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From a linear-chain model to a network model for sustainable innovation

Construction of a sustainable innovation combining eco-design and functional economy

Justine Bisiaux, Thierry Gidel, Frédéric Huet

COSTECH laboratory

University of Technology of Compiègne

Compiègne, France

{justine.bisiaux, thierry.gidel, frederic.huet}@utc.fr

Dominique Millet

LISMMA Laboratory

SUPMECA

Toulon, France

dominique.millet@supmeca.fr

***Abstract*— Tensions between economy and environmental issues due to hyper and mass production leads to reflection about a new model of innovation. To shift from intensive innovation to sustainable innovation, we propose an approach which involves the design of a sustainable product's diffusion system. Our hypothesis is that both the product and the business model should be redesigned in tandem, combining eco-design and functional economy from an interactionist point of view. We argue that the business model should be based on a network model, instead of linear chain. The research focuses on evolving products systems or upgradable products, including services offered iteratively throughout a product's multiple life cycles. Field studies will be conducted to verify the viability of the project among consumers and manufacturers.**

***Index Terms*—Innovation, Eco-Design, Functional Economy, Business Model, Value chain, Interaction, Network, Upgrade.**

I. From intensive innovation to sustainable innovation

Economic dynamic is currently anchored in permanent innovation logic, characterized by frequent replacement and purchase of products. Innovation is defined by: "*the process of creating new ideas and their transformation in new value for the company*" [1]. Permanent innovation underlines the phenomena of continuity and stability of the approach [2]. Intensive innovation refers to Armand Hatchuel's definition [3]. This logic of permanent innovation maintains a hyper-consumption and a mass-production model. The environmental consequences are huge, as there is both an increase of waste and a rarefaction of the natural resources and raw materials.

There is therefore a potential tension between the economic and environmental dimensions of this industrial, intensive innovation model. Moving forward requires leaving behind product-centered innovation and adapting service-centered innovation. Indeed, even if the actual system provides economic benefits for the companies, the coordination involved in managing such a large collection of resources can weaken the viability of a product-centered solution from an environmental point of view. Our research question is simple: Which innovation model could integrate economic and environmental dimensions to enable the diffusion of sustainable products? In other words, how can we move from permanent innovations to sustainable innovations? To answer this question, we based our research on eco-design and functional economy principles and we propose concepts and approaches to design sustainable innovation. The challenge is to consider not only the emergence of new products called "evolutionary" or "upgradable" but also the emergence of new business models. Business model are defined as the company's remuneration method [4], [5]. According to Chesbrough and Rosenbloom, Business model "*spells out how a company makes money by specifying where it is positioned in the value chain*"[5]. Our hypothesis is that services based on upgradable products offers will combine environmental improvements (due to a specific ecodesign method), business profitability (due to an innovative and profitable compensation system) and customers' satisfaction (due to a specific socio-technique approach).

To support these hypotheses, field studies will be conducted to establish the feasibility of the diffusion of such upgradable systems close to consumers and industrials from Business to Business and Business to Consumers markets.

II. ECO-DESIGN AND FUNCTIONAL ECONOMY ARTICULATION

A. Eco-design, a solution of sustainable design

Pollution, fossil energies and other environmental issues are at the center of an ever-increasing number of debates concerning the future of our planet's limited resources and our economic systems [6]. To address these environmental issues, numerous actors agree to say that the industrial world must make proposals and put on the market new products and services that allow for clean use, less pollution from manufacturing and a less-wasted-energy distribution. Indeed, because of its role and responsibility to society, industry must reduce its environmental impact related to its activity by evolving toward a more responsible and sustainable activity. In this context eco-design is an approach in the conflict against natural resources rarefaction.

Jeswiet and Hausschield define eco-design as: *«Design and manufacture of products, with the goal of protecting the environment and conserving resources, while encouraging economic progress, keeping in mind the need for sustainability, and at the same time optimizing the product life cycle and minimizing pollution and waste. »* [7]
This environmental dimension in eco-design is integrated directly within the product life cycle. Six main steps (the extraction of raw materials, the production, the distribution, the use and the end of life of the product) have been defined in ISO 14 062 standard as the product lifecycle phases. In our model, we decided to separate the second phase, production, into two separated phases, which are design and manufacturing. We consider that these two steps should be examined separately in the life cycle as their goals are different and important to consider (*Figure 1*).

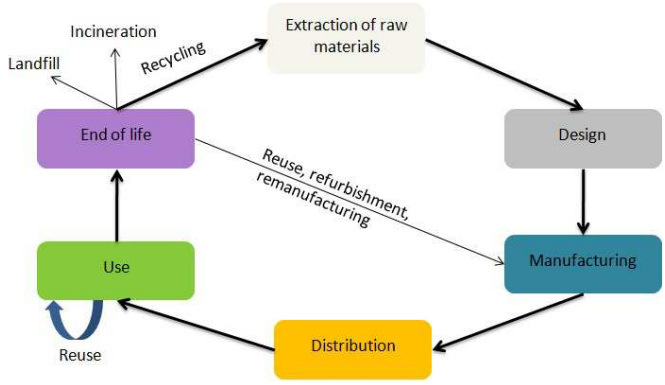

Fig. 1. Product life cycle [6].

Environmental concerns are generated from all over the product life cycle "from cradle to grave", that is from the extraction of raw materials to the product's end of life. The goal of environmental impact management is to reduce quantitatively and/or qualitatively a product's environmental impact while still preserving its qualities and intrinsic performance [8].

A review of eco-design applications shows that innovations are mainly anchored on the products by themselves [9]. Influencing a product's use phase remains unaddressed as consumers' behaviors and needs are not taken into account enough during eco-design. As N. Boughim and B. Yannou suggested, our society appears to be changing from a product-centered economy to a service-centered economy [10]. Consumers' needs are more oriented on services associated to the product than on the good itself. Nowadays, eco-design has seen only a limited integrated within the dimension of service consumption.

Eco-design does not provide a solution to intensive innovation. In some case, eco-design can be coherent with a hyper-consumption and a mass-production model. For example, a product can be eco-designed, with more environmental-friendly component and material, but in the same time designed to meet the planned obsolescence model. That is why eco-design cannot be used alone as a solution to solve the problem of intensive innovation.

To introduce more sustainable products with longer life cycles and associated services on the market requires thinking and defining new remuneration models for companies which are currently focused on the produced quantity of the product and thus encourage frequent purchases. The aim is to find new economic models that allow companies to make benefits on more sustainable products. These new sustainable business models could be a substitute to the obsolescence model which is currently used.

B. Functional economy, toward a sustainable economy

Though eco-design has its limitations, functional economy offers promising lines of thought to complement it. For example, one way for companies to introduce new business models or business models adapted to products with a longer lifecycles would be to sell the products with the associated services, or exclusively to sell services. That is the purpose of functional economy.

The words "functional economy" or "service economy" has been first used by Walter Stahel and d'Orio Giarini in 1986. [11] According to Walter Stahel *"The economic objective of the functional economy is to build the highest possible use value for the longest possible time while consuming as few material resources and energy as possible. This functional economy is therefore considerably more sustainable, or dematerialized, than the present economy, which is focused on production and related material flows as its principal means to create wealth."* In this way, the added value would be separated from the material consumption [12].

Functional economy consists of the replacement of the sale of the product by the sale of either its uses, its functional units or its service. The value of the offer depends on the service given and its access rather than its ownership. There is a service-oriented move when compared to intensive innovation. This implies deep changes in the

producers/consumers' relationship. It is turned to commercial transactions on the use of capital assets and not on the sale of the property itself, which could have positive effects in terms of economic, social and environmental impacts. Indeed, functional economy suggests the creation of value with consumers' satisfaction as main objective. It also implies changes in the business strategy, moving from subcontracting to network cooperation (*Figure 2*).

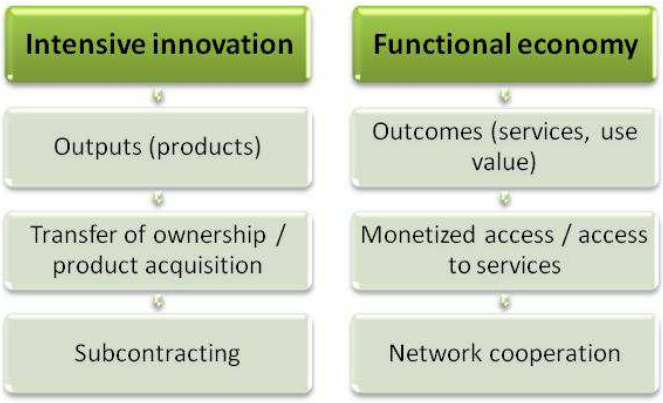

Fig. 2. Functional economy in opposition of intensive innovation.

This value creation meets consumers' needs and allows the companies to improve their competitiveness. The functional economic system also suggests an economic system separated from the product, which could be an environmental improvement by increasing for example the product's life, and thus limiting the planned obsolescence. However, this assumption is questionable. Indeed, it remains to show that this system does not cause adverse effects in the environment. [13], [11], [14], [10], [15]

Nevertheless, the functional economy as it is described is limited. First of all, it requires a fundamental change in the company's culture. It is necessary to deploy considerable time and effort to implement such a model, leading some companies to be skeptical about this approach. This model can also lead to frequent renewal or return of products, as the duration of use is limited in time and the products must remain active if the customer chooses not to purchase the product at the end of the contract. Also, if the product is bought at the end of the lease, its maintenance, recovery, recycling or reconditioning cannot be guaranteed. These are limits to environmental opportunities of the functional economy [10].

Previously stated limits lead us to develop the hypothesis that sustainable innovation cannot only be achieved by addressing eco-design or the functional economy independently, but necessitate the combination of these two approaches.

C. Sustainable innovations: an alliance between functional economy and eco-design in a network model

Combining eco-design and functional economy seems to be a way to take into account tensions between economy and environmental issues. It offers an alternative model allowing for sustainable innovation. Sustainable innovation is defined as an innovation that allows companies to benefit together by preserving natural resources and reducing the environmental impact. Sustainable innovation allows for consumer satisfaction as well as the companies' economic profitability and growth by applying the principle of moderation in the use of natural resources and energy consumption. In our research, we study functional economy and eco-design focusing on their relations, not seeing those as two different entities. In this way we are not going to study the consumers' needs and the products separately but rather the existing links between them in order to identify aspects of sustainable innovation.

Eco-design and functional economy could be complementary. Eco-design focuses on environmental aspects in the product life cycle. A functional economy approach can overcome the product-centered eco-design approach, and propose a sustainable business model to meet the consumers' and companies' needs. As an example of moving from intensive innovation to sustainable innovation by combining eco-design and functional economy, we can cite the evolution of automobile. Indeed, the example of automobile sector illustrates a progression in design, from classical design to eco-design and in parallel, a gradual transition in economy from classical economy to functional economy. The result, in this case, is eco-designed-car rental; this is a good example of a sustainable innovation combining eco-design and functional economy *(Figure 3)*.

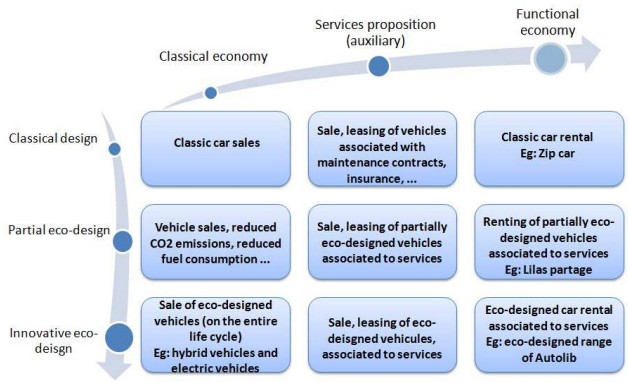

Fig. 3. A gradual evolution from intensive innovation to sustainable innovation

There are various business models adapted to the functional economy which allow this gradual transition. These models can be based on simple association services with a product, for example, or mix offers, bundling products and services usually sold separately. There are also functional economy based models that fully breaks away with the product-centered economy in favor of a service economy. For instance, there are:

- The functional Sales (FS) model, where the goal is to sell the product's function without taking into account the

environment. And there is a transfer of ownership from the distributor to the consumer;

- Eco-Efficient Services (EES) models which would reduce the resources and energies consumed and sell the utility, the service given by a product while leaving a part of the ownership to the distributor;
- The Product Service Systems (PSS) model whose purpose is the realization of the idea of moving from the product to more services with a strong consideration of environmental aspects [16], [15], [10].

One of the most studied models related to the functional is the PSS. This model seems to be in line with the idea of a functional economy coupled with the eco-design. According to Arnold Tukker and Ursula Tischner: "*PSS consists of a mix of tangible and intangible products and services designed combined so that they are able of fulfilling jointly final customer needs*." [17].

There are different types of PSS; many classifications have been made. The most common has been suggested by Hockerts, who differentiates three types of PSS [14]: product-oriented PSS, use-oriented PSS and result-oriented PSS.

The product-oriented PSS provides a few additional services to the product sold, like financing, maintenance, recovery at the end of life, training in the use, etc., in an existing system [17]. There is still a transfer of ownership but converges to a service offering added to the product. This approach is still centered on the product [14], [10], [15]. Moati talks about complementary services, which is an improvement of the existing customer relationship [16].

The use-oriented PSS does not involve the sale of the product itself, but the sale of its function and its use. These approaches are linkable to the contexts of renting, leasing, or even pooling and sharing. It is a transition between the purely material sale and the sale of services. It provides intermediate steps between the product-oriented PSS and the result-oriented PSS. This type of PSS intensifies the use of the products [14], [10], [15], [17]. In Moati's classification of functional economy, this type of PSS is associated with "Bouquet" model which consists in the association of a product and additional services [16].

Finally, result-oriented PSS engages the producer to ensure consumer needs' satisfaction. Moati defines this model as functionality-oriented business model [16]. This latter type of PSS focuses primarily on the function, the utility that the user needs. There is no longer transfer of ownership but an offer of service and function that meets consumer expectations. This type of PSS requires a change of the company's remuneration system. It cannot be based on an existing system [14], [10], [15] , [17].

The PSS classification and Moati's classification have been linked; nevertheless it has to be underlined that Moati's classification does not directly involve the environmental aspects unlike the PSS in which the consideration of environmental impacts is one of the basic rules. That is why it has been chosen to refer to PSS models in our research.

The use and result-oriented PSS seem much more refined than the product-oriented PSS in a functional approach and are a good starting point for studying the development of sustainable innovation.

This business model allows a transition to a more dematerialized system than the eco-efficient services or the functional sales. The goal is to minimize the environmental impacts of consumption by reducing it through alternative ways of using products and by increasing globally resource productivity and dematerialization of PSS. These types of business models are interesting to study and link to eco-design as a starting point of the study. This alliance will set new compensation systems focused on services, networks of actors and eco-designed products and services. This type of innovation should allow evolving sustainable distribution systems in response to a more sustainable economy.

Two approaches can be used in thinking about the sustainable innovation model and its transition from linear chain model to network model: first, an innovation model based on an essentialist point of view, and second, an innovation model based on an interactionist point of view.

In the essentialist point of view, the product's characteristics are supposed to be the only motives for product acquisition by a consumer who wants to have the ownership of the product. Consumers' willingness to pay can be evaluated according to the product's characteristics. From the collection of different product's characteristics, those that are the most critical for differentiation should be identified. The value of those products' characteristics is relative to the singular preferences of consumers.

The interactionist approach is based on a socio-technical analysis where societal and technical dimensions are studied together. The situations of use and purchase, the property, the prescription mechanisms (brand, social convention…) and intermediation (distribution arrangements, access to information) become key elements to understand the consumers' willingness to pay.

The substantialist approach is also widely used nowadays to apprehend innovation. For example, the chain-linked model defined by Kline and Rosenberg [18]. This model supposes an internalization of the innovation process but omits external sources of knowledge for instance when collaborating with different actors. The substantialist approach has been proven to be successful in some case, such as Xerox [19]. Nevertheless, societal changes have led to new ways of thinking about a more "open" innovation. This is an important limit of the substantialist approach.

Open innovation is defined by Chesbrough as *« Paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology »*[19]. Chesbrough talks about erosion factors that undermined the logic of what he calls the "closed innovation", or the old paradigm consisting in internalizing everything within the company. These erosion factors are for example the growing

mobility of highly experienced and skilled people, or the growing presence of private venture capital, which specialized in commercializing external research [19].

Our hypothesis is that technical performances cannot be understood independently from relations and socials conventions within which they will be expressed. In this context consumers' behaviors can no longer be explained solely by its own preferences and product's characteristics. The consumers' behaviors are therefore influenced by the enlisting process, actors' network, which includes consumers' preferences. The most appropriate approach, which includes all dimensions of sustainable innovation, is based on an interactionist principle. This takes into account actors' network as suggested by Chesbrough [19]. This way of thinking allows involving different knowledge areas and enriching knowledge by sharing the way of thinking about a variety of actors.

To summarize, the most appropriate method to define a sustainable business model would be an interactionist approach in which a socio-technical network would be built around the innovation, in order to promote the success of this innovation. Sustainable innovation model based on an interactionist approach involves thinking differently about the entire value chain. Sustainable innovation necessitates sustainable business model design as well as eco-design. That design should take into account the entire network of stakeholders, moving from a linear management chain to a network management in an interactionist way of thinking. *(Figure 4*, [20]*)*

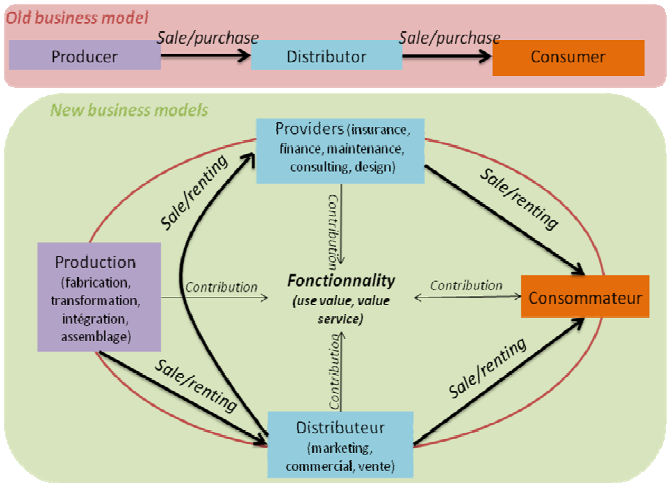

Fig. 4. From a linear chain model to a network model for sustainable innovation. Adapted from Oksana Mont works [20]

III. Evolutionary Systems' Diffusion

The articulation of service economy and eco-design as a solution for sustainable innovation will occurs around the evolutionary systems. These evolutionary systems are products with multiple cycles of upgrades. The aim is to develop a system with product improvements on a regular basis, thus providing more value to the product without totally changing it.

Field investigations related to this discussion will be based on the ANR project IDCyclUM (Innovation Durables à Cycles d'Upgrades Multiples): Multiple Upgrades Cycles for Sustainable Innovations.

This project aims at designing and integrating multiple upgrade cycles of products on market within the framework of sustainable innovation. Sustainable innovation is made possible by the diffusion of eco-designed products for which the whole life cycle includes several subcycles consisting of product improvement. This approach involves an increase in the overall life of the product, a reduction of raw material consumption and other beneficial environmental impacts. These evolutionary systems must be eco-designed to optimize their life and their environmental impacts, but they will also allow a simplified replacement of worn parts, and allow several product improvements. *(Figure 5)*

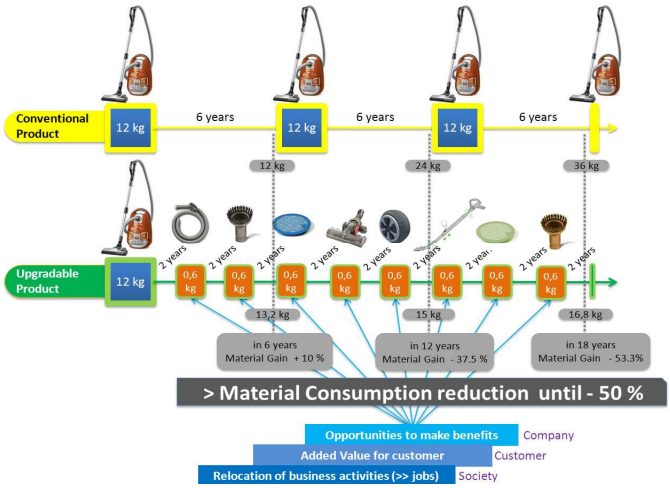

Fig. 5. Example of an IDCyclUM applied to a vacuum cleaner. Extracted from 2011 annual report of Ecotech Programm, IDCyclUM project

These upgradable systems require exceeding the technological dimension of the design to enter into a networking, interactionist and sustainable process, with binding eco-design and functional economy as it has been previously developed. This type of design requires rethinking the business model associated with the product to develop a sustainable business model to meet the needs of both businesses and consumers. The hypothesis put forward here is that such a system requires not only a sale of the product but a service performance. This involves thinking about new business models.

However, making the Multiple Upgrades Cycles for Sustainable Innovations requires overcoming the many difficulties involved with conducting change in business model.

IDCyclUM project will allow testing our hypothesis using surveys, consumers' studies and industry based case. The research will include a vacuum cleaner study to illustrate the business to consumer market.

Firstly, we will analyze the reasons behind a product's replacement. We will study consumer needs and expectations trying to understand why consumer needs are shifting to a service economy rather than product property. This study will be supported by a survey realized with consumers who want to change their vacuum cleaner. It will determine whether consumers are influenced by the intrinsic characteristics of products, changes in social status or relative to the market innovations proposed by encouraging the purchase of new products.

Secondly, the project aims to identify the limitations and opportunities of upgradable system dissemination for businesses and consumers. This part of the project will support and test the hypothesis proposing the distribution of evolutionary products combining eco-design and functional economy as an innovative solution to meet the consumers and businesses needs. This will be done by focusing in particular on their willingness to pay for upgradable systems and by assessing the feasibility of implementing such systems in companies. Surveys will be conducted with consumers to determine if they are attracted by upgradable solutions on products such as vacuum cleaners. The industrial value chain of the vacuum cleaner (distribution, subcontractors and after-sales service, for example) will also be interviewed to assess the willingness and feasibility of implementing such systems in companies.

The project also includes the development of a design method for upgradable systems by creating tools and determining a definition of integration strategies for multiple upgrade cycles. This step will define a design methodology integrating eco-design as well as build an adapted sustainable business model. This stage of the project will verify and support the hypothesis defining the covenant of the service economy and eco-design by creating innovative business model to serve eco-design, as a solution on environmental, social and economic plans. It will also test the effectiveness of an interactionist system compared to a conventional product-centered system.

Test will be conducted with two industrial partners to check concretely whether a sustainable innovation to serve eco-design and functional economy can allow solving potential tensions observed between current economic system and the environment. This IDCylcUM research project aims at integrating Multiple Upgrade Cycles Sustainable Innovations in business and will support the research topic on the type of business model to develop in order to jointly integrate economic and environmental aspects to achieve the main goal: the development of sustainable diffusion for products.

IV. Conclusion

This research is part of the service economy and eco-design and addresses the potential tensions between the economic system and the scarcity of natural resources with thinking and defining a new innovation model based on multiple product upgrade cycles.

This topic raises challenges that have been highlighted. New knowledge is needed to overcome these obstacles and to make this pattern emerge. We have suggested a definition of sustainable innovation and an approach to its implementation. This research theme is supported by the IDCyclUM project that will test hypotheses by experiments conducted with two industrial partners. Our main question is: How can we build a network allowing this innovation that is accepted both by the consumers and the companies?

Our proposition is based on an interactionist approach and promotes a shift from a linear to a networked business model.

This should lead to new type of innovation model taking into account consumers' expectations and business needs. We must innovate in a sustainable way to survive.

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