. This ensures that sharing of productive capital will, of necessity, begin at a small enough scale to enable the software developed to be scalable to various levels of community. At the same time, the community is able to innovate quickly with considerable local control, relatively fewer regulatory hurdles (typically associated with larger urban centres), and little economic dependence on existing industry that might discourage introduction of a disruptive technology. In terms of community competitiveness, the introduction of this technology can potentially be viewed as allowing a relative competitive advantage to a small town by negating the value of ownership of large amounts of physical capital associated with well-developed industrial centres in large urban areas. With this software, single industry towns are envisioned as transforming themselves into "many-industry" towns as their productive capacity is liberated. A second stage of the project will seek to implement the technology in communities and organizations in larger urban centres in the province of Saskatchewan along with other RCEs globally (potentially to date including RCEs in the United Kingdom, Sweden, the Netherlands, and Nigeria).

An approach grounded in the community of implementation has been used in developing the software. An initial meeting was held in Craik, Saskatchewan, in April 2009 in order to discern interest in the project. More specifically, the community was asked how this kind of software might be used in the community. This included identifying the kinds of equipment that the community might seek to share (see Table 4).

Table 4: Proposed Physical Capital to be Shared in Craik, Saskatchewan, Canada

Type of Physical Capital to Be Shared	*Examples of Machinery/Equipment to be Shared*
Equipment for building ecologically friendly houses in the Craik Eco-village	Specific tools used in straw bale construction for people building their own homes
Town greenhouse	Gardening tools; assigned spaces for growing plants
Specialized equipment requiring supervision or a specific skillset of the user	Power saws, masonry tools, large BBQs for town events
Conference presentation equipment	Computer projector, screen, and notebook computer
Outdoor education equipment	Materials used by 4H Club to educate about sustainable development

A scenario approach in relation to each of the 5 types of equipment identified is being developed. From each scenario it is expected important software functionalities needed for the software's development in that context will emerge. In addition, in order to ensure the software designed is fitted to the communities needs (and to thereby help facilitate its take-up), the software is designed building on existing practices of sharing within this rural community. The grounded theoretical approach taken seeks to develop software that enhances and enables existing social practices of sharing rather than seeking to alter existing practices to conform to the software designed. It is recognized that the kind of software needed in a small, rural community where there is a greater degree of trust and knowledge of others will differ from what is needed in larger centres with greater anonymity. This type of grounded, scenario-based approach to software design built on existing F/OSS is thought to also lead to a more efficient development model and more rapid use of the technology.

6. Conclusion

This paper has highlighted the strategic role for a specific kind of Free/Open Source Software that enables a paradigm shift in the way physical capital (e.g. machines, buildings, and vehicles) is understood and treated. By treating physical capital as autonomous citizens, one is able to enhance the efficiency and effectiveness of its use, thereby reducing natural capital inputs to the production process. The technology being developed builds on historic shifts in identities between human beings (and living organisms) and physical, non-living artifacts that takes place with large scale shifts in the dominant modes of production (e.g., from tributary systems under monarchies to industrial production under markets). Some may be skeptical that the development of software enabling the treatment of physical capital as autonomous citizens would be an important means by which natural capital stocks and ecological systems might be preserved. Others may seek this as an overly circuitous route in achieving environmental ends. However, since the rise of industrial production, the role of the ownership of the means of production in shaping political, economic, and ecological circumstances has not gone unnoticed by political philosophers and theorists. What is perhaps surprising is the turn recommended, namely that physical capital, something already so highly valued in a market economy by investors, should be placed on an even higher pedestal, namely, accorded with the principles of self-ownership and the ethical status of a citizen (particularly when so many human beings on our planet do not yet have the status of citizen or are losing this status). This paper, has attempted to show, however, that this counterintuitive move could play a significant role in altering current practices of physical capital accumulation and energy use. Oddly, if one views Free Software itself as having the dignity accorded to the autonomous citizen, one perhaps can see Free Software deployed in this way as "liberating" other forms of capital. The "Sharing Productive Capital" software project does not advocate the shift of software from a non-rival and non-excludable good into a form of intellectual property that is rival and excludable, as has occurred with proprietary software. In this case one instead makes the radical shift of taking physical capital (which by its nature is rival and excludable) and transforming it into a kind of capital that is non-rival and non-excludable.

As this software is developed, it may also be possible to include various forms of natural capital (e.g., land, water, forests, etc.) within its parameters. Such a move would codify the intrinsic value of these natural objects alongside the machines included within the software's repository of productive capital. Emancipation of natural capital might be able to occur in this way in line with those seeking to expand our ethical treatment to non-human plants and animals and environmental systems. Importantly, an extension of the concept of autonomy to both physical and natural capital is a precondition for the creative self-expression of these systems thereby expanding their current production and productive possibilities while respecting and nurturing the underlying systems on which these depend. Enabling the creative self-expression of these systems through Free Software could be instrumental in ushering in new sustainable production systems characterized by resilience and abundance.

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