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THÈSE

Pour obtenir le grade de

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Présentée par

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Les business modèles de l'open source hardware

Business models for Open Source Hardware

Thèse soutenue publiquement le **22 novembre 2019**,
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BUSINESS MODELS FOR OPEN SOURCE HARDWARE

Laetitia THOMAS

Under the supervision of Pr. Karine EVRARD SAMUEL

To all my grandmothers and to my beloved son, Adam

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1. REVUE DE LITTÉRATURE ET CADRE CONCEPTUEL DE LA RECHERCHE

1.1. CONTEXTE DE RECHERCHE

Impulsée par un courant social, la technologie évolue d'une manière de plus en plus difficile à appréhender. Ces changements, comprenant l'intelligence artificielle, l'internet des objets, le big data, l'informatique en *Cloud*, l'impression 3D et la fabrication additive, font partie de ce que l'on nomme aujourd'hui la « 4ème révolution industrielle ». Cette dernière est décrite comme la numérisation de l'industrie au sens large, c'est-à-dire son intégration « à la conception des produits et aussi aux moyens de production associés » (Gaudron & Mouline 2017).

En 2014, Richard Branson, impressionné par Jeremy Heimans le fondateur de Avaaz, a écrit dans son blog : « *cette transformation n'est pas technologique, elle est rendue possible grâce à la technologie, mais elle est menée par les gens et l'évolution de leurs attitudes envers la participation et le changement. Jeremy oppose l'ancien pouvoir qu'il assimile à une monnaie (détenue par quelques-uns, fermée et inaccessible) à ce "nouveau pouvoir" qui s'apparente davantage à un courant (créé par beaucoup, ouvert et dirigé par des pairs)* »¹. Ces changements impliquent que le monde des affaires change lui aussi, modifiant les rôles des clients et des producteurs. Certains des changements radicaux s'opèrent en ces termes : plus distribués, décentralisés, collaboratifs, attrayants, plus de réseaux en termes d'écosystèmes, et travaillant avec différents types de partenaires, plus partagés.

Pour préserver leur modèle économique, les entreprises ont longtemps protégé leurs processus d'innovation par des brevets. Cependant, depuis quelques années, la réduction des cycles de vie des produits et les coûts grandissants de Recherche & Développement ont poussé les entreprises à ouvrir leurs processus d'innovation à des communautés externes. C'est ce qu'on appelle l'innovation ouverte (*open innovation*). Chesbrough & Bogers (2014) ont tenté de définir ce phénomène complexe, qui défie l'idée la sagesse reçue sur la nature même d'une innovation. Cette dernière se situant de plus en plus à l'extérieur des frontières de l'entreprise. Leur définition propose que l'open innovation est un « *processus d'innovation distribué avec*

¹ <https://www.virgin.com/richard-branson/occupy-yourself>

des flux intentionnels à travers les frontières organisationnelles ». Ces flux intentionnels démultiplient l'innovation selon trois processus distincts. Les processus « *inside-out* » permettent d'exploiter des connaissances internes en externe sans en assumer tous les coûts. À l'inverse, les processus « *outside-in* » permettent d'incuber en interne des idées venues de l'extérieur. Enfin, le « processus couplé » (*coupled process*) permet un développement et une exploitation en commun de la R&D entre l'entreprise et des acteurs externes. Certains chercheurs suggèrent que ce dernier schéma permettrait une vraie création de valeur partagée, ainsi que des business models vraiment ouverts (Enkel *et al.*, 2009). En rendant leurs innovations ouvertes, les entreprises renoncent à certains de leurs droits au profit d'une participation externe motivée, et d'un sens de copropriété de la part des contributeurs. Les deux avantages principaux de cette approche sont : 1) l'hyper innovation où la création de nouvelles idées est accélérée ; 2) la création de communautés de co-créateurs qui permettent d'externaliser les ressources de l'entreprise.

Cependant, la barrière entre concepteurs et consommateurs s'estompe de plus en plus, grâce, par exemple, aux outils de fabrication digitale, comme les imprimantes 3D ou les découpeuses lasers accessibles via des Fab Labs ou des Maker Spaces permettant aux citoyens de créer et de tester des produits beaucoup plus facilement. Partant d'un phénomène isolé, il existe maintenant 1200 Fab Labs dans 100 différents pays organisés en réseau, « the Fab City Network », dont le but est d'aider les villes à produire 50% des ressources qu'elles consomment d'ici quarante ans.

Dans ce contexte, construire un drone pour dépolluer les océans, une ruche connectée, ou un filtre à eau en « Open Source Hardware » (OSH) vise à créer des solutions de manière plus rapide, efficace et à moindre coût. L'« Open Source » est un processus collaboratif de développement de produits, dans lequel les plans de conception, jusqu'aux « secrets » de fabrication sont accessibles à tous, de manière à décupler la capacité d'innovation, en s'appuyant sur l'expertise des clients, de communautés d'utilisateurs, des entreprises pour améliorer de façon plus rapide, plus pertinente et plus transparente, les produits. L'innovation en open source hardware (OSH) est un mode de développement de produit collaboratif, dans lequel les plans de conception, les instructions d'assemblage, et la liste des matériaux sont mis à disposition du grand public afin que quiconque puisse étudier, répliquer, modifier, distribuer et vendre le produit fini issu de ces plans (Raasch *et al.*, 2009; Bonvoisin *et al.*, 2017; Bonvoisin *et al.*, 2017). Les principes de conception de l'OSH sont la modularité, (permettant de fabriquer des produits avec des pièces faciles à assembler, démonter et réarranger) et les standards

ouverts (la conception des composants selon une forme et une taille communes). De plus, ces innovations sont gardées volontairement libres de droit. Elles constituent un socle de connaissances, un « bien commun digital », c'est-à-dire une réserve d'idées et de solutions disponible sur Internet via des plateformes numériques.

Cette approche nouvelle soulève de nombreuses questions, notamment celle de savoir comment rendre ce processus d'innovation collective rentable dans un contexte où les interactions entre les membres des communautés d'innovation pratiquant l'OSH sont basées sur des relations volontaires, non lucratives et non hiérarchiques. Etudier le phénomène des business models de l'OSH est une question empirique très concrète, car la création d'un business model relève d'une activité de design, c'est-à-dire comme relevant d'un processus de conception visant à créer de la valeur. Cependant, le design d'un business model ne peut pas être copié. Il relève plutôt d'une évaluation approfondie de la question « qu'est-ce qui marche pour nous ? », et de la compréhension fine des ressources et des capacités d'une entreprise. C'est tout l'enjeu de cette recherche dont le but a été de comprendre et de modéliser les business models de l'OSH.

1.2. IMPORTANCE DE LA RECHERCHE

La notion d'ouverture de l'innovation ainsi que ses implications sur la gouvernance et les connaissances, déroutent autant les chercheurs que les entreprises. Jusqu'à présent les révolutions industrielles ont souvent suivi un mode de fonctionnement où les innovations étaient privatisées, centrées sur la maximisation des profits dans une optique « Friedmanienne ». Or, l'Internet a rendu sa fameuse maxime « les affaires des affaires sont les affaires » caduque. L'Internet permet une plus grande transparence et ainsi une prise de conscience croissante sur la chaîne de valeur d'un article, ou les agissements d'une entreprise, ce qui soulève quelques fois des questions critiques. Historiquement, l'open source excluait les ambitions commerciales. L'objectif libre et non-matériel de « la production par les pairs » (P2P) basés sur les communs déconcertait alors des chercheurs comme Henry Chesbrough (2003) à l'origine d'études sur l'open innovation et les open business models. Effectivement, comment peut-on créer un business model utilisant de la propriété intellectuelle afin de garder l'innovation ouverte ? Comment peut-on générer de la valeur à partir d'un bien commun ?

En dépit de ce verrou scientifique, et sans attendre, pour l'instant, le succès des initiatives en Open Source dans le secteur des logiciels informatiques, les initiatives ouvertes n'ont cessé de se propager touchant progressivement les domaines de l'art (creative commons), de l'éducation (open education) ; des sciences (open science, open access) ; des données ; et même celui de la

gouvernance (open government) (Benyayer, 2014). Dans cette recherche, celui que nous allons approfondir touche au domaine industriel, l'Open Source Hardware (OSH).

1.2.1. PROJET DE RECHERCHE OPEN !

Le but du projet de recherche OPEN! conduit de Mars 2016 à Septembre 2019 et co-financé par l'ANR français et le DFG Allemand, est de comprendre et de modéliser les méthodes et les outils nécessaires au développement de produits en open source issus de communautés d'innovation. Initialement, l'équipe OPEN ! a établi une distinction entre l'OSH où les plans de conception d'un produit sont révélés au final, et d'autre part, le développement produit en open source (OSPD) où le processus de développement lui-même est ouvert à une contribution externe. Après trois ans de recherche sur le sujet, l'équipe a constaté que l'OSH comprend ces deux approches. L'OSH permet une nouvelle organisation du développement d'un produit basée sur des droits d'auteurs ouverts et sur un mode de travail décentralisé et volontaire. Elle offre une alternative au développement de produits industriels conventionnels, une opportunité d'amélioration en continu des produits ainsi qu'un potentiel formidable d'innovation et d'incubation de nouvelles entreprises.

Le projet a été divisé en quatre groupes de travaux menés (appelés workpackages ou WP) par une équipe multidisciplinaire composée de chercheurs français et allemands. Il est conduit par des laboratoires d'ingénierie (G-SCOP [Fr], TU Berlin/IWF [De]), avec la contribution de laboratoires en sciences d'économie d'entreprise (HU Berlin/HIIG [De]) et de gestion d'innovation (CERAG [Fr]). La portée de notre recherche, correspondant au WP4, vise à comprendre et modéliser les business models accessibles à l'OSH, et à définir les lignes directrices permettant aux entrepreneurs de réduire les risques associés au développement de produit en open source.

1.2.2. DES BUSINESS MODELS ORIENTÉS-VERS OU BASÉS SUR LES COMMUNAUTÉS D'INNOVATION

La littérature académique sur les business models permet d'opposer deux perspectives divergentes, que les chercheurs Wolf & Troxler (2016) ont résumé de cette manière : d'une part, les business models *orientés vers* les communautés d'innovation, et d'autre part, ceux *basés sur* les communautés d'innovation.

Nous appelons « communautés d'innovation » les communautés internes, externes (ou les deux) à une entreprise regroupant des communautés d'utilisateurs, de pratique, d'intérêt, et des communautés virtuelles. Jusqu'à présent, ces communautés n'ont pas beaucoup pesé dans la

dynamique d'innovation d'une organisation. Cependant aujourd'hui, les entreprises reconnaissent leur capacité à décupler l'innovation pour améliorer les produits et les services de façon plus rapide, plus pertinente et plus transparente. Les communautés d'OSH sont hybrides, c'est-à-dire qu'elles regroupent à la fois des aspects de communautés de pratique (CoP) visant à améliorer l'expertise de leurs membres, et des communautés épistémiques extrêmement multidisciplinaires qui cherchent à créer de nouvelles connaissances et à briser les règles établies. Dans la littérature, les idées déviantes et non-standard des communautés épistémiques sont à l'origine de beaucoup d'innovations de rupture, qu'il s'agisse du Cubisme, du Cirque du Soleil, de Marie Curie ou d'Albert Einstein. Les communautés épistémiques transcendent les séparations entre les individus, les communautés et les entreprises (Cohendet *et al.*, 2010; Capdevila, 2017).

La littérature sur l'innovation ouverte s'accorde avec la notion de business models orientés *vers* les communautés, où une entreprise référente cherchera à trouver un business model adéquat, qui serait acceptable auprès de sa clientèle tout en lui permettant de maximiser ses profits. A l'inverse, les business models *basés sur* les communautés n'ont pas pour origine une entreprise qui cherche à créer une communauté. Ils concernent plutôt les cas où une entreprise ou une organisation référente émerge du contexte d'une communauté collaborative ou d'un réseau de clients, de communautés d'utilisateurs, et vont chercher à améliorer un produit donné. Ces initiatives sont dites « ascendantes », ou bottom-up. Leurs trajectoires d'innovation ne sont pas guidées par des institutions, c'est leurs actions qui vont permettre la création de nouvelles institutions. Ces communautés comprennent des utilisateurs, ingénieurs indépendants ou amateurs, souvent appelés « Makers », qui tendent à tirer parti de l'unification ponctuelle de leurs compétences créatives, de manière volontaire et non hiérarchique, pour créer des produits dont ils ont l'utilité. Cette dernière perspective relève du domaine de l'OSH et de l'OSPD tels qu'ils ont été définis par les chercheurs du projet OPEN ! à l'origine de cette recherche.

1.2.3. L'OUVERTURE DES BUSINESS MODELS

Teece (2010) définit les business models comme l'architecture des activités par le biais desquelles une entreprise crée, capture et délivre de la valeur. Les chercheurs Frankenberger *et al.*, (2014, p. 175), définissent les open business models comme une sous-catégorie des business-models, où « *la collaboration d'une entreprise donnée avec son écosystème est un élément décisif et nouveau de création et de capture de valeur* ». En accord avec les travaux de Massa *et al.* (2016), nous avons élargi notre approche des business models de l'open source hardware (OSHBM) à la création, la capture ainsi que la livraison de la valeur au-delà d'une

entreprise de référence, en considérant un ensemble plus large de parties prenantes. De nombreux travaux de recherche sont axés sur les composants des business models, tels que la proposition de valeur, les ressources, activités et partenariats clés (Osterwalder & Pigneur, 2010, Tech *et al.*, 2017 ; Clauss 2017, p.4). Cependant, une question demeure : qu'est-ce qui relie ces composants entre eux, notamment lors d'échanges volontaires non-lucratifs et non-hiérarchiques comme dans le cas de la production par les pairs (P2P) ? (Fuster Morell, 2014, p. 37). Comme Jouison & Verstraete (2008) le décrivent dans leur modèle de création de valeur, les business models sont dynamiques et ceux touchant à l'OSH hardware encore plus. Menichinelli, cité par Wolf & Troxler (2016, p.3) explique que les « *systèmes distribués open source, et basés sur une production par les pairs ont des frontières plus floues et plus d'unités* » (Menichinelli, 2015). Nous retenons deux choses de la revue de littérature sur les business models ouverte effectuée au commencement du projet par OPEN! : 1) les limites entre partenaires et consommateurs deviennent floues dans les business models ouverts, 2) les flux de revenus et la manière dont la création de valeur peut bénéficier à plus d'une entreprise, sont nébuleux (Tech *et al.*, 2017).

Dernièrement, même si les initiatives en OSH se propagent, l'état de l'art actuel visant à décrire ce qu'est un « business model pour l'OSH » montre une grande hétérogénéité du concept. Une revue de toutes les typologies définies et associées à l'OSH n'est aucunement actionnable pour les praticiens, et ne relève pas de perspective stratégique (Fuster Morell *et al.*, 2017; Gassman *et al.*, 2014; Pearce 2017; Tebbens 2017; Stacey, 2016; Tinck & Bénichou, 2014; Wolf & Troxler 2016).

1.3. CADRE THEORIQUE

Les théories utilisées pour comprendre les business models et leur innovation comprennent la théorie des capacités dynamiques (ACAP), la théorie des coûts de transaction, la cognition managériale et les théories relevant des rigidités nominales, de l'entrepreneuriat, de la réplication et de la compétition, et des ressources (RBV), (Foss & Saebi, 2018, p. 10). Ces théories relèvent d'une approche centrée sur l'entreprise et n'abordent pas les « processus couplés » permettant le partage d'une création de valeur co-construite entre des acteurs internes et externes à une entreprise. Aussi, aucune de ces théories ne permet de combiner l'exigence de viabilité et de pérennité, propre aux business models, à celle de l'ouverture collaborative, propre à l'OSH. Notre objet d'étude concerne le développement de produits issus de communautés d'innovations, nous ne pouvons donc pas considérer que la dynamique d'innovation repose seulement sur des institutions formelles existantes. Nous avons donc

mobilisé la théorie des communs car elle offrait la possibilité de transcender les frontières entre les pouvoirs publics, le marché et les citoyens.

1.3.1. LA THEORIE DES COMMUNS

La théorie des Communs a été construite par Elinor Ostrom – pour laquelle elle a reçu le prix Nobel de la paix en 1990 – puis reprise par d’autres chercheurs comme Raworth (2017, p. 83) et Benkler (2013; 2016) dans le contexte des communs de connaissance digitaux. Cette théorie introduit « les communs », comme un nouvel acteur en économie, et prouve que dans certains cas, une action hybride public-privée appuyée par des lignes directrices co-construites, est plus efficace que le marché ou l’Etat dans la gestion durable d’un commun, naturel ou numérique (Ostrom, 1990 ; Hess & Ostrom, 2011). Nous partons du postulat que notre phénomène empirique, les business models de l’open source hardware, permettra de contextualiser et d’enrichir cette théorie. L’autre raison pour laquelle nous nous intéressons à cette théorie est qu’elle offre de nouvelles configurations de valeur au travers du design *distributif* et *régénérateur*.

Le constat des acteurs de l’OSH est que les technologies visant à créer de la valeur au triple avec bénéfice économique, sociétal et environnemental, doivent être « open-sourcées » afin d’atteindre le plein potentiel régénérateur de l’économie circulaire. L’objectif de cette économie est de créer un fonctionnement en boucle, afin de limiter la consommation et le gaspillage pour métamorphoser l’industrie *dégénérative* actuelle en *régénérative*. Dans cette optique, les déchets deviennent des nutriments technologiques ou biologiques qui sont idéalement recyclés à l’infini, c’est la notion de *re-généralité*. La seconde notion importante de création de valeur offerte par les communs est la *distributivité*. Ce qui veut dire que grâce à l’Internet quiconque disposant d’une connexion peut divertir, informer, apprendre et enseigner dans le monde entier. Les technologies de fabrication digitales sont des technologies latérales, et sont l’essence même de conception distributive qui permet la réplique, et l’estompement du fossé entre les producteurs et les consommateurs. Chaque ménage, école ou entreprise peut produire de l’énergie sur son propre toit et vendre l’excédent sur un micro-réseau. Les principes de design open source (tels *la modularité* ; *les standards ouverts* ; et les données ouvertes) sont essentiels aux besoins de l’économie circulaire. Cependant, ces deux notions de distributivité et re-généralité, associées à l’économie circulaire, ne prennent pas en compte le potentiel créatif humain.

Or, ce qui est fondamental à notre sujet sur l'OSH, est la notion de *générativité*. Cette notion permet d'investir dans l'ingéniosité humaine et l'intelligence collective, afin de créer des synergies pour résoudre des problèmes de façon créative, multiple, et adaptée à une pléthore de contextes différents, qu'on ne pourrait résoudre seuls. « La magie du Fab Lab » est l'incroyable pouvoir généré par le passage de l'idée au prototype qu'on tient dans ses mains (Troxler 2010). Ron Eglash définit la « justice générative » comme « *le droit universel de générer une valeur inaliénable et de participer directement à ses bénéfices ; le droit des créateurs de valeur de créer leurs propres conditions de production ; et le droit des communautés génératrices de valeur d'entretenir des voies autonomes pour sa circulation* » (Eglash, 2016). Selon cet auteur, cette notion est en rupture avec les systèmes capitalistes et communistes qui sont à la fois aliénants et extractivistes en termes de ressources et de labeurs. Nous postulons donc que le design génératif offre une nouvelle configuration de valeur, propre aux communs, qui enrichie la réflexion sur l'économie circulaire en rajoutant l'élément humain.

1.3.2. CADRE CONCEPTUEL

Afin de rendre notre recherche cumulative, nous cherchons à clarifier quelles sont les parties prenantes clés dans le processus de création de valeur d'innovation en OSH, et quelle est la nature de leurs interactions. Notre étude qualitative exploratoire initiale sur 23 projets d'OSH nous a permis de comprendre qu'il ne s'agissait pas d'un phénomène propre à un seul secteur, entreprise ou territoire, mais une transformation beaucoup plus globale. Après cette première étude, nous avons compris qu'étudier seulement les communautés d'OSH, ou les entreprises qui expérimentent cette démarche, ne permettait pas de saisir l'impact du phénomène dans son ensemble. Nous avons choisi de mener notre recherche à la fois sur les niveaux communautaires, d'entreprise et de territoire, soit une unité d'analyse que nous avons nommée « les écosystèmes d'OSH ». Le niveau spatial ou territorial est identifié par Bogers *et al.*, (2016) comme celui qui est actuellement le moins couvert par la recherche sur l'innovation ouverte. Ce niveau nous a paru particulièrement intéressant pour comprendre le rôle et la qualité d'interaction entre les communautés d'OSH et des parties prenantes non nécessairement impliquées dans la conception des produits physiques, mais intéressées à soutenir ce genre d'initiatives. Au final, le choix d'une d'analyse multi-niveaux nous a semblé nécessaire, car il nous a permis d'étudier notre phénomène à travers des niveaux perméables. Les membres de communautés d'OSH pouvant se retrouver dans des Hack Labs ou des Maker Spaces (des

structures beaucoup plus informelles que les Fab Labs), pour développer leurs prototypes, peuvent être reliés à des réseaux multiples de parties prenantes.

Pour chercher à comprendre les conditions nécessaires à la survie et à la montée en puissance de ce phénomène, il est apparu nécessaire de cartographier qui étaient ces acteurs, ainsi que la nature de leurs interactions. Pour dimensionner notre analyse, nous nous sommes basés sur le modèle classique des parties prenantes de Donaldson & Preston (1995). Lors d'une session de Lego Serious Play, nous l'avons adapté aux parties prenantes clefs dans l'écosystème d'un Fab Lab, qui servent d'infrastructure de support aux initiatives en OSH². Deuxièmement, afin de comprendre les mécanismes d'innovation dans des dynamiques « bottom-ups », nous nous sommes positionnés sur le concept du *middleground*, développé par Cohendet *et al.*, (2014; 2010). Ce concept est intéressant car il permet de modéliser les interactions entre les acteurs d'initiatives informelles, très innovantes mais non-optimisées, émanant de l'« *underground* » avec des acteurs de courants plus formels, l'« *upperground* », comme les pouvoirs publics, les universités ou les entreprises. Un *middleground* est intentionnellement co-créé par les acteurs des deux sphères afin de rendre l'innovation viable (du point de vue des communautés émergentes) et d'accéder à de nouvelles idées stimulantes (du point de vue des entreprises).

Aussi, il nous a semblé que si des individus se rassemblent de manière volontaire et non-hiérarchique—afin de co-créer une solution technique (Fuster Morell 2014, p.8), on peut supposer qu'ils ne sont pas nécessairement motivés de manière extrinsèque par la valeur de l'argent, mais plutôt par des valeurs qui se réfèrent à des notions plus larges de ce qui est désirable, intégrant au caractère économique des business models les dimensions sociétale et environnementale.

1.4. QUESTIONS DE RECHERCHE

Au regard de la littérature présentée, nous avons identifié une lacune de connaissances sur la façon de monétiser un objet physique issu d'un processus de conception collaborative basée sur les communs, et d'en partager la valeur produite. Il y a aussi un manque de compréhension sur ce qui cimente et fédère les interactions émanant de communautés d'innovation autour de l'OSH. Enfin, il n'existe aucune typologie compréhensive des business models de l'OSH. Cette première analyse de la littérature nous a conduits à formuler les questions de recherche suivantes :

² Cette session de Lego Serious Play a été effectuée sur les parties prenantes clefs dans l'écosystème d'innovation du Fab Lab de la Casemate à Grenoble, lors de l'Ecole d'Hiver de la Créativité en Février 2018.

RQ1 : Comment monétiser la valeur créée par le biais de l'OSH ?

RQ2 : Dans le contexte de l'OSH, est-il possible de trouver un cadre permettant d'inclure des parties prenantes dans la création et le partage de valeur.s. ?

RQ3 : Dans le contexte de l'OSH, quels liens peuvent être établis entre les composants d'un business model ?

2. METHODOLOGIE

Pour répondre à ces questions, il nous a semblé crucial de combiner les perspectives académiques avec celles des praticiens. À cette fin, nous avons choisi le modèle dialogique développé par Avenier & Cajaiba (2012) pour structurer nos travaux. Ce modèle est cohérent avec le cadre épistémologique auquel se rattache cette recherche. L'objectif du constructivisme pragmatique (PECP) et du modèle dialogique est de générer de la connaissance académique, en mettant en lumière un phénomène donné (l'existence de business models pour l'OSH) et en intégrant explicitement la connaissance et l'expérience des praticiens. Cette approche relève d'une action collaborative pour co-construire des connaissances entre chercheurs et acteurs.

Le phénomène des business models pour des initiatives en OSH est émergent, c'est pourquoi nous avons opté pour une approche qualitative exploratoire suivant un mode de raisonnement abductif (Mantere & Ketokivi 2013) afin de travailler à partir de la théorie des communs (Ketokivi & Choi 2014). La posture (PECP) permet de bâtir des « *modèles intelligibles d'expériences humaines* » afin d'apporter des idées sur « *l'organisation du monde des expériences* » (Avenier & Thomas 2015). En somme, le but de cette recherche n'est pas d'expliquer la réalité telle quelle est, mais de générer de nouvelles « briques » de connaissances en combinant les perspectives d'acteurs et de chercheurs afin de proposer des outils pratiques pour aider les entrepreneurs inscrits dans une démarche d'OSH à viabiliser leurs initiatives et à réduire les risques associés.

Les données ont été collectées durant trois phases d'études distinctes selon notre unité d'analyse d'écosystème d'OSH. Dans un premier temps, des entretiens qualitatifs ont été menés auprès de vingt-trois initiatives issues de « l'Observatoire de l'Open Source Hardware ». Ces initiatives ont été choisies en respectant un protocole de recherche formulant des critères de sélection des cas. Cette phase correspond aux « *business models basés sur les communautés* ». Les projets étudiés portaient sur le développement ouvert de produits mécatroniques ou textiles complexes grâce au recours des communautés. Nous avons ensuite

mené une étude de cas sur quatre acteurs du secteur automobile, ainsi que sur une entreprise du secteur textile, pour étudier leur réaction face à l'OSH issu de communautés d'innovation. Cette deuxième phase d'étude cherchait à comprendre comment des entreprises dans des secteurs industriels compétitifs réagissaient aux initiatives en OSH provenant de communautés d'innovation informelles « bottom-up ». Cette phase correspond aux « *business models orientés vers les communautés* ». Durant la troisième phase, le cas d'étude de Barcelone a été choisi pour le rôle pivot de la ville dans le réseau des « Fab Cities ». Des entretiens ont été réalisés avec des parties prenantes clés dans l'écosystème d'innovation OSH de Barcelone.

Tous les entretiens ont été retranscrits et analysés thématiquement avec l'aide de logiciels d'analyse qualitative (NVivo et Sphinx). Les données pour la première phase d'étude ont été analysées selon les dimensions identifiées par Fjeldsted *et al.*, (2012) : *la communauté, la portée du projet, le business model, le processus de développement, et la plateforme*. Les données de la seconde phase d'étude ont été analysées en utilisant le modèle de contingence de Saebi & Foss (2015) pour le succès d'initiatives ouvertes : la valeur générée par la co-création, par les flux de connaissances et par la capacité collaborative d'une entreprise donnée. Ces dimensions se rattachent aux aspects de contenu, de structure et de gouvernance des business models. Les données pour la troisième phase d'étude ont été analysées selon les dimensions du *middleground* afin d'identifier les acteurs, et la nature de leurs interactions dans la poursuite de la création, capture et livraison de valeur d'initiatives en OSH.

Finalement l'ensemble des projets a été analysé suivant les dimensions d'évaluation du Open-O-Meter (Bonvoisin *et al.*, 2017), du Sharing Star (Fuster & Espelt 2018), et des dimensions identifiées par Troxler (2010) pour l'analyse des business models de Fab Labs, à savoir la proposition de valeur, les modèles de revenus, les processus et ressources, le marketing déployé ainsi que les partenariats d'innovation. Suite à notre première étude, l'équipe du projet OPEN ! a cherché à évaluer le degré d'ouverture d'un projet basé sur sa documentation. Au fil de la recherche, nous avons découvert le modèle du Star Framework, développé par l'équipe DIMMONS. Dans une perspective itérative de co-création de standards ouverts, il nous a semblé que les deux approches étaient complémentaires. En effet, l'OSH ne trouve pas seulement sa finalité dans l'ouverture technologique (Bonvoisin *et al.*, 2017), mais surtout dans l'action d'une gouvernance ouverte, et co-créée, visant à gérer collectivement un bien commun. Se basant sur plus de cent cas d'études sur des plateformes digitales collaboratives basées sur les communs dans la région de Barcelone, les chercheurs Morell & Espelt (2018; 2018) ont pu établir une corrélation entre les dimensions d'ouverture de gouvernance, de technologie et de

connaissance. Leur Star Framework lie ces dimensions à celles non moins importantes d'impact environnemental et sociétal. Nous avons donc décidé d'intégrer ses outils pour l'évaluation de l'ouverture des projets étudiés.

3. RESULTATS

Pour le premier niveau d'analyse sur les communautés en OSH, nous avons pu observer deux phénomènes. Le premier est qu'un nombre significatif d'initiatives étudiées répond à un enjeu environnemental ou sociétal majeur. Aussi, il semblerait que les projets à plus fort impact, sont ceux qui génèrent le plus de contributions d'une communauté étendue à l'inverse de ceux faits « juste pour se divertir ». Nous pouvons aussi observer différents types de flux de revenus utilisés. Les propositions de valeur couvrent un large spectre passant d'options « à faire soi-même » (*Do It Yourself*), à des kits d'assemblage, des ateliers, des services de maintenance, des abonnements, des options personnalisables, jusqu'à l'achat de produits finis. Deuxièmement, nous observons une équation de type Pareto, où la plupart des revenus viennent de l'achat de produits finis et servent à faire vivre le projet, tout en poursuivant son développement. Cependant, le cœur de la proposition de valeur se situe dans le développement communautaire ouvert, sans quoi les projets perdent de l'élan. Cette offre au large spectre semble nourrir le processus d'adhésion à la communauté. Les consommateurs sont progressivement incités à participer davantage au processus de développement des produits.

Les données de notre deuxième niveau d'analyse sur l'interaction entre les entreprises et les communautés OSH ont montré l'importance d'une cohérence entre d'une part une culture organisationnelle ouverte et d'autre part le succès d'initiatives comme OSH. L'OSH est surtout utilisé comme un espace cognitif pour développer les capacités collaboratives des entreprises avec des communautés d'innovation internes, externes et mixtes. En étudiant les dimensions de valeur générée par la co-création, les flux de connaissances et les capacités collaboratives des entreprises, nous avons pu constater que la plupart des entreprises envoient des éclaireurs repérer les possibilités et les risques associés. Nous observons une variété de réponses à l'OSH utilisé soit comme un démonstrateur de changement, soit comme une approche de marketing visant à montrer aux usagers que leurs suggestions sont prises en compte. Le manque de clarté au-niveau de la propriété intellectuelle concernant les droits d'auteurs et les brevets apparaît comme un frein majeur à l'adoption de l'OSH comme mode de conception.

Les données sur notre troisième niveau d'analyse sur l'écosystème de Barcelone ont révélé l'importance des valeurs comme facteur de soutien entre les parties prenantes. Pour le cas de Barcelone, on peut trouver un front commun de valeurs centrées sur la démocratie, la citoyenneté, et la souveraineté technologique, énergétique et alimentaire. Les projets avec une mission de technologie au service des citoyens étaient mieux à même d'être incubés et accélérés par différents organismes, de recevoir du soutien financier ou de la couverture médiatique. De plus, nous avons pu constater un processus à plusieurs itérations que peuvent suivre les porteurs de projets en OSH afin d'enrichir leur projet en termes de portée et d'échelle.

Finalement, notre analyse transversale nous a permis de faire deux constats. Premièrement, il n'existe pas un seul business models de l'open source de produits physiques, mais plusieurs. Deuxièmement, ces initiatives de collaboration ouverte peuvent s'inscrire dans des perspectives long terme, et pas seulement à court-terme pour répondre à des défis spécifiques (Tech *et al.*, 2017). Faisant écho au principe de modularité intrinsèque à l'OSH, nous avons pu observer des archétypes de business models utilisés comme des briques de construction qui se recomposent en fonction des besoins, des ressources et de la stratégie qu'une organisation décide d'employer. Nous avons organisé cette typologie dans un modèle en spirale en partant des activités qui étaient le plus fréquemment utilisées par les projets étudiés à celles qui étaient le moins répandues, et générant potentiellement, le plus de risques. Ce modèle en soi n'est pas prescriptif. C'est un outil créatif. Les étapes ne sont pas forcément linéaires, et la cinquième étape n'est pas forcément la visée de tous les projets. Cependant, considérées d'une manière cyclique et itérative, elles permettent à un porteur de projet d'affiner progressivement son business model en gagnant en perspective à chaque étape, comme quelqu'un gravissant une montagne, changeant de perspective en fonction de son altitude. Ces innovations peuvent avoir un modèle économique durable, par l'effet levier de partenariats privés ou publics (entrepreneurs, universités, décideurs politiques...) qui va démultiplier la visibilité et donc le soutien financier, la combinaison de ventes de produits et de services. Ce nouveau modèle de développement de l'innovation repose sur l'intelligence collective pour la recherche de solutions économiques et environnementales durables adaptées au contexte local. Selon Thomas Huriez, le fondateur de la marque de jeans éthique 1083 avec qui nous avons testé notre modèle, « *le but est de réussir à créer des business models qui sont non-compétitifs avec nos alliés, mais qui rentrent en compétition avec le modèle actuel* ».

4. CONTRIBUTIONS DE LA RECHERCHE

Notre recherche permet de mieux comprendre en quoi les communs digitaux sont stratégiques et constituent le fondement de nouveaux business models dont l'ancrage est à la fois global et local. En accord avec Breuer & Lüdeke-Freund (2017), nos résultats démontrent le rôle crucial des valeurs pour cimenter la participation des parties prenantes au business model, afin de faire grandir la portée d'un projet donné ainsi que sa valeur économique, sociétale et environnementale.

Notre recherche montre qu'une « approche business model » (Demil *et al.*, 2018; Demil & Lecocq 2010) est en effet nécessaire pour que les initiatives en OSH montent en puissance (Chesbrough & Bogers 2014, p.21). En effet, notre typologie démontre des constellations d'activités qui évoluent au fil du temps à mesure qu'une organisation découvre son écosystème dans une logique d'effectuation (Sarasvathy 2001), c'est-à-dire une perspective d'essais et d'erreurs pour affiner progressivement son business model en fonction de ses ressources de ses capacités. Les composants clés des business models interagissent de manière dynamique au fil de rencontres avec de nouveaux partenaires, de la prise de maturité des projets, et de la découverte de nouveaux besoins pour les utilisateurs. Nous montrons comment différents flux de revenus peuvent être activés afin de créer une architecture d'activités par lesquelles de la valeur est créée, capturée et délivrée, d'une manière spécifique à l'OSH, et qui de plus, laisse des niches profitables aux autres parties prenantes (Gassman *et al.*, 2014, p. 231).

THEORIQUES

Notre principale contribution théorique s'appuie sur la théorie des communs que nous avons contextualisée pour analyser les business models de OSH. Nous montrons comment des initiatives de production par les pairs, basées sur les communs peuvent réussir à générer des revenus, tout en gardant le cœur de leur innovation ouverte, et en partageant la création et la capture de valeur avec d'autres. Notre modèle en spirale utilise les principes de redistribution et de générativité propres aux communs, ce qui nous permet d'illustrer la notion de générativité, à savoir la capacité humaine à résoudre des problèmes de manière créative, de multiples façons et adaptées à une multitude de contextes différents.

Nos résultats permettent de mettre en lumière des prérequis nécessaires à la mise en œuvre de business models pour l'OSH. Le constat de départ est la nécessité d'un changement de posture. Face à des changements technologiques et sociétaux profonds, sous fond de changement climatique, les entreprises doivent s'appuyer sur leurs réseaux pour créer des offres adaptées

(Breuer & Lüdeke-Freund 2017). Il est nécessaire de passer d'une logique centrée sur l'intérêt personnel et la rareté à celle de l'intérêt collectif et de l'abondance, sur laquelle se base la production par les pairs, elle-même basée sur les communs. Effectivement, à la différence des communs naturels, les communs digitaux et la connaissance deviennent plus efficaces et transparents, et en somme gagnent de la valeur, quand ils sont partagés.

De plus, nous avons pu constater l'importance des valeurs centrées sur les principes de liberté, de démocratie, et de souveraineté (technologique, énergétique, alimentaire) comme facteur liant les interactions entre les membres des communautés et un ensemble plus large de parties prenantes. Au niveau communautaire, les projets OSH portant une vision sociétale et environnementale forte avaient plus de chances de recevoir des contributions externes que d'autres. Au niveau de l'écosystème, nous avons pu voir que des projets qui présentaient un « front commun » de valeurs centrées sur la technologie au service des citoyens étaient davantage sollicités par les parties prenantes externes. Les contributions de ces projets n'étaient pas forcément basées sur des nouveautés techniques, mais présentaient un intérêt d'une autre nature, comme l'incubation, la couverture médiatique ou du soutien financier, ou politique.

L'autre prérequis que nous avons identifié est la nécessité d'un mode de gouvernance imbriqué dans tous les niveaux des écosystèmes d'OSH et de leurs *middlegrounds*. En conformité avec nos résultats sur l'importance des valeurs, nous suggérons que cette gouvernance doit être axée sur les valeurs afin de promouvoir des processus d'innovation génératifs, décentralisés et bottom-up. Ce point correspond à l'un des principes de succès des ressources communes identifiés par Ostrom (1990 ; 2011). Selon elle, les valeurs essentielles intrinsèques à un commun quel qu'il soit sont « *inévitablement liés à l'équité, l'efficacité et à la pérennité* ».

Compte tenu de l'augmentation de plateformes de production digitale, les initiatives en OSH ont maintenant un impact local et mondial. Ceci correspond à ce que Capdevila (2017) nomme « *le caractère géographique multi-niveaux des processus d'innovation* ». Ce mode de gouvernance imbriquée signifie que les initiatives en OSH doivent non seulement participer aux *middlegrounds* de leurs écosystèmes afin de bâtir des consortiums mais elles doivent également devenir des *middlegrounds* afin d'assurer une interaction dynamique entre les membres de la communauté.

Le troisième prérequis à la diffusion d'initiative d'OSH est la création de « manifestes » et de codebooks afin de faire grandir la communauté. Ces documents servent à exprimer de nouvelles règles qui guideront le travail cognitif de la communauté (Cohendet *et al.*, 2014, p.

235). L'OSH est un phénomène peu connu du grand public, cependant les initiatives que nous avons étudiées ont souvent des buts sociétaux et environnementaux positifs. Ces processus, liés à l'économie circulaire, ont besoin d'être open-sourcés car le potentiel de régénération de la production circulaire ne peut pas être atteint par les entreprises individuelles qui cherchent à la réaliser dans leurs propres usines : ce serait une base illogique et irréalisable pour la création d'une économie circulaire.

Nous pensons cependant que la valeur créée par l'OSH va au-delà du recyclage d'éléments technologiques ou biologiques décrit par le modèle de l'économie circulaire de la Fondation Ellen Mac Arthur. L'OSH offre le potentiel de renforcement des capacités humaines, c'est l'aspect de design *génératif* offert par les communs digitaux. Les technologies dites « latérales » de fabrication digitale permettent de démocratiser l'innovation. Les infrastructures plus ou moins formelles comme les Fab Labs, les Hackers ou Maker Spaces ou les Repairs Cafés permettent à quiconque de monter en compétences techniques de passer de l'idée au prototype. La générativité permise par l'OSH permet de casser la dépendance technologique des citoyens et de les transformer, de consommateurs passifs, à producteurs et concepteurs actifs des objets dont ils ou elles ont besoin, que ce soit une chaise, une video caméra ou même une maison (Berrebi-Hoffman, Bureau, Lallemand, 2018). Le concept de générativité tel qu'il est porté par la théorie des communs digitaux permet de développer les compétences humaines pour co-créeer des solutions locales aux problèmes mondiaux (Raworth, p.220).

MANAGERIALES

Dans une perspective managériale, nous proposons des outils concrets afin de 1) bâtir une communauté autour de projets en OSH et 2) graduellement bâtir un business model permettant une stratégie long-terme.

Basé sur notre cas d'étude de Barcelone, notre approche illustre comment des projets en OSH peuvent grandir via des interactions successives avec les parties prenantes de leur écosystème. Le modèle « flipper » que nous avons développé est utile pour des initiatives émergentes (Figure 34). Il explique les étapes proactives qu'une initiative en OSH peut suivre afin de gagner l'appui de sphères du *upperground*, construire leur *middleground* et un consortium à la fois local et global.

Nous proposons ensuite un cadre d'analyse des différentes constellations d'activités dans lesquelles s'engagent les entrepreneurs en OSH lorsqu'ils créent et capturent de la valeur en

interagissant avec un ensemble plus large de parties prenantes. Les trois premières phases du modèle sont des stratégies assez communes pour des entreprises industrielles. Les deux dernières requièrent un changement de mentalité du modèle extractif sur lequel fonctionne notre économie actuelle, vers un mode plus démocratique et génératif.

Les deux modèles (Figure 34, Figure 48) décrivent un processus d'apprentissage qui permet aux initiatives en OSH de grandir en portée en interagissant avec les acteurs de leur écosystème.

Enfin, nos résultats font apparaître une condition de mise en œuvre des business models orientés vers les communautés. Nous montrons que le processus d'ouverture ne peut être mis en place que s'il est cohérent avec la culture organisationnelle en place et les valeurs partagées par les parties prenantes. Ainsi, notre recherche permet d'établir que la création de laboratoires d'innovation internes, externes et mixtes permet à l'ensemble des acteurs d'apprendre progressivement à interagir avec les communautés d'innovation.

METHODOLOGIQUES

Lors de cette recherche multidisciplinaire, nous avons développé le concept des écosystèmes en OSH, comme une unité de mesure distincte à trois niveaux. Nous l'avons dimensionnée en utilisant le concept du *middleground* afin de comprendre les mécanismes d'interaction nécessaire pour animer la participation d'une communauté. Nous lions les résultats à l'ampleur de la diffusion des initiatives grâce à leur nature distributive et générative. Nous avons identifié les valeurs démocratiques, citoyennes et de souveraineté, comme le ciment nécessaire à une participation communautaire.

5. LIMITES

La principale limite de cette recherche est que nous n'avons pas eu le temps de valider nos résultats en organisant des ateliers avec des praticiens. Ainsi, l'application du modèle dialogique, basé sur des échanges constructifs entre théorie et pratique, reste à mettre en œuvre dans différents contextes. La présentation de nos résultats lors d'ateliers, notamment à La Comunicadora en Espagne ou au programme REMODEL au Centre Danois du Design, permettra dans un avenir proche d'améliorer la compréhension des processus que nous avons identifiés.

D'un point de vue méthodologique, cette recherche présente des résultats émergents et novateurs. Par exemple, le classement des projets ainsi que les corrélations qui en ont découlé dans la première phase d'étude, ont besoin d'être validés par d'autres travaux quantitatifs. Le

Fleiss kappa utilisé pour évaluer la fiabilité inter-coder était faible, suggérant un manque de compréhension commune entre les coders. Cela s'est produit malgré tous les efforts mis en place afin d'instaurer une compréhension commune parmi les chercheurs du projet OPEN!.

Un autre résultat qui mérite d'être revisité par une analyse quantitative est la corrélation, dérivée de notre premier niveau d'analyse, entre des projets de portée « hautement critique » et la dimension de décentralisation des contributions. Nos résultats montrent que les projets servant simplement à se divertir génèrent moins de contributions que ceux avec une portée hautement critique. Bonvoisin *et al.*, (2018), dans une étude utilisant une approche d'exploration de données sur la plateforme Github de mars 2016 à mars 2018, ont observé que les projets OSH avec les communautés les plus actives étaient moins complexes que les projets industriels généralement fermés. Une analyse quantitative sur au minimum 100 projets permettrait de voir si les projets OSH à portée sociale et environnementale hautement critique reçoivent le plus de contributions, même si la collaboration demeure inférieure à celle des projets industriels fermés.

Notre recherche pourrait également être enrichie par une étude longitudinale afin de pouvoir étudier l'évolution d'un processus et d'évaluer des liens de causalité. Ceci serait particulièrement utile dans le cas de l'industrie automobile, afin d'observer si des initiatives en OSH permettraient de faire évoluer les business models ou non.

Enfin, notre recherche n'aborde pas assez les aspects légaux cruciaux aux questions d'open source. Le cadre légal nécessaire pour donner des lignes directrices et des sanctions en cas de violation de brevets n'est pas abordé—dans cette recherche. Nos conversations avec les praticiens ont révélé que « *nous sommes à l'âge de pierre des réglementations concernant les plateformes coopératives basées sur les communs* ». Les réglementations légales semblent être en retard par rapport aux pratiques des communautés d'OSH et de celles du public. C'est pourquoi un géant du numérique « manquant de bonne foi » peut aisément s'emparer d'une initiative en OSH et la transformer en innovation fermée. Les praticiens avancent de manière optimiste que ce type d'action pourraient être bénéfique si une grande firme s'emparait de leur innovation, parce qu'ainsi elle pourrait ainsi faire référence, voire devenir la norme. Il n'en demeure pas moins que le manque de clarté concernant les aspects juridiques propres à l'OSH est une barrière significative d'adoption au sein des entreprises.

6. PERSPECTIVES FUTURES

Nous avons observé comment les entreprises cherchaient à créer des business models autour d'initiatives en OSH. Cependant, dans les secteurs étudiés, l'inertie opérationnelle semblait si lourde que certains de nos exemples phares, comme Local Motors ou Renault, utilisaient principalement leurs initiatives comme démonstrateurs de changement, mais celles-ci n'irriguaient pas véritablement le reste de l'organisation. Dans un premier temps, il serait intéressant d'étudier si l'OSH permet de renforcer à long-terme les capacités collaboratives de ces entreprises en matière d'innovation, et s'il permet de faire évoluer l'ensemble de leurs business models. En utilisant une analogie dans le domaine médical, on pourrait se demander de quelle manière les initiatives en OSH « infectent » leur hôte et en changeant les processus opérationnels, et auraient dans ce contexte, une nature « virale ». Le concept du *middleground* pourrait offrir une bonne opportunité de dimensionner cette recherche afin d'évaluer les points d'entrée de cette contamination, ainsi que les freins qu'elle rencontre.

Dans un deuxième temps, il serait intéressant d'étudier le rôle de l'OSH comme facteur de générativité dans certaines industries, et la manière dont l'OSH pourrait contribuer à replacer ces industries dans la zone de sécurité du « Doughnut » évoqué par Kate Raworth (2017). Par exemple, le secteur textile est l'un des plus polluants de la planète, comprenant une chaîne de production allant de l'agriculture à la distribution et vente au détail. Notre modèle permettrait d'analyser les compétences organisationnelles nécessaire à la modernisation des chaînes de production en impulsant l'innovation, la production et la consommation de manière plus pérenne. Dans la lignée des travaux de Fletcher and Grose (2011), nous pourrions nous demander de quelle manière des solutions en OSH pourraient être appliquées pour créer une industrie textile intégrée et générative.

Une troisième piste de recherche serait de comparer différents cas d'écosystèmes fondés sur des approches OSH afin de valider nos travaux sur les facteurs permettant aux initiatives en OSH de se développer. Le livre blanc des Fab Cities fournit une bonne base pour la sélection de cas. Nous pourrions, par exemple, opposer d'anciennes bases d'industrialisation utilisant la fabrication digitale pour réincorporer des activités de production dans les villes, à la réalité de certains méga-centres comme la ville de Shenzhen, en Chine qui actuellement est « l'usine des usines ».

Enfin, il serait utile de poursuivre les travaux d'Ostrom portant sur les principes de design « d'institutions de ressources communes, solides et durables » afin de mieux intégrer des

considérations d'ordre juridique dans la théorie des communs. D'une part, ces principes pourraient être actualisés au contexte des communs digitaux et de connaissance, et d'autre part ils seraient utiles dans la création de standards afin de voir comment ils pourraient être appliqués, voire imposés, en cas de violations. L'idée est de passer de l'ordre de l'agencement épistémique, fonctionnant sur la création de manifestes et de codebooks, à la garantie des droits de souveraineté individuelle et collective. Ce travail servirait à requestionner la notion de contrat social à l'ère du numérique, et d'instaurer des standards éthiques et démocratiques pour que les plateformes coopératives basées sur des communs puissent assurer un système génératif et non-aliénant.

7. STRUCTURE DE LA THESE

Les chapitres sont articulés selon la logique du modèle dialogique d'Avenier & Cajaiba (2012; 2013) (voir Figure 1). Les cinq types de processus ont été organisés en trois parties de deux chapitres chacune.

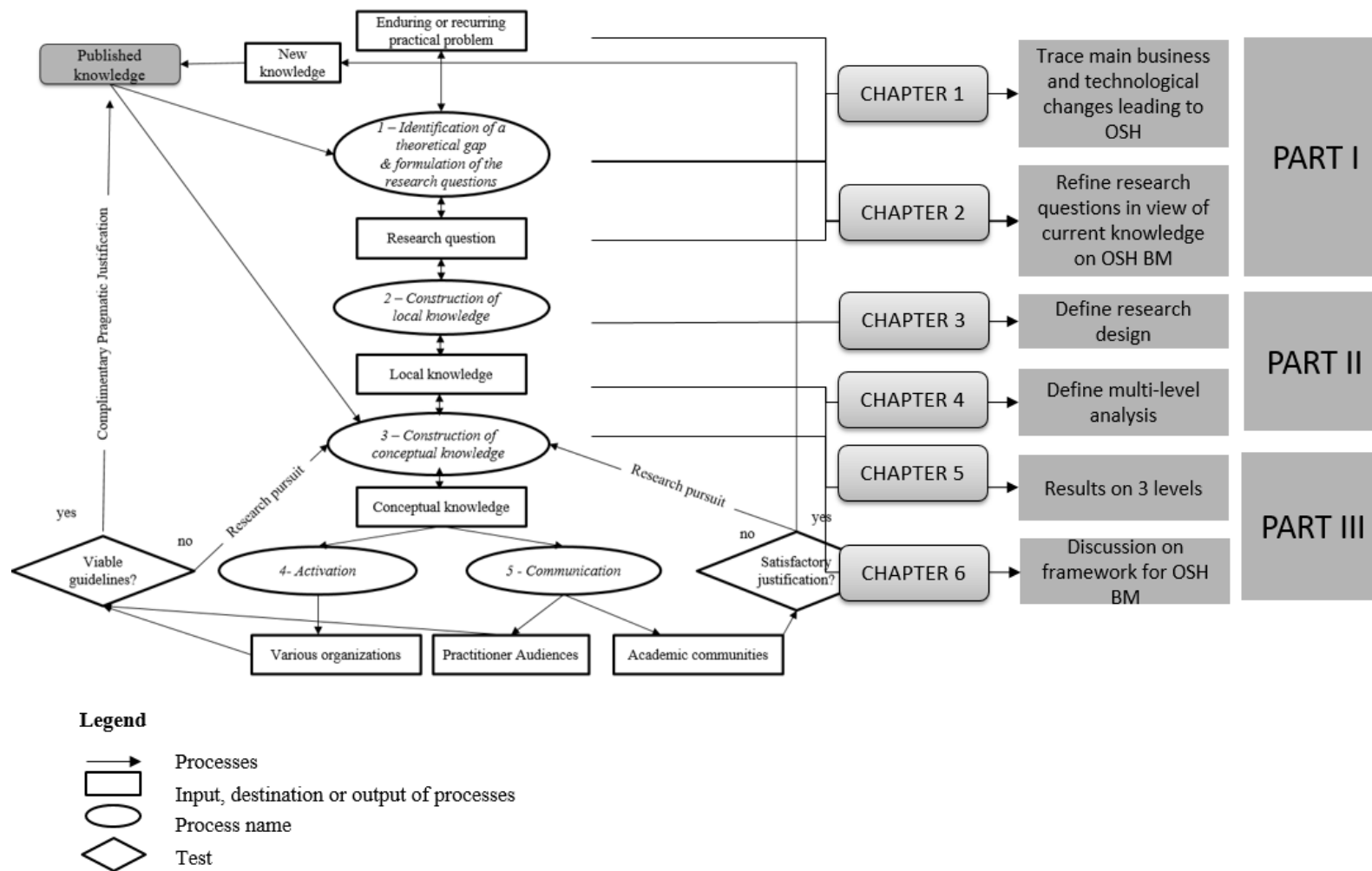


Figure 1: Structure de la thèse suivant le modèle dialogique

La **PARTIE I** présente la revue de littérature permettant de justifier notre cadre conceptuel, le choix théorique et d'affiner les questions de recherche. Cette section est le fruit d'interactions et d'échanges avec l'équipe OPEN! et de plusieurs séminaires, ateliers et conférences auxquels nous avons assisté durant trois années. Elle est aussi nourrie par les revues de littérature systématiques qui ont été menées.

Le **Chapitre 1** positionne le phénomène de l'OSH entre l'approche entreprise de l'open innovation et celle, plus communautaire, des communs digitaux. Afin d'opérationnaliser la recherche sur les acteurs et leurs interactions, nous avançons l'idée que les communautés d'OSH sont des communautés hybrides : un mélange entre des communautés de pratiques et des communautés épistémiques. Nous justifions le recours au concept du « middleground » comme moyen d'étudier les mécanismes d'interaction autour de la création de valeur en OSH.

Le **Chapitre 2** établit une synthèse des recherches sur les business models, puis sur les business models « ouverts », et enfin sur les business models de l'open source hardware. Nous suggérons que lors de situations collaboratives, les interactions et les « liens doux » qui cimentent les business models sont tout aussi importants que les éléments qui les composent dans ces nouvelles configurations où les frontières traditionnelles entre clients et créateurs deviennent de plus en plus floues. Le chapitre 2 se termine sur les lacunes identifiées et présente les questions de recherche.

La **PARTIE II** présente l'approche méthodologique de notre recherche.

Le **Chapitre 3** explique le choix d'une posture épistémologique de type constructiviste pragmatique et expose nos choix méthodologiques. Afin d'étudier le phénomène empirique et émergent de l'OSH, nous avons opté pour une approche qualitative, suivant un raisonnement abductif. Nous avons choisi d'élaborer sur la théorie des communs en utilisant plusieurs cas d'études.

Le **Chapitre 4** justifie notre choix d'une analyse multi-niveaux en présentant les écosystèmes de l'OSH comme l'unité de mesure de notre recherche. Cela nous a permis d'aborder un ensemble plus large de parties prenantes à travers lesquelles la valeur est créée, capturée et partagée. Nous expliquons la manière selon laquelle les données empiriques, sur trois niveaux, ont été collectées et analysées.

La **PARTIE III** présente nos résultats et les discute afin de faire émerger les implications de notre recherche.

Le **Chapitre 5** présente les résultats de notre analyse multi-niveaux utilisant les dimensions clés de l'open design (Fjeldsted *et al.*, 2012), les outils d'analyse complémentaires de l'Open-O-Meter (Bonvoisin, Mies *et al.*, 2017) et du Sharing Star (Fuster & Espelt 2018), ainsi que les dimensions pour l'analyse des business models identifiées par Troxler (2010). Pour étudier comment les entreprises des secteurs établis de l'automobile et du textile répondaient à l'innovation issue de communautés en OSH, nous avons utilisé le modèle de contingence développé par Saebi & Foss (2015).

Le **Chapitre 6** présente une typologie des business models de l'OSH. Nous les avons catégorisés dans un modèle en spirale qui présente un processus itératif au travers duquel les initiatives d'OSH peuvent générer des revenus, et élargir la création et la capture de valeur à un ensemble plus large de parties prenantes dans leurs écosystèmes. Nous présentons les prérequis nécessaires pour aider les entrepreneurs en OSH à se forger une conviction personnelle afin de collaborer avec d'autres, et nous présentons des recommandations pour une mise en pratique du développement de produit en OSH afin de présenter une vision stratégique et concrète à long-terme.

En conclusion, nous présentons nos contributions théoriques et managériales à la théorie des communs en expliquant en quoi notre approche permet de comprendre les initiatives en OSH comme étant redistributives, régénératives et génératives par nature. Enfin, nous exposons les limites de notre travail et suggérons des pistes pour des recherches futures.

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GLOSSARY

Terms	Definition	Selected references
Business Ecosystem	“An economic community supported by a foundation of interacting organizations and individuals [...] produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders. Over time, they coevolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies”.	(Moore, 1996, p.26)
Innovation ecosystems	“The collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution. Enabled by information technologies that have drastically reduced the costs of coordination, innovation ecosystems have become a core element in the growth strategies of firms in a wide range of industries.”	(Adner, 2006, p. 1).
Knowledge ecosystems	“The flow of tacit knowledge between companies and the mobility of personnel have been advanced as the main advantages of geographic colocation which characterize these hotspots. Such hotspots have been characterized as knowledge ecosystems where local universities and public research organizations play a central role in advancing technological innovation within the system.”	(Clarysse <i>et al.</i> , 2014, p. 1).
Peer production	The emergence of a mode of creation and production of value that is free, just and sustainable, promoting diffusion and co-creation among commoners	(Bauwens, 2005; Benkler, 2017 ; Acquier, Carbone, Massé, 2016

Open commons	Systems that eschew the core of property-the allocation of asymmetric rights to exclude, use, and manage the resource set whose use they govern-and instead offer (a) symmetric access and use privileges to (b) an open class of potential users.	(Benkler, 2013)
Common Pool Ressources	Forms of property that do not rest on private or state regulation but on collective management.	(Acquier, Carbone, Massé, 2016)
Knowledge commons	Intelligible ideas, information and data that is jointly used and managed by groups of varying sizes and interest.	(Hess, Ostrom, 2011, pp. 5-7)
Commons based peer production	Forms of production in which, with the aid of the Internet, the creative energy of a large number of people is coordinated into large, meaningful projects without relying on traditional hierarchical organizations or monetary exchanges and rewards	(Benkler, 2006).
Collaborative economy platforms	This term refers to exchange, sharing, and collaboration in the consumption and production of capital and labor among distributed groups, supported by a digital platform	(Fuster-Morell & Espelt, 2018)
Generative Justice	« The universal right to generate unalienated value and to directly participate in its benefits; the right of value generators to create their own conditions of production; and the right of communities of value generation to nurture self-sustaining paths for its circulation”.	(Eglash, 2016, p. 381)
Innovation mechanisms	Mechanisms are “the wheelwork or agency by which an effect is produced” that support the social phenomenon of innovation.	(Hernes, 1998, p. 74; Parmentier, 2015, p.80)
Shared value	The creation of economic value in a way that also creates value for society by addressing its needs and challenges	(Porter & Kramer, 2011)
Coupled innovation process	facilitates co-creation with trusted partners while relying on external resources to develop innovation and create value while also creating new revenue streams by externalizing knowledge	(Enkel <i>et al.</i> , 2009; Sandulli & Chesbrough, 2009)

LIST OF ACRONYMS

CoP	Communities of Practice
FLOSS	Free/Libre Open Source Software
FOSH	Free Open source hardware
FOSS	Free Open source software
IAAC	Institute for Advanced Architecture Catalonia
OBM	Open Business Models
OSH	Open source hardware
OSHBM	Open source hardware business models
OSPD	Open source product development
PECP	Pragmatic constructivism epistemological paradigm
SDGs	Sustainable Development Goals
OCCs	Online Creation Communities
OSHBM	Business models for Open Source Hardware

INTRODUCTION

1. RESEARCH CONTEXT

Driven by a social undercurrent, technology is changing rapidly in ways that are harder to predict. These shifts involving artificial intelligence, the internet of things, big data, 3D printing and additive manufacturing, cloud computing and so forth are being blanketed as the 4th industrial revolution. This revolution is described as the digitalization of industry in the broad sense, where digitalization is integrated into product development and associated means of production (Gaudron & Mouline 2017).

Richard Branson, in 2014, at the Davos Economic Forum was impressed with Jeremy Heimans the founder of Avaaz and other citizen participatory actions. He wrote in his blog, “this transformation is not a technological one – it might be enabled by technology, but it’s driven by people and their changing attitudes to participation and change. Jeremy contrasts old power, which he likens to a currency (held by a few, closed and inaccessible) with this “new power” which is more like a current (made by many, open and peer-driven)”³.

These changes imply that business is changing as well, flipping around the roles of customers and producers in new ways. Some of the radical changes involve the words: more distributed, decentralized, more collaborative, more engaging, more networks in terms of ecosystems, and working with different types of partners, more shared.

Headlines claim that large companies from IBM and Red Hat to Google are paving the way for a roadmap to open innovation. Dubbed as “open source hardware” (OSH), companies such as Baidu and Tesla are making their car platforms⁴ or building plans freely available to the automotive industry. The movement appears to be progressing to NGOs with UNICEF launching a venture fund of open-source civic technology⁵. The United Nations 2030 Vision report states that digital technology and open source will be critical enablers on the journey to implementing sustainable development goals (SDGs).

In line with its official definition, we consider Open Source Hardware (OSH) innovation to be a collaborative, product development process, in which building plan designs, assembly instructions and bills of material are made publicly available for anyone to study, replicate,

3 <https://www.virgin.com/richard-branson/occupy-yourself>

4 <https://techcrunch.com/2017/04/18/baidu-project-apollo/>; <https://www.bloomberg.com/news/articles/2014-06-12/why-elon-musk-just-opened-teslas-patents-to-his-biggest-rivals>

5 <https://www.fastcompany.com/3056420/unicef-is-launching-a-venture-fund-for-open-source-civic-technology>

modify, distribute, and sell, including the hardware created, based on those designs (Raasch *et al.*, 2009; Bonvoisin *et al.*, 2017; Bonvoisin *et al.*, 2017).

By open sourcing their innovations, firms relinquish some of their rights on behalf of motivated external participation and a certain sense of contributor co-ownership. The two main advantages of this approach are: 1) hyperinnovation, where the capacity of thinking up new ideas is accelerated; 2) building communities of co-creators by expanding resources to the externalities of the market. If the blueprint of the innovation is rendered open to community participation however, organizations engaging in OSH have to come up with creative ways of capturing value. How does one go about building a non-competitive business model in a competitive economy? If open business models rely on creating and capturing value with an ecosystem of actors (Frankenberger *et al.*, 2014), how does a firm go about making money? This is the precisely the tension that this works seeks to address.

Studying the business models for OSH is very problem oriented, and phenomena-anchored. In line with members of the REMODEL team from the Danish Design Center, we propose that creating a business model is a design, or we can chose to frame that activity as a process of designing. A design activity targets designing something very concrete and very tangible. Design activity is also a set of creative processes that are focusing on creating value, and this can be applied at all scales, including the scale of a business model (Bason, 2018). The design of a business model is not something that can be copied from elsewhere. Rather, it requires a thorough assessment of “what works for us”: a firm’s understanding of its core competencies and resources.

2. IMPORTANCE OF RESEARCH

Business models for OSH are considered a new frontier. Historically, since open source initially excluded business ambitions, the non-monetary focus of commons based peer production baffled researchers like Chesbrough (2003). Indeed how can a business model be built around intellectual property rights? How can value creation be based on a collective good?

Despite these questions, business models for open source hardware emerge in practice. OSH is similar to Wikipedia in the sense that, according to De Filippi, (2018), “Wikipedia only works in practice, in theory it doesn’t work”.

The phenomenon of “business models for open source hardware” is at the confluence of different streams in literature: Open Innovation (OI) from a firm’s perspective, OSH from a

community perspective, business model literature and literature on platform-based digital commons.

2.1. COMMUNITY-ORIENTED VERSUS COMMUNITY-BASED BUSINESS MODELS

Academic literature contrasts two divergent views, which Wolf & Troxler (2016) aptly summarize as community-oriented and community-based business models. Literature on open innovation is in line with community-oriented business model, whereby focal firms “strive to find an appropriate revenue model (...) that would be both acceptable to their (...) clients and allow them to maximize their profits”. Community-based business models, on the other hand, do not start from the focal firm aiming to create a community around it. They are concerned with a (focal) firm that emerges from the context of some collaborative, networked, user community. This community composed of users, freelance or hobby engineers, referred to commonly, as “makers” tend to take advantage of unifying punctually their creative skills in order to create products. This falls under the scope of OSH as it was defined in the multi-disciplinary OPEN! Project which is the origin of this research⁶.

2.2. OPEN! PROJECT

The goal of the OPEN! Project, initiated in 2016 and co-financed by the German and the French national research foundations, was to understand and model methods and tools for community-based and open source product development. The OPEN! project marked the difference between open source hardware, often understood as disclosing product openness ex post (OSH), and product development, where the product development process itself is opened up for contributions (OSPD). This innovative organization of product development based on a new conception of copyright as well as decentralized and voluntary work offers a disruptive alternative to conventional industrial product development. It provides a great opportunity for continuous improvement of products as well as formidable potentials for product innovation and incubation of new businesses.

The goal then sought to identify concrete support and methods adapted to ensuring significant process efficiency and economic viability for OSPD, beyond toys for do-it-yourself hobbyists. The project was divided into four workpackages, carried out by a multidisciplinary consortium involving French and German research laboratories and companies. It is being/was led by French and German industrial engineering laboratories (G-SCOP [Fr], TU Berlin/IWF [De])

⁶https://opensourcedesign.cc/wiki/index.php/OPEN!_Methods_and_tools_for_community-based_product_development

and involves contributions from business economics (HU Berlin/HIIG [De]) and innovation management sciences (CERAG [Fr]). The scope of this research falls under WP4 which seeks to define guidelines for business models helping entrepreneurs reduce risks associated with the development of business models based on open source.

2.3. BUSINESS MODELS & OPEN BUSINESS MODELS

For this work we abide by Teece's (2010) definition of business models as the architecture of activities through which a firm creates, captures and delivers values. In line with Frankenberger *et al.*, (2014, p. 175), we see open business models as a subclass of business models, in which “collaboration of the focal firm with its ecosystem is a decisive or novel element of value creation and capturing”. Therefore, necessarily, along with Massa *et al.*, (2016), we agree that research on the OSH BM needs to extend value creation, capture and delivery beyond a focal firm to a wider set of stakeholders. Going past static components, the key question is what links the components of key suppliers, partners and resources (Jouison & Verstraete 2008). We understand that OSH BMs are dynamic, and should be used as creativity tools for projects and organizations in answer to the “what is right for us” question, and to design through trial and error an appropriate and evolving business model. From the work of our fellow OPEN! Team members, Tech *et al.*, (2017) we retain that a blurring of boundaries exists between partners and customers in open business models, that there is a lack of discussion on what revenue streams Open BMs can activate, and value capturing that benefits more than one focal firm.

2.4. COMMONS THEORY

What is lacking in literature concerning Open Innovation, OSH or business models, is an overarching theory that fits the phenomenon of business models for open-source hardware. Foss & Saebi (2018, p. 10) list the theories that have been used to treat BM and BMI: dynamic capabilities, threat rigidity and prospect theories, entrepreneurship theory, TCE, RBV, managerial cognition, replication and competition... Yet none of these successfully address the notion of how to remain sustainable and economically viable, while *not* being competitive, *and* opening up the core value of your innovation to collective product development.

Since the OPEN! Project goal was to identify concrete support and methods adapted to ensuring significant process efficiency and economic viability for OSH, “beyond toys for do-it-yourself hobbyists”, we chose the Commons theory as the overarching foundation for our work.

This theory introduces a new cast in economics and proves that collective action, following community created guidelines, outperforms both state and market in sustainably stewarding and equitably harvesting a common, whether natural or digital (Raworth, 2017, p.83; Benkler 2013).

3. RESEARCH OBJECT

The purpose of this research is to present practitioner and academic findings on business models available for Open Source Hardware (OSH) in a comprehensive and actionable manner. Despite the exponential rise in designs for open hardware released under open source, research on business models for OSH lacks a holistic integration of academic and practitioner perspectives (Fuster Morell *et al.*, 2017; Gassman *et al.*, 2014; Pearce 2017; Tebbens 2017; Stacey, 2016; Tinck & Bénichou, 2014; Wolf & Troxler 2016). Our goal is therefore to combine and simplify overlapping and disparate findings for pedagogical and strategic purposes, displaying the unique and novel potential that OSH offers to management science.

3.1. DIMENSIONING BM RESEARCH

In order to make research on business models “fundamentally researchable and cumulative” Foss & Saebi (2018) advise clarifying the following issues. The first is identifying the explanatory gap. In our case this follows abductive reasoning (Mantere & Ketokivi 2013). BMs for OSH exist in practice, “but in theory they don’t” (De Filippi, 2018).

Secondly, they recommend choosing a unit of analysis. In our case, the unit of analysis chosen is the OSH ecosystem, which is illustrated in concentric circles of OSH inner communities, and their progressive interactions with stakeholders in firms and wider territorial circles. Bogers *et al.*, (2016) had identified these “higher levels of analysis such as regions” as the least covered in Open Innovation research. This multi-level unit of analysis enables us to research our phenomenon through very porous and permeable layers. OSH community members can meet in Hack Labs to develop their prototypes, but they are also connected to broad sets of stakeholders and roles. Moreover, they can belong to established organizations and can seek to develop their innovations internally. Our phenomenon, by nature is thus intra-inter organizational and beyond.

Thirdly, they suggest dimensioning the unit of analysis. Here, we have chosen the *middleground* concept developed by Cohendet *et al.*, (2014; 2010). This concept enables tracking the interaction mechanisms between green-field initiatives originating from players in the underground, and mainstream actors in government, firms, or universities. A *middleground*

is thus intentionally co-created by actors in both spheres in order to make innovation viable (from the community perspective) and to tap into stimulating new ideas (from the firm's perspective).

Fourthly, Foss & Saebi (2018) propose linking the unit to the outcome. In our case the notion of value created, in line with Massa *et al.*'s (2016, p 91-92) research recommendation to extend the business model framework to « broaden notions of value creation and value capture », needs to be more holistic. If individuals are willingly and on a voluntary basis, collectively coming together to co-create a technical solution (Fuster Morell 2014, p.8), a fair-assumption is that they are not extrinsically motivated by the notion of value as money, but rather by the plural form of values. Breuer & Lüdeke-Freund (2017) add that “values” refer to broader notions of the desirable, i.e., the underlying beliefs and motivational forces of individuals, organizations or society as a whole”.

For these reasons, we have chosen the Star Framework, developed by the DIMMONS team to complement work done by the OPEN! Team, on the outcome that can be attached to successful OSH BMs. The finality of OSH BMs is not solely that they are open on an Open-O-Meter scale (Bonvoisin *et al.*, 2017), but that guidelines be set in place as collectively devised rules to regulate the use of a Common (Ostrom, 1990). Morell & Espelt (2018; 2018) based on a study of one hundred commons-based digital platforms in the Barcelona region identified the correlations of governance, technological and knowledge openness. Their framework links these dimensions to the equally important dimensions of social and environmental impacts.

4. RESEARCH QUESTIONS & METHODOLOGY

In light of the literature presented, we have identified a gap of academic and practitioner cross-overs concerning guidelines to help OSH entrepreneurs ensure the sustainability of their endeavors and reduce risk. There is a lack of understanding of the binding factors and mechanisms cementing community-based interaction. And, there is no comprehensive typology of OSH BM strategic use.

In light of this gap, our research seeks to address the following questions:

RQ1: How to **monetize** value created through OSH?

RQ2: In the context of OSH, how can the **business model framework** be developed to include *value creation and sharing* for all **stakeholders**?

RQ3: In the context of OSH, **how does a business model hold together**?

4.1. METHODOLOGY

For this research, we wanted to include the richness of combined academic and practitioner perspectives. The dialogical model, devised by (Avenier & Cajaiba 2012) to develop academic knowledge for and from practice was chosen as the structural backbone of our work.

This model is coherent with the pragmatic constructivism epistemological paradigm (PECP) this research belongs to. The goal of the model and the objective of PECP is to generate academic knowledge by shedding light upon a given phenomenon (the existence of business models for OSH) and by explicitly integrating the knowledge and experience of practitioners.

The phenomenon of OSH BMs is emerging. Therefore a qualitative exploratory research using an abductive reasoning mode was chosen (Mantere & Ketokivi 2013) in order to elaborate on the Commons theory (Ketokivi & Choi 2014). Since this phenomenon is deeply rooted in human-based, “artificial sciences”, we chose the epistemological paradigm of constructive pragmatism. The epistemological stance offers “building intelligible models of human active experience” to provide insights “for organizing the world of experience” (Avenier & Thomas 2015). In sum, the goal of this research is not to explain reality as it is, but to offer practical tools to help OSH entrepreneurs gain economic viability and avoid risks.

Data was collected during three distinct phases following the identification of the multi-levels of OSH ecosystems. The first phase was the community level, where 23 projects were interviewed from the Open source hardware observatory. This phase corresponded to “community-based business models” (Wolf & Troxler 2016). The second phase sought to understand how firms in traditional and highly competitive sectors, such as the Automobile and Textile industries responded to OSH community-led and bottom-up initiatives. This phase corresponded to community-oriented business models. The case of the trail running company, Raidlight, partner to the OPEN! Project, was chosen along with two incumbent OEM car manufacturers (Renault and Volkswagen) and two newcomers to the automobile sector (Kreatize and Local Motors). During the third phase, semi-directed interviews were conducted with identified OSH stakeholders in the Barcelona ecosystem.

Data for the first phase was analyzed using the key dimensions identified by (Fjeldsted *et al.*, 2012): the community, the drive, the business model, the product development process and the platform. Data for the second phase was analyzed using Saebi & Foss's (2015) contingency model for the success of open initiatives: the value generated by co-creation, by knowledge flow and by collaborative capability. These dimensions are respectively linked to the content,

structure and governance of business models. Data for the third phase on the Barcelona OSH ecosystem was analyzed using the *middleground* concept (Cohendet *et al.*, 2014; Capdevila 2017).

Finally all projects (N=27) were transversally analyzed using the Open-O-Meter (Bonvoisin *et al.*, 2017), the Sharing Star (Fuster & Espelt 2018) as well as the dimensions used by Troxler (2010) when analyzing Fab Lab Business models: value proposition, revenue model, processes and resources, marketing, and innovation partnerships.

5. RESEARCH CONTRIBUTIONS

In line with Chesbrough & Bogers (2014), our research shows how a business model perspective helps OSH initiatives scale for impact. Following up on the work of Teece (2010), we indicate that different revenue streams can be activated in order to create an architecture of activities through which value is created, captured and distributed in a manner specific to Open business models, that is, leaving profitable niches for others (Gassman *et al.*, 2014, p. 231).

Our research shows how Digital and Knowledge Commons are strategic and have both local and global impact. In line with Breuer & Lüdeke-Freund (2017), our findings show the crucial role of values in cementing stakeholder participation.

Based on the case-study of Barcelona, our “Pinball model” illustrates how OSH projects can grow in scope through progressive rounds of interactions with the stakeholders in their ecosystem.

The “Spiral framework for OSH BMs”, which we devised based on our findings, articulates “constellations of activities” in which practitioners engage as they create and capture value, and interact with a broader set of stakeholders.

The three first stages are comfortable and fairly standard. The last two stages are progressively more challenging for organizations to implement. They reveal where the scaling potential for OSH lies. However, they require a shift in mindset from the extractive perspective upon which our current economy is based, to effective, democratic and generative collaboration.

6. STRUCTURE OF THESIS

The following chapters, structured according to the Dialogical Model (Avenier & Cajaiba 2012; 2013), are used to explain how the research was planned corresponding to the thesis objective (see Figure 2).

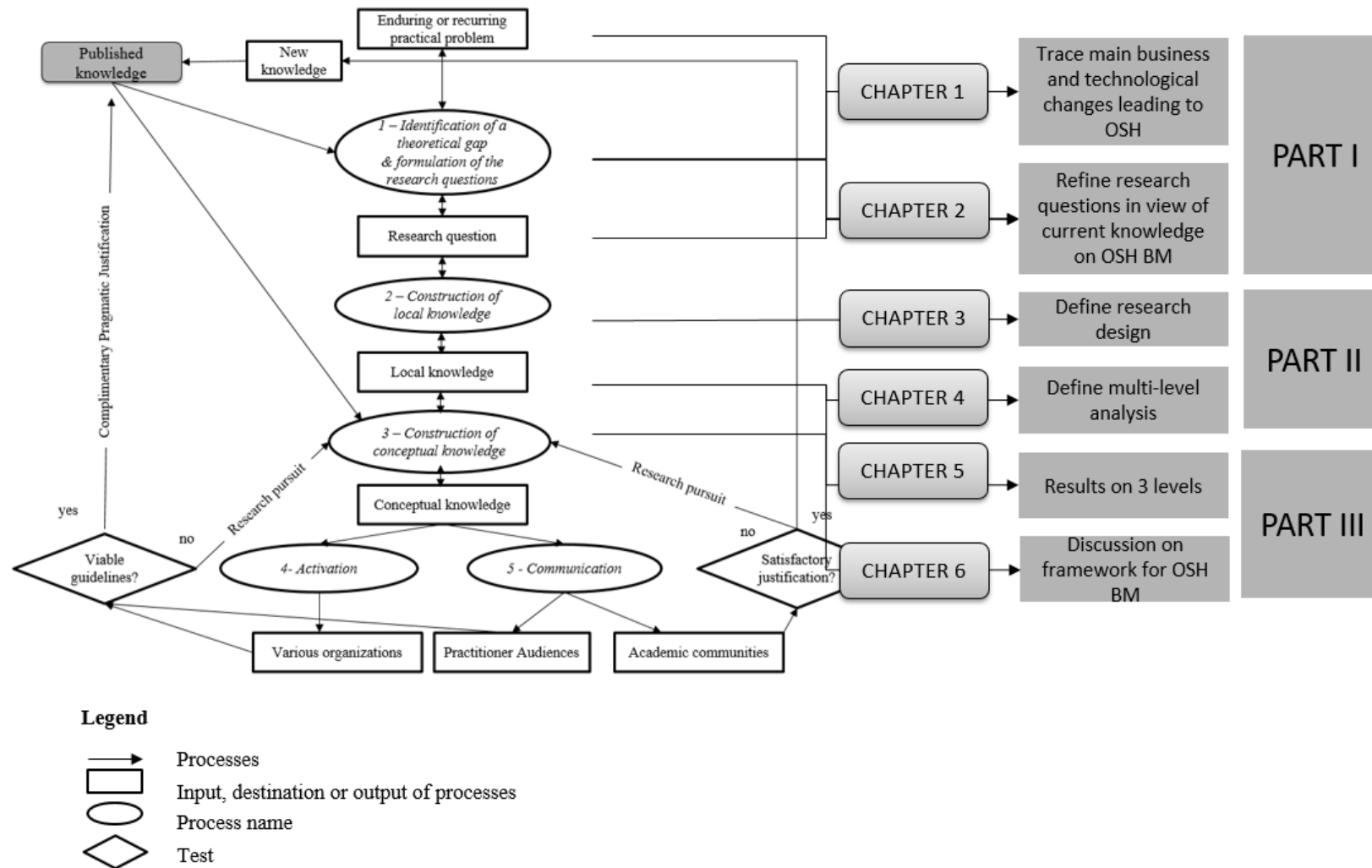


Figure 2: Structure of the thesis following the Dialogical Model (adapted from Avenier & Cajasiba 2012, p. 202)

The five process types developed and representing the Dialogical Model, have been organized into 3 main parts and 6 chapters (see Figure 2).

PART I is the literature review of our thesis, the justification of our conceptual and theoretical choices and the refinement of our research questions. This section is the fruit of interactions and exchanges between the OPEN! Team members and the various seminars, workshops, and conferences attended by the researcher these last three years, along with periodic, systematic literature reviews on the key words mobilized in this research.

-Chapter 1 positions the phenomenon of open source hardware between firm-led Open Innovation, and community-led Digital Commons. To operationalize research on the actors and their interactions we propose that open source hardware communities are the hybrid mix of communities of practice and epistemic communities. We introduce the concept of the *middleground* as a means of studying the interaction mechanisms around OSH value creation.

-Chapter 2 traces the evolution of the concepts of business models, to open business models, to what are currently known as business models for open source hardware. We suggest that in collaborative models the interactions, or soft links, binding the components together, are just as important as the components themselves in this novel configuration where traditional boundaries between customers and creators become increasingly blurred. Chapter 2 ends by reducing the research gap identified and refining the research questions.

PART II is the methodological backbone of our thesis.

-Chapter 3. Explains the choice of pragmatic constructivism as the epistemological paradigm corresponding to this thesis and exposes our research design. To study the empiric and emerging open source hardware phenomenon, we have chosen a qualitative approach. Data, collected through semi-conducted interviews is examined using thematic analysis.

-Chapter 4 justifies our choice of a multi-level analysis to study the OSH phenomenon empirically. This permitted addressing a broader stakeholder set through which value is created, captured and shared. We present OSH ecosystems as the unit of analysis of our study and explain how we implemented our methodology in order to gather and analyze our empirical data.

PART III presents our results and discusses the implications of our contribution.

-Chapter 5 presents the findings of our multi-level analysis analyzed using the key dimensions for Open Source Design identified by (Fjeldsted *et al.*, 2012); the complimentary tools of the Open-o-meter (Bonvoisin, Mies *et al.*, 2017) and the Sharing Star (Fuster & Espelt 2018), and the dimensions for Fab lab business models identified by Troxler (2010). To study how firms in the automobile and textile sector where responding to OSH innovation we used the contingency model devised by Saebi & Foss (2015).

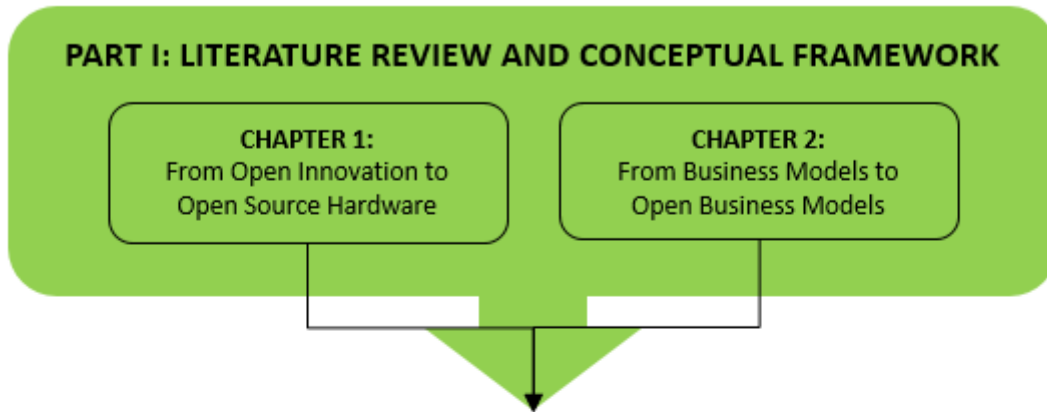
-Chapter 6 discusses our findings by presenting a typology of the business model patterns found in our interviews. We proceed to categorize this typology into a Spiral Framework for OSHBM which represents an iterative process through which OSH initiatives can make revenues, and broaden value creation and capture with actors in their ecosystems. We present pre-requisites needed in order for OSH actors to see the big picture and convince others to join in; recommendations for use and conditions necessary for their successful implementation.

In conclusion, we highlight our theoretical and managerial contributions to the Commons theory explaining how our framework contributes to making OSHBM redistributive, regenerative and generative by design. We discuss the limits of our work, and suggest avenues for future research.

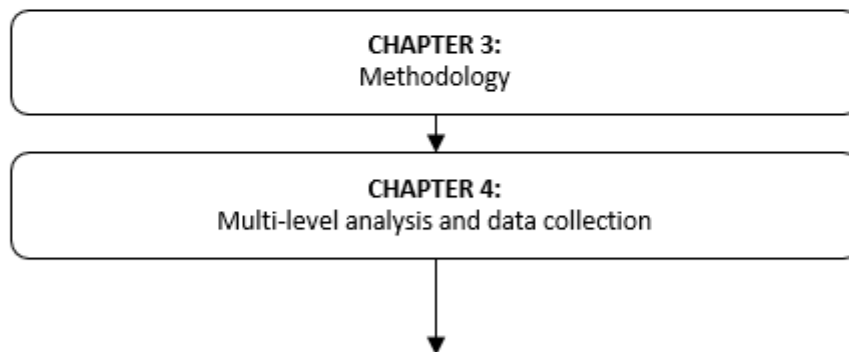
PART I: LITERATURE REVIEW & CONCEPTUAL FRAMEWORK

PART I: LITERATURE REVIEW & CONCEPTUAL FRAMEWORK

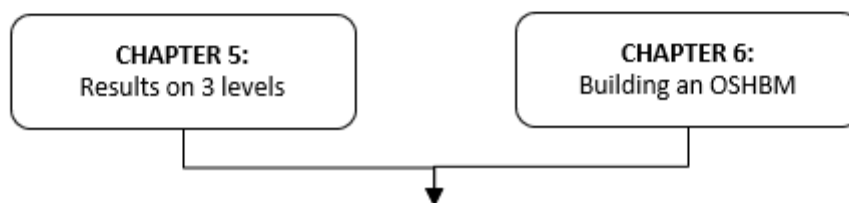
GENERAL INTRODUCTION



PART II: METHODOLOGY, RESEARCH DESIGN AND JUSTIFICATION FOR A MULTI-LEVEL ANALYSIS

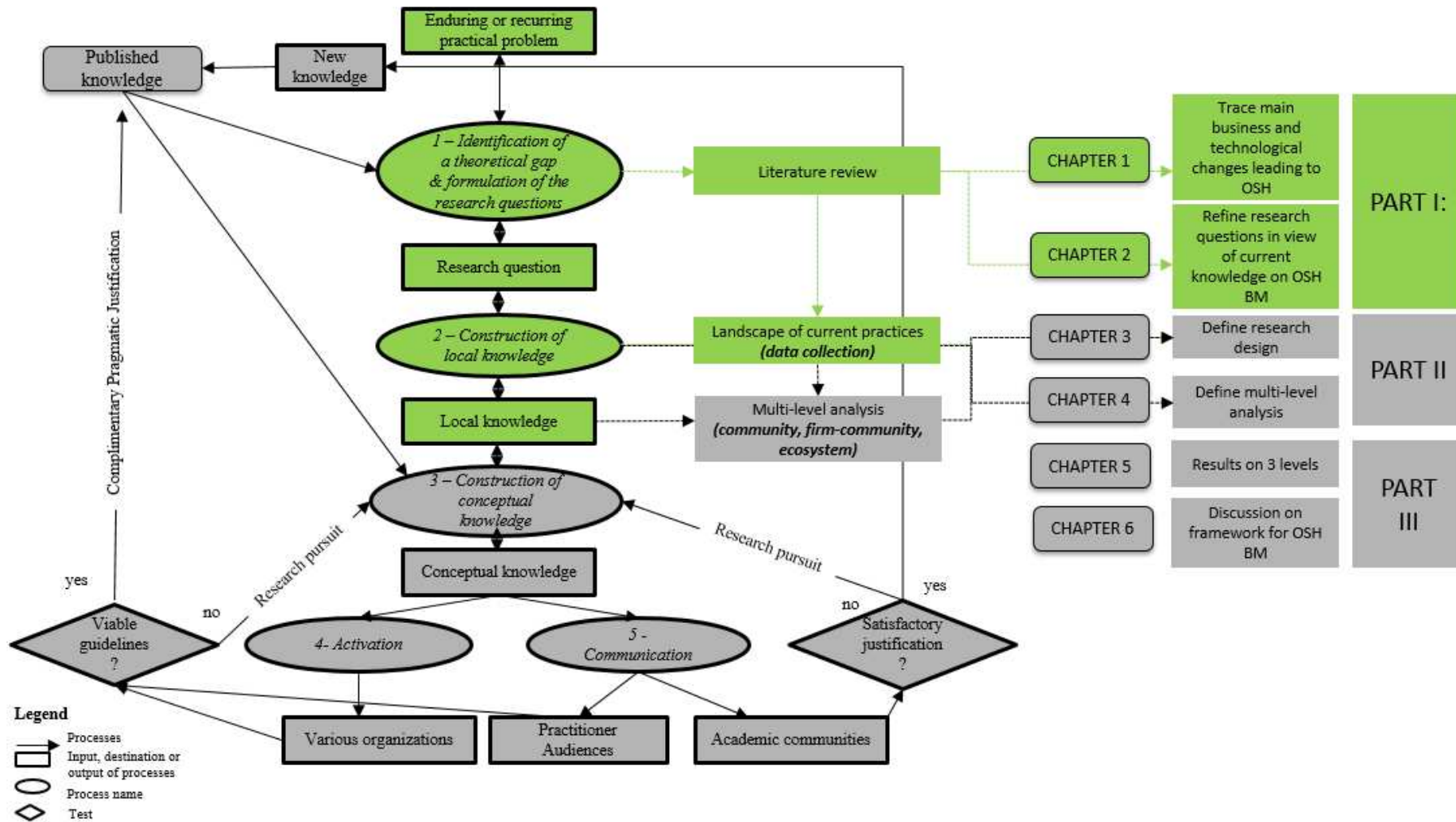


PART III: RESULTS AND DISCUSSION



GENERAL CONCLUSION

Part I



CHAPTER 1: FROM OPEN INNOVATION TO OPEN SOURCE HARWARE

CHAPTER 1: FROM OPEN INNOVATION TO OPEN SOURCE HARDWARE

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CHAPTER 1 SUMMARY

Objective - This chapter positions the phenomenon of OSH in management science literature as indicative of changes in business and technology. We provide the conceptual framework required for studying the actors in OSH communities and their interactions in wider, innovation ecosystems in the pursuit of bottom-up, value creation and capture.

Methodology/approach – This chapter results in systematic literature reviews on Open Innovation, Open Source Hardware, Commons Based-Peer-production and Innovation Communities.

Results –OSH is closer to literature on common-based peer production and Digital Commons, than the firm centric approach of Open Innovation. We retain the complimentary tools of the Open-O-Meter (Bonvoisin *et al.*, 2017) and the Sharing Star (Fuster & Espelt 2018) as means of holistically assessing the openness of commons-based collaborative platforms. We also retain, the use of the *middleground* concept (Cohendet *et al.*, 2014) as an analytical tool to study innovation mechanisms in complex environments where roles and boundaries are fluid.

Limits – The challenge of this chapter has been to select and justify the appropriate conceptual framework ex post in order to: 1) position the OSH phenomenon in the current research stream 2) start to problematize this research on business models for open source hardware.

Managerial implications – The scope of the changes in business and technology are rendering formerly closed innovation processes accessible to a larger public. Insights are provided into particular situations when seeking innovation communities' participation is beneficial, and their conditions for success.

Theoretical implications – The study of the Commons theory, from tragedy, to comedy, to triumph is provided. To this day, there is no strategic perspective as to how to monetize OSH initiatives in order to make them viable long-term.

Originality/value – Building on Foss & Saebi's (2018) recommendation to make business model research “fundamentally researchable and cumulative” we problematize why business models for OSH exist in practice but not in theory. We consider which unit of analysis to use to study this phenomenon. Innovation communities (Sarazin *et al.*, 2017) and innovation ecosystems (Scaringella & Radziwon 2018) both display fluid boundaries, therefore the *middleground* concept was chosen as a means to study the actors and their interactions.

1.1. COLLABORATION AS EVOLUTIONARY INTELLIGENCE IN BUSINESS AND TECHNOLOGY?

Management science is the study of organizations. In essence, organizations are a consequence of changes in business and technology. Every industrial revolution we have lived is tied to technological improvements and associated managerial perspectives. Although theories in management science seek to explain why people do what they do, how organizations morph and evolve in response to their environment, fully understanding “the relation between what we see and what we know is never settled” (Berger, 1972). Management science, from Selznick (1953) and Gouldner (1954), who focused attention on the rise of organizations as a dominant social institution to Chandler’s “Visible Hand”, to the Smith and Lewis (2011) “Paradox theory” and to Lahlou’s (2018) “installation theory”, reflects the understanding of the social currents at a given time. What we understand and know is conditioned by the socio-historical evolution of the installations and technologies we have created.

Never before in history have humans been able to see the impact of their activity upon the planet. Ironically, advances in technology that have led us to the moon and to the depths of the ocean, have also shown us the extent of devastation our “take-make and waste” activity is wreaking on the planet. Exponential growth with its associated mindset and industrial practices, known as the Great Acceleration in terms of humanity’s increased use of Earth’s resources, is moving us out of the Holocene period, the only one in the history of our planet, and the Universe as we know it, in which humanity has been able to thrive (Raworth, 2014, p. 46). Through our extractive use of resources, we are altering the conditions of life on earth. The Great Acceleration, has caused us to exploit resources to the point where animals are dying faster than the dinosaurs did at the time they became extinct (Barnosky and Hadly, 2015). “It is difficult to overestimate the scale of speed and change” says Will Steffen, the scientist who led the study documenting these trends. “In a single lifetime humanity has become a planetary-scale geological force... a new phenomenon and indicates that humanity has a new responsibility at a global level for the planet”. Climate change has become an existential threat.

Threats however trigger evolutionary intelligence. Richard Barrett (2018) explains that achieving the complex goal of staying alive requires intelligence and experimentation. He defines evolutionary intelligence as adaptive thinking over time. Barrett says that when faced with a threat, our species evolves through three stages. The first one is individually seeking to become stronger and more resilient, the second is bonding to form a group structure and the third is collaborating to form a higher order entity.

Open source hardware (OSH) which we discuss in this chapter is indicative of radical changes in industrial product development. Our progressively, knowledge-based economy, progressively disrupted by the internet revolution and ensuing digitalization means that innovation today has left the confines of organizations and, as some claim, is becoming democratized. The locus of innovation is moving beyond the limits of the firm into the hands of everyday people who collaborate openly on product development (Fjeldsted *et al.*, 2012; Raasch *et al.*, 2009; van Abel *et al.*, 2010; Bonvoisin *et al.*, 2016).

In this chapter, first we position the phenomenon of OSH between two distinct research streams: the firm centric approach of Open Innovation and the bottom-up community-led Commons-based peer production approach. We will present two complimentary means of assessing “openness” in a holistic manner: the Open-O-Meter (Bonvoisin *et al.*, 2017b) and the Sharing Star (Fuster & Espelt 2018). Then, we operationalize our research by defining the conceptual framework chosen as a basis for our investigation of OSH business models.

1.2. OPEN INNOVATION: PART OF A PARADIGM SHIFT

Research notes a flow of trends leading to a paradigm shift in innovation and product manufacturing (von Hippel 2005; Benkler 2006). Changes in technology and business linked to digitalization are being qualified as the 4th industrial revolution (Gaudron & Mouline 2017). Digital fabrication technology is becoming better and more accessible to a larger set of individuals (Blikstein 2013, Gershenfeld, 2005). In 2006 Von Hippel explained that changes such as “user innovation” were becoming both “an important rival and an important feedstock for manufacturer-centered innovation in many fields”. Democratizing innovation is also due to improvements in technology, such as computing advances enabling user design, and communication technologies making possible the combination and coordination of innovation-related efforts. In light of the Suddaby *et al.*, (2011) article on new organization theories, contrasting questions arise: why do we buy products manufactured in firms, rather than producing our own? Or, why are production activities organized in firms, rather than in markets? ...or in the Commons? Does community-based product development generate more value than firm-based products and services? Already in 2006, Von Hippel had identified important benefits of user-innovation: users who innovate can develop exactly what they want; they don't need to develop everything on their own; they can benefit from innovations developed and freely shared by others; user innovation appears to improve social welfare.

According to Benner and Tushman, “two secular trends drive the expanding importance of open innovation. The first is the increasing prevalence and importance of “digitization” (Greenstein *et al.*, 2013). Initially confined to information products and software production, digitization now affects large parts of the economy. The information component of any material object can now be represented as a digital good (Baldwin & Clark, 2000). Thus, material and physical objects can be created, represented, and modified with the same relative ease as software goods. The second trend is modularity associated with task decomposition (Baldwin & Clark, 2000). Drastic shifts in information processing costs and increased modularity have important implications for the locus of innovative activities. In contexts where computational costs are low and widely available and distributed communication is inexpensive, open or peer innovation communities displace organization-based innovation (Benkler 2006; O’Mahony & Lakhani 2011). Chesbrough & Bogers (2014, p.16) end their chapter on “explicating open innovation” by saying that “these erosion factors are at the core of why open innovation reflects a paradigm shift as they challenge the basic assumptions, problems, solutions and methods for the research and practice of twenty-first century industrial innovation.”

1.2.1. EROSION FACTORS

Over the last decade, research has documented trends, or erosion factors, challenging the practice of industrial innovation (Benner & Tushman 2015; Chesbrough & Bogers 2014). Shifts in communication and information processing costs, with the increasing modularity of products and services, have caused the nature and locus of innovation to move “beyond the boundaries of the firm to open or peer communities” (see (Adner 2002; 2012; Afuah & Tucci 2013; Chesbrough, 2006; O’Mahony & Lakhani 2011; Lakhani *et al.*, 2013).

Benner & Tushman (2015. p. 506) write: “the availability of inexpensive computation power and ease of communication permit a fundamentally different form of innovation—a mode of innovation rooted in free choice, sharing, and openness absent formal boundaries and formal hierarchy. In these open contexts, variation, selection, and retention are all done beyond the firm’s boundaries. Thus, these non-market, peer-innovation methods complement and, under some conditions, displace firm-centered innovation”.

Other erosion factors include increased startup firm access to venture capital and more capable universities, or the continually reduced product lifecycles witnessed in industries from hard

disk drives, which according to (Christensen 1997), are “the closest things to fruit flies that the business world will ever see” due to the speed with which companies in that sector are born, rise and die, to the internet of things (IOT) or even to frenetic fashion product lifecycles. In all sectors, programmed obsolescence and competition have dramatically reduced product lifecycles. The increased cost of R&D is an additional factor. Tamoschus *et al.*, (2015) explain that in the pharmaceutical industry, the important rate of innovation failure and the cost of putting new drugs on the market, have forced the industry to admit that the system no longer works and to move the risk to players outside the organization. Thus, a formerly vertically integrated industry has shifted to one where an entire ecosystem of players needs to be managed, as can also be observed in the automobile industry (Roland Berger 2016).

Diminished western hegemony, called transmodernism (Bendell & Thomas 2013), is another erosion factor. Indeed, recent economic and climate crises are often considered failures of the western industrial revolutions. Taylorism, Fordism and Toyotism, recognized as the pillars of economic growth from the 40’s through the 70’s (Gaudron & Mouline 2017), have relied on heavily extractive exploitation models for both labor and resources (Emarcora, 2018; Eglash 2016, p. 380), moving our civilization away from the Holocene safety zone in which we know it can survive (Raworth, 2017).

Over the past decade, because of erosion factors, technical progress and dramatically decreasing information costs, open innovation has become considerably cheaper and more easily integrated. As it is increasingly situated outside business boundaries; our received wisdom of the very nature of innovation is challenged. Where the firm is the focal unit in Chandlerian closed innovation, the community is the focal unit for open innovation (Adner 2002; 2012; Afuah & Tucci 2013; Fjeldstad *et al.*, 2012; Gulati *et al.*, 2012). Community organizing logics and principles are fundamentally different from those of closed contexts (Benkler 2006), and open innovation is increasingly prevalent. In sum, although organization dynamics are crucial, erosion factors cannot be attributed to organizations alone. Rather, social undercurrents also contribute to the changing role of customers and/or users, but we might also say, to people’s behavior across ecosystems, or to understanding what motivates different actors and stakeholders such as partners, suppliers, collaborators, co-creators.

In response to these factors, we are witnessing a shift toward decentralized solutions that better fit and serve local needs (see Capdevila 2017). A roaming, globalized workforce has made it more difficult for companies to retain key talent and has forced them to realize that “not all

smart people work for us”. One leading example of this shift described by Lifshitz-Assaf (2014) concerning NASA’s change in organizational culture and mindset from “problem-solvers to solution seekers”. The change was particularly difficult to manage since the “not invented here” syndrome was so strong. The author relates how NASA opened up its own solar flare prediction calculations, at 50% accuracy, just 2 hours before crowdsourcing them. Within 8 hours, a retired telecommunications officer had worked the algorithm up to 80% accuracy from which it was further improved saving lives and millions of dollars.

Companies are challenged to revisit traditional “closed assumptions” and progressively open their organizational culture (Lang *et al.*, 2016; Lang *et al.*, 2017). This requires flexibility and an almost counter-intuitive, aikido-like approach of integrating opposite beliefs. Indeed, many of the beliefs shaping macro and micro economics (Raworth, 2014, p. 64) and the past industrial revolutions (Gaudron & Mouline 2017) evolve around the idea that the best people are working for us; that whoever finds an innovation first wins; that if a firm develops a technology or product, that firm is best placed to market it; and that R&D should be safely guarded, since if a firm tells others what they are working on, their ideas will be stolen, or worse, used against them.

Research describes the gradual opening of mindsets in leading firms to acknowledge that perhaps not all smart people are working for them; that it could be beneficial to collaborate both inside and outside the company; that external R&D can create significant value both in time and money, and that internal R&D need only claim some portion strategically aligned with its key business units, its core competencies and how the firm has chosen to develop. A firm doesn’t need to invent a product, service or technology to profit from it, because the secret sauce is not so much getting to market first, but in adapting a better business model with a more fine-tuned understanding of the market and orchestration of key resources, partners, and activities. The point therefore is not to accumulate an inordinate number of patents, but to better use internal and external ideas. Indeed, the organizational culture shift that open innovation entails, is for a firm to profit from other firms’ use of their own intellectual property, and to buy that of others whenever it advances their own business model.

1.2.2. CONTRASTING DEFINITIONS OF OPEN INNOVATION

Henry Chesbrough in 2006 was first to identify open business models as an independent pattern. Yet the definitions given to open innovation fail to interpret the magnitude and

complexity of the phenomena to the point that in their reflections on the past decade, Benner & Tushman (2015), state that extant theories of innovation “do not reflect the current more complex context within which organizations operate [...]. Our increasingly deductive and disciplinary approach to research on innovation runs the risk of missing the changing nature of innovation itself (Suddaby *et al.*, 2011). We risk knowing more and more about a type of innovation that is being displaced.” (p.502)

Chesbrough progressively adapted the definition of open innovation from “purposive inflows and outflows of knowledge”, referring to gradually porous organization boundaries, to a “distributive innovation process, with purposive flows across organizational boundaries” (2014). This definition includes pecuniary and non-pecuniary based innovation streams (Dahlander & Gann 2010), as long as they are in line with the firm’s original business model. From the most recent definition, non-organizational related innovation, or that relating to the public good, is still excluded. Lead-users are not included either since, arguably, the knowledge generated is applied individually and directly as has been the case for innovations relating to mountain bikes (von Hippel 1986), windsurfing and baby joggers. Furthermore, once lead-user ventures become businesses, the number of improvements, i.e. innovation, plummet. Spillovers are also not included because they relate to unintended knowledge flows that by nature are unmanageable and unpredictable. As Moore explained (1993), the success of an innovation does not rely on a single organization, but rather on the capacity of the organization’s partners, competitors and the general environment to accompany that innovation. This changes a company’s strategic focus from the stance of how to position itself to capture value, to one where it can act upon that environment as a value co-creator within an innovation ecosystem (Adner 2006; Adner & Kapoor 2010).

With the concept of open business models as an independent pattern taking outside partners into normally closed value creation processes, such as R&D, Chesbrough defined a new type of collaboration differing vastly from the classic, customer-supplier relationships (Gassman, Frankenberger, Csik, 2014). Essentially, however, this definition remains a bottom-up view of innovation management, focused on the relationships of formal institutions and how they drive innovation-trajectory actions. It does not take into full account other trends simultaneously reshaping society and industry, such as the democratizing of digital fabrication and open technologies.

Open innovation makes company boundaries more permeable to outside knowledge. Innovation capabilities are leveraged with smart externals through outside-in, inside-out and coupled-process innovation mechanisms, as described in the following figure. Inbound or outside-in open innovation means the company's innovation process has opened by incorporating external knowledge and contributions, perhaps through technology scouts or acquisitions, through licensing-in, user-integration, crowdsourcing or collaborations. Examples of outbound innovation occur when internally generated innovations are incubated outside firms via spin-offs, out-licensing or corporate venturing. The coupled process facilitates co-creation with trusted partners and relies on external resources to develop innovation and create value while also creating new revenue streams by externalizing knowledge (see Figure 3). According to Enkel *et al.*, (2009); Sandulli & Chesbrough (2009), it is through these coupled processes that truly open business models emerge.

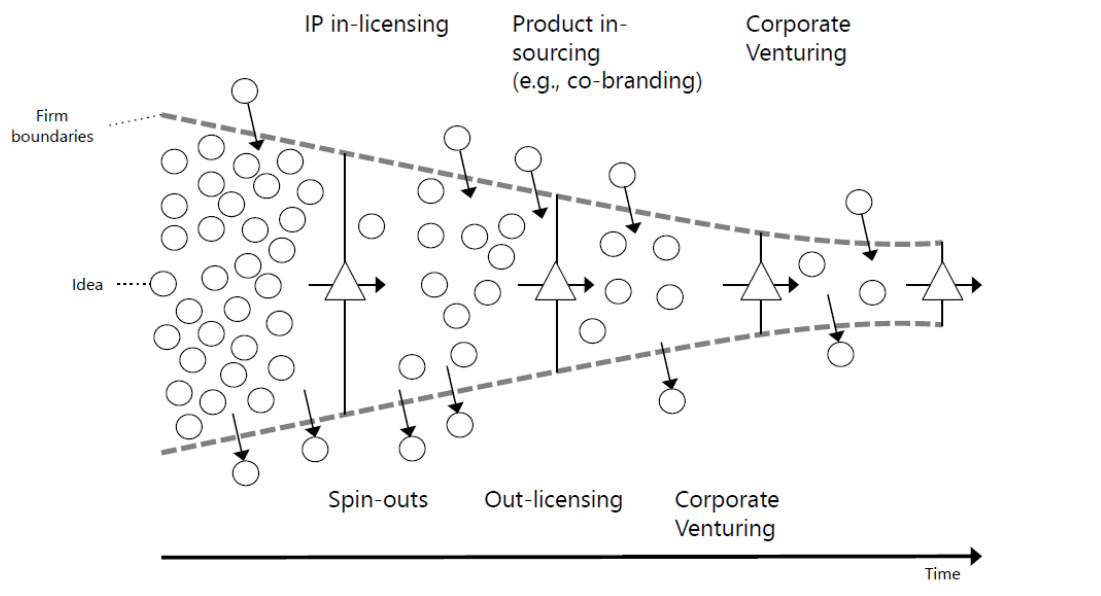


Figure 3: Mechanisms of open innovation (Chesbrough, 2006)

1.2.3. OPEN INNOVATION: AN UMBRELLA TERM AND A PARADOX

Research has recently noted that “open innovation” has become an umbrella term covering conflicting areas of research and definitions of what openness stands for (Bonvoisin *et al.*, 2018; Stanko *et al.*, 2017). The concept of openness has been attributed fairly loosely, its

definition changing according to the needs and reality of a given organization or a given community (Parmentier 2015). For instance, as Baldwin & von Hippel (2011) state, there are presently on-going and competing definitions of openness that do not refer to the same object of study: the firm-based view of openness refers to the permeability of the firm's boundaries engaging in outside-in, inside-out and coupled processes to leverage innovation capabilities with smart externals (Enkel *et al.*, 2009) The community-based view considers openness a protocol regarding the gradual quality of openness as a possibility and a basic right of all involved (Raasch *et al.*, 2009; Bonvoisin *et al.*, 2017). Parmentier (2015), says the effects of openness "are the attraction and engagement of creative users in co-creation activities. The user is no longer simply an information provider, but rather a co-creator in the innovation process." The most consistent definition of open innovation (Chesbrough & Bogers 2014, p.17) defines the phenomena as a firm-centric approach to innovation, thus distinguishing it from some parts of user innovation literature (C. Baldwin & von Hippel 2011; Bogers *et al.*, 2010; Bogers & West 2012). The main argument for this distinction, as stated by Chesbrough (2006a), is that open innovation and open source, while similar in their approach to innovation, are different in so far as: "Open innovation explicitly incorporates the business model as the source of both value creation and value capture [...] while open source shares the focus on value creation throughout an industrial value chain, its proponents usually deny or downplay the importance of value capture."

Notably, as the boundaries of the firm itself become more permeable, the center of innovation is no longer within the firm and has become part of the firm's internal and external network (Bogers & West 2012; Chesbrough, 2006; Frankenberger *et al.*, 2014). This co-creation network includes partners, customers and innovation communities (Chanal & Caron-Fasan 2010; Lauritzen 2017; Sarazin *et al.*, 2017). Co-creation is a "joint, collaborative, concurrent, peer-like process of producing new value" (Galvagno & Dalli 2014, p. 644). Innovation therefore requires the participation of external parties in value creation and in re-designing internal processes, making external involvement possible (Hienerth *et al.*, 2011). The knowledge flows from this network interaction result in innovation (Chesbrough 2007) and value creation for all parties.

For firms engaging in open innovation with innovation communities, business models must be defined: specifically the interface of value creation and value capture. For Chesbrough & Appleyard (2007), the opening of companies to web communities is a new challenge for

strategy: “We believe the concept of open source development and similarly inspired ideas such as open innovation, the intellectual commons, peer production, and earlier notions of collective invention, represent phenomena that require a rethinking of strategy” (Chesbrough & Appleyard 2007, cited in Chanal & Caron-Fasan 2010, p.319). The challenge is even greater when working with open source hardware, as open business models designed around hardware require managing various levels of tension around openness (Lauritzen 2017; Gassmann, O., Enkel, E., & Chesbrough 2010; Sandulli & Chesbrough 2009).

In 2014, Chesbrough and Bogers noted that the analysis levels of open innovation should be broadened to include communities. “As a distinct level of analysis, they (the communities) are in essence “extra-organizational sets of actors”; and “of society at large, given the opportunities of open innovation in the public commons through, for example, initiatives like open government and open data”.

1.3. OPEN SOURCE HARDWARE

Mainstream economic theory claims that without intellectual property protection, innovators lack the incentive to bring new products to market because they cannot recover their costs. Today innovators are defying this received wisdom, co-creating and using free, open source software known as FOSS, as well as free open source hardware, or FOSH. In terms of open innovation gradients, open source hardware is more radical as the innovation is opened beyond the firm and trusted partners (Benner & Tushman 2015).

Originally, the term comes from the software world. In the early 80s, people began to see that the more proprietary closed model, where a company hires engineers to make a certain software product, might not necessarily be the only way, the most efficient, or the least expensive means of making the product. So they came up with this idea of a crowdsourcing model, where instead of trying to build the thing yourself you actually source code – put it out into public ownership, in public view and then invite everyone to contribute to it to invent whatever should come next. By doing this, firms relinquish some of their rights to motivate and have contributors feeling a certain sense of co-ownership. The two main advantages of this approach are: 1) hyperinnovation, where the capacity of thinking up new ideas is accelerated; 2) building communities of co-creators by expanding resources to the externalities of the market.

Today, we are seeing a global trend, or perhaps more of an emerging trend as headlines claim that large companies from IBM and Red Hat to Google are paving the way for an open roadmap

to innovation; that companies such as Baidu and Telsa are making their car platforms⁷ or building plans freely available to the automotive industry. Tesla recently surpassed General Motors Co. to become America’s most valuable carmaker, “eclipsing a company whose well-being was once viewed as interdependent with the nation’s⁸”. The movement appears to be progressing with NGOs and UNICEF launching a venture fund of open-source civic technology⁹. The United Nations 2030 Vision report states that digital technology and open source will be critical enablers on the journey to implementing sustainable development goals (SDGs). Companies are following suit. The OPEN! Project established an Open Source Hardware observatory¹⁰ that, as of September 2017, had identified 132 products which satisfied the conservative selection criteria. Products covered a wide range of categories: machine tools (33 products), vehicles (18 products), robotics (11 products) as well as medical and laboratory equipment (9 products) (see Figure 4).

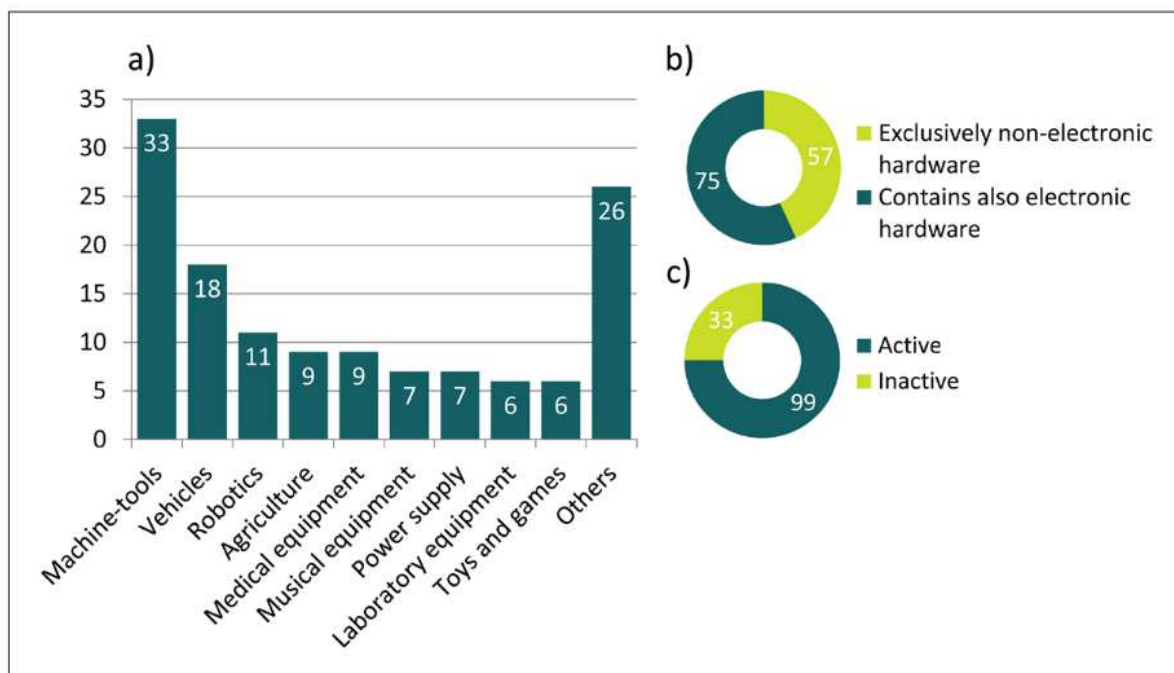


Figure 4: Characterization per product category (a), per technology (b) and per project status (c) (Bonvoisin *et al.*, 2017)

⁷ <https://techerunch.com/2017/04/18/baidu-project-apollo/>; <https://www.bloomberg.com/news/articles/2014-06-12/why-elon-musk-just-opened-teslas-patents-to-his-biggest-rivals>

⁸ <https://www.bloomberg.com/news/articles/2017-04-10/tesla-passes-gm-as-musk-s-carmaker-becomes-america-s-top-valued>

⁹ <https://www.fastcompany.com/3056420/unicef-is-launching-a-venture-fund-for-open-source-civic-technology>

¹⁰ <https://opensourcehardware.cc/observatory/>

1.3.1. OPEN SOURCE HARDWARE, OPEN SOURCE PRODUCT DEVELOPMENT, OPEN DESIGN:

The focus of the OPEN! project is open source product development (OSPD), meaning tangible hardware product development achieved by a community and whose *process* is open. OSPD and OSH are subcategories of the larger open design approach that relies on two levers: the power of the crowds in contributing improvements, and ‘standing on the shoulders of giants’ where effort is spent on improving existing solutions, and not reinventing the wheel (Boisseau *et al.*, 2018). Though originally focused on electronic hardware, the term "open source hardware" has come to refer to any type of tangible artefact, like mechanical, construction or textile hardware, as these technologies are increasingly impacted by the open approach phenomenon: that is “the sharing [of] the original design files for an object in a way that allows it to be modified or reproduced by others, including for commercial use” (Mellis & Buechley 2012, p. 1175, cited in Boisseau *et al.*, 2018).

Open Source Product Development (OSPD) goes a step farther than open source hardware, since both the final product and the process are rendered open. OSPD is defined as the development of open source hardware products in a collaborative process permitting the participation of any person interested. OSPD is a form of open source innovation described by Raasch *et al.*, (2009) as: “free revealing of information on a new design with the intention of collaborative development of a single design or a limited number of related designs for market or non-market exploitation.” OSPD projects are characterized by little process support. Such projects generally have a low level of restrictions, of self-motivation and of self-selection of modular tasks; the projects are not embedded in formal organizations, but rather in communities of practice (Müller-Seitz & Reger 2010). Whereas in conventional product development, the technological output is well defined from the start, in OSPD, it tends to be loosely defined at the beginning and to mature over time.

Open source hardware holds the promise of going from mass manufacturing of that which is average to creating something optimal and unique for each user (Bonvoisin *et al.*, 2016). The challenge of the open source hardware approach is that building plans are rendered public, transparent for anyone who wishes to see them and their bill of materials (BOM); they are replicable and accessible, meaning that anyone may reproduce the plans or modify *distribute*,

*make, and sell the design or hardware based on that design*¹¹. The studied benefits of open source hardware done in a collaborative fashion are amplified: innovations are more effective, faster, cheaper and more efficient (Bonvoisin *et al.*, 2016; Thomas & Samuel 2017), an approach which is usually and completely at odds with many competitive sectors.

1.3.2. MOTIVATIONS FOR OPEN SOURCE HARDWARE

Through the analogy “we value free speech, not free beer”, Stallman (2009) sought to establish the difference between the freedom to replicate, fork, and distribute source code versus the methodology to make software more reliable and robust. This is the difference between Free and Libre Open Source Software (FLOSS) and open source. He explained “this comes from the supposition that the software is designed to serve its users. If it is powerful and reliable that means it serves them better. But software can only be said to serve its users if it respects their freedom” not if it’s designed to put chains on them. “Then powerfulness only means that the chains are more constricting, and reliability, that they are harder to remove” (p.33).

Studies on the motivations of community-based product design indicate a clear shift in priorities from traditional industrial processes (Benner & Tushman 2015; Parmentier & Mangematin 2014). Via the Maker Movement people “reclaim production”, that is, they contest industry’s product manufacturing monopoly. Supported by open source, or inexpensive CAD software, an emerging category of “home engineers” experiment home-based production and share their designs in online CAD repositories. Organized in repair-café’s or Makerspaces, they learn and teach each other how to produce and repair things on their own. The aim is not solely to generate functional technology, but also personal development and process learning (Aksulu & Wade 2010).

Existing research suggests that innovation communities practicing OSH are driven by values, i.e; referring “to broader notions of the desirable, the underlying beliefs and motivational forces of individuals, organizations or society as a whole” (Breuer & Lüdeke-Freund 2017, p. 4). Troxler, in his 2010 study on the ‘Pain and Pride of Fab Lab Managers and Assistants’ identified that the effect a Fab Lab has on its users, on children, and on a community in terms of empowerment, was a great source of pride. He cites a manager saying:

¹¹ From the Open Source Hardware (OSHW) Statement of Principles 1.0 <https://www.oshwa.org/definition/>.

“The best thing about a Fab Lab is the smile on the face of a middle-aged, unemployed, African American male who has been very, very discouraged. That's the second best thing. The first best thing is when he holds up the thing he just made and says: What I think: I'm going to play with this and make it better.”

From Troxler's research, the second most important motivation is innovation and the 'Fab Lab magic': the feeling of empowerment that comes from “letting anyone who has an idea make something”.

Unterfrauner & Voigt (2017, pp.2-7), in their qualitative research on Maker initiatives presented at the European Academy of Design conference, analyze the values and impact of Making. They explain that Makers often use open design with a social innovation and even a “grassroots, anti-establishment heroism” mind-set that reflects an “awareness of [the] societal problems in the first place and a way to develop solutions that are acceptable to most of the actors involved”. Their findings reveal that the values and expectations Makers bring to the design process have educational, inclusion and environmental ambitions.

Education is seen as the tool to change the prevailing mind-set of people from passive consumers to co-creators. Consumption of programmed obsolescence, the pillar of growth promoted thus far to uphold our current economy is “linked to a level of ignorance” regarding how the objects around us are made. Making and hacking are understood as a means for people of all ages to understand how a device is made and how to potentially change it to fit one's own needs. Hacking education, is therefore the means of teaching people not to live in today's world, but to be actors in creating a new one¹².

Inclusion is the willingness to foster pro-democratic qualities by including diverse kinds of Makers in the Makerspace, the idea being that the more heterogeneous the encounters and skill sets, the more innovative the outcome and its potential benefits for diverse communities. The value of inclusion is written in the Fab Lab Charter which implies open access for individuals as a core value. “This is realized economically by reducing entrance levels with free-of-charge use or low membership fees, but also technologically by reducing the complexity of the operating machineries available to a level that can be attained through workshops or self-

¹² <https://library.teachthefuture.org/>

regulated learning”. The authors cite workshops dedicated to bringing solutions into hard-to-reach communities, such as refugee camps, unemployed people or senior citizens.

Environmental ambitions were the last group of values the researchers observed in their qualitative research, with a special focus on upcycling and recycling as well as on circular economy. They indicate that Making could contribute to local, decentralized production and consumption, and to lowering the environmental footprint by supporting a carbon free or a reduced carbon life style. Unterfrauner and Voigt suggest that Making is linked to social innovation. Paraphrasing Schumpeter, who explained innovation as a ‘new combination of production factors’, “social innovation can be defined as a new combination of social practices”.

From this discussion we will retain the notion of value with the drive required to motivate contribution, as one of the four key elements characteristic of OSPD projects (Fjeldsted *et al.*, 2012; Public Interest Research Center, 2011; Breuer & Lüdeke-Freund 2017). The premise of understanding how values work and identifying the frameworks needed to engage or disengage groups from a certain set of values, is of critical importance in fostering the adoption of new business models for both companies and consumers, and in encouraging people to develop skills for a radically different future. Indeed, facts alone and “messages communicated through numbers” are seldom acted upon. To understand how markets, businesses and society are maturing, one needs to know what values shape current behavior. Values evolve as societies evolve. The values we develop affect how we look at the world.

Bearing in mind the distinction between OSPD where the *process* is open and OSH where only the *final product* is shared, for the purpose of this study we will generally use open source hardware (OSH), as this term is most commonly employed and we understand it to be an extension of FLOSH: Free Open Source Hardware, because the notion of being free is fundamental to the motivation of OSH contributors.

1.3.3. ASSESSING OPENNESS FOR OPEN SOURCE HARDWARE

In open source hardware, the building plans are published under free license guaranteeing the four freedoms¹³ or rights that apply to free software: a) to use or perform the work for any

¹³ These four freedoms are derived from the free software definition (Free Software Foundation 2015), which are: Freedom 0, the freedom to run the program for any purpose; Freedom 1, the freedom to study how the program works; Freedom 2, the freedom to redistribute copies; Freedom 3, the freedom to distribute copies of modified versions. In the transition from the context of immaterial intellectual property to the realm of tangible products,

purpose, b) to study and adapt it to ones' needs, c) to make copies and share them, and d) to distribute derivative works. Thus "the recipe" of the innovation; meaning the plans, bill of materials and assembly instructions are rendered transparent, accessible for anyone to see, replicate or modify (Balka *et al.*, 2010). The plans refer to tangible, complex goods (mixing electronic, mechanical, and textile components).

Bonvoisin *et al.*, (2017) distinguish sequential and collective forms of community based product development. The first is "peer to peer development where products are designed and produced by individuals working sequentially". This is made possible by the modularization of product development and tasks that co-creation spaces offer, such virtual platforms associated with tools that encourage creativity and innovation (Parmentier 2015; Bonvoisin *et al.*, 2016; Benner & Tushman 2015). Mies *et al.*, (2019) explain: "These processes occur in the form of a sequential series of remakes: one maker develops a version, which is taken over and developed further by someone else, and so on. While the processes are collaborative in the sense that designs are generated by the action of more than one person, they are not collaborative in the sense of coordinated action of people with common objectives. 'Designers get inspired by each other' (Özkil 2017, *cited in* Bonvoisin *et al.*, 2018) and 'build on top of each other's work' in an evolutionary process where each representation of the species is a design created by one designer. This form of community-based design is often associated with low complexity designs, such as DIY and 3D-printed products – 'personal accessories [. . .] which are [for a large part] ornamental and have limited functionality or complexity' (*ibid.*). Nonetheless, similar processes may also be involved in developing variants of more complex products, as observed in the case of the electronic, Arduino Duemilanove board (Mellis & Buechley 2012, *cited in* Bonvoisin *et al.*, 2018).

The second form of community-based product development is referred to as "collective design where product development is performed by the coordinated action of individuals working in parallel" (Paulini *et al.*, 2013 *cited in* Bonvoisin *et al.*, 2018). This form applies to complex products, with a combination of technologies, and a greater number of parts and requirements." (Bonvoisin *et al.*, 2018). Figure 5 illustrates the forms of openness involved in open source hardware.

these freedoms have been reinterpreted. For example, running a program requires compiling the source code (an action alternatively termed as building or making in the software jargon). The freedom to run became the freedom to make the product, that is, to produce it.

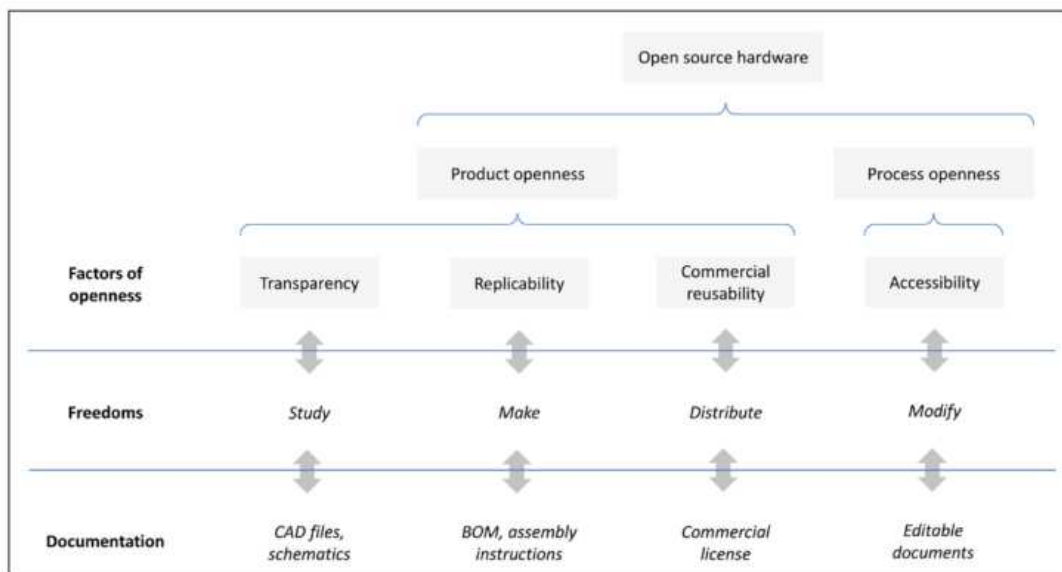


Figure 5: Forms of openness involved in open source hardware (Bonvoisin *et al.*, 2017)

In order to clarify the multidimensional and gradual concept of openness in the case of open-source hardware, the OPEN! Team devised an “Open-O-Meter” for clear definitions as to whether a piece of hardware could be qualified as open source or not. From the OSHWA definition of open source hardware a number of questions remain. What needs to be open? What does it mean to “make a design publicly available”? What are the documents that enable others to study, distribute, make or sell your design? These are indeed distinct aspects very specific to open source hardware. The first notion: transparency, is the possibility (Balca *et al.*, 2014) or the right (Benkler 2013; Decode, 2017) for any interested person to see how the product is designed and to have unrestricted access to information sufficient for understanding the product in detail. The second notion: replicability, is the possibility for any interested person to physically make the product. The third: refers to accessibility, in the sense that any person should have the possibility or the right to take part in the further development of the product. From these criteria, the question arises: “does a product need to be transparent, replicable and accessible to be labeled open source? Or is it enough to satisfy only one of these requirements? In other words: for both questions, “is this product open source?” and “how far is this product open source?” which notion is the most relevant? We consider it would be too much to expect that one product satisfy the three requirements before being termed open source. The Open-O-Meter is thus a flexible assessment indicator to measure how far a product is open source. In essence, the meter is a simple scale from 0 to 8. If a product scores 8 points

it fully adheres to the best practices of open source hardware. If a product receives 0 points, it should not be labeled open source. A score between 1 and 7 reflects a progression of the openness concept. The Danish Design Center has folded the Open-O-Meter into its toolkit for helping businesses open their business models and has enriched the assessment with questions regarding product distribution (for commercial or free purposes see Figure 6).

DO THEY ALLOW FREE REDISTRIBUTION OF THE FULL PRODUCT, ALSO FOR COMMERCIAL PURPOSES? Do they use an open (source) license on all elements of the product?	<input type="checkbox"/>
DO THEY ALLOW FREE REDISTRIBUTION OF SOME ELEMENTS, ALSO FOR COMMERCIAL PURPOSES? Do they use an open (source) license on some parts/elements of the product?	<input type="checkbox"/>
DO THEY ALLOW PARTIAL OR FULL REDISTRIBUTION FOR NON-COMMERCIALS PURPOSES? Do they use a legal license that allows users to redistribute without economic gain?	<input type="checkbox"/>
IS THE PUBLISHED BILL OF MATERIALS EDITABLE? The bill of materials is published in editable format	<input type="checkbox"/>
IS THE PUBLISHED ASSEMBLY INSTRUCTIONS EDITABLE? The assembly instruction is published in editable format	<input type="checkbox"/>
ARE THE PUBLISHED DESIGN FILES IN EDITABLE FORMATS? One or more of the file formats used is editable	<input type="checkbox"/>
IS THE CONTRIBUTING GUIDE PUBLISHED? A guide for how users can contribute is available	<input type="checkbox"/>
IS THE BILL OF MATERIALS PUBLISHED? The product bill-of-material is publicly available	<input type="checkbox"/>
ARE ASSEMBLY INSTRUCTIONS PUBLISHED? Instructions for how to assemble are publicly available	<input type="checkbox"/>
ARE DESIGN FILES PUBLISHED? Technical components of the product is publicly available (CAD-files, computer code, schematics etc.)	<input type="checkbox"/>

POINTS TOTAL:

10 Fully open source

0 Fully closed

This version of the Open-o-meter is a derivative of the original Open-o-meter developed by Jérémie Bonvoisin et. al. from Open/Technische Universität Berlin, CC BY 4.0.




Figure 6: Danish Design Center revision to the Open-O-Meter (Bonvoisin *et al.*, 2017b)

1.4. DIGITAL COMMONS AS THE THEORETICAL BASE OF OSH

Clearly, what is novel in OSH and OSPD, is the commons approach (Benkler 2013; Raworth, 2017, p. 83-84). The commons are shareable resources of nature or society that people chose to use or govern through self-organizing that is vulnerable to social dilemmas (Hess & Ostrom, 2011). They expresses the transition from a hierarchical and proprietary logic based on closed property, to an open, decentralized and contributive logic, affording free and universal public access. The alternative governance of the commons and of peer production depend on cooperative principles. “Commons can be well bounded (a community park), transboundary

(a river, or the internet), or without clear boundaries (knowledge, the ozone layer)” (Hess & Ostrom, 2011, p.5).

Traditionally, markets are established on private rights or, when markets fail, goods can be managed by the government in the interest of overall efficiency. Yet these two notions do not logically exhaust all situations. In particular, outside of purely private property, or government-controlled "public property", there is the common, open road, the sea passage, at the very foundation of trade, open to everyone. In this research we relate OSH to open commons, or knowledge and intellectual commons and commons based peer production (Benkler 2013; Benkler 2016; Acquier *et al.*, 2016; Fuster Morell *et al.*, 2017; Benkler & Nissenbaum 2006) as opposed to natural commons (Ostrom 2008; 2010).

Historically, research has been witness to the tragicomedy, then triumph of the commons. Garrett Hardin described the commons as ‘tragic’ in 1968. Underpinning Adam Smith’s celebration of the self-organizing market and the ‘invisible hand’, Hardin contended that resources such as pastures, forests and fishing grounds, if left as open to all would lead to overconsumption and consequent depletion. More recently in her book “Pioneering the Possible” Scilla Elworthy, who was nominated three times for the Nobel Peace Prize, paints a grim picture:

“The UN Framework Convention on Climate change, whose job for the last twenty years has been to ensure the stabilization of greenhouse gases, has failed in its goals. Likewise the Convention on Biological Diversity, whose job has been to reduce the rate of biodiversity loss, has failed. Governments either cannot make the necessary agreements to halt the devastation of the planet, or they cannot stick to them [...] We are in a classic – and this time global – case of the Tragedy of the Commons”, which is the depletion of a shared resource by individuals acting “rationally”, each according to his or her own self-interest” (Elworthy, 2014).

However, open access is not how successful commons are actually governed. Political scientist, Elinor Ostrom offered an alternative view when she started calling attention to the equally powerful alternative of self-organization in the commons, and proved Hardin wrong. She sought out real-life examples of well-managed natural commons from Southern India to Southern California and what made them work. In 2009, she received the Nobel Prize in economics for her discoveries. Ostrom’s work demonstrated that in the context of a natural

crisis, the management of natural resources as commons could make the resource endure in contrast to the failure of public-based or exclusive, private property based management. Rather than being left ‘open access’, successful commons were governed by clearly defined communities which collectively established rules and punitive sanctions for those who broke them. “Far from tragic, the commons can turn out to be a triumph, outperforming both state and market in sustainably stewarding and equitably harvesting Earth’s resources” (Raworth, 2017, p.83).

The notion of state is, however, crucial. The digital revolution has unleashed an era of collaborative knowledge creation that could radically decentralize wealth ownership. But, as argues the commons theorist Michael Bauwens, it is unlikely to reach its potential without state support. Just as corporate capitalism has long depended on the backing of government policies, public funding, and pro-business legislation, so now the commons need the backing of a state partner able to defend common value.

Immaterial resources were absent from the scope of Ostrom’s study. Precisely, after Ostrom’s Nobel Prize, a body of literature began to fill this gap as the concept progressively evolved to include Cultural and Knowledge Commons (Madison, Frischman and Sandburg, 2014), and Digital Commons (Benkler & Nissenbaum 2006; Fuster Morell 2014; Benkler 2016; Benkler 2013; Acquier *et al.*, 2016; O’Mahony & Ferraro 2007). First, in the 1990s, authors such as Boyle (2003; see Fuster Morell *et al.*, 2017 citing Nelson, 2004; Orsi & Coriat, 2006; Shapiro, 2000) denounced the overreach of exclusive property rights all over the world as detrimental to innovation. A second stream of literature followed, focused on the difference between natural commons and immaterial commons. “The comedy of the commons” (Rose 2006; Litman 2014), explained that they need neither to be preserved, nor protected from overconsumption. On the contrary, they “may be mined by any member of the public”. Purposefully left open as raw material for ideas and a resource for future creators, knowledge commons are improved through use (Benkler 2013, p. 1514). Indeed, “the challenge of today’s generation is to keep the pathways to discovery open” (Hess & Ostrom, p.8). Free riders are not a problem as the “the value of the outcome of Online Creation Communities (OCCs) increases when more people use them” (Rose, 1994, *cited in* Fuster Morell 2014, p. 19). The goal of Commons is to expand the resource in quality and over time, as well as the flow of innovation spurring knowledge where exclusivist intellectual property rights have blocked it.

Last but not least, in many cases immaterial commons, in contrast to most of the natural resources-based commons studied by Ostrom, were necessarily permeated by the market. In order for the common to be produced, maintained and expanded, communities required more and more complex monetary exchanges with the market and organization that were rarely based on commons (Fuster Morell *et al.*, 2017).

1.4.1. ROOTS AND TENSIONS OF THE COLLABORATIVE ECONOMY

Collaborative commons relate to other floating signifiers, i.e. umbrella term constructs lacking in clarity such as: shared, collaborative, collaborative platform economy or cooperative economy that have emerged in recent decades. Here we will seek to quickly establish the theoretical background of such movements, the tensions they generate, and position OSH within the sphere of cooperative economy as defined by (Fuster & Espelt 2018).

Acquier *et al.*, (2016) sought to identify the theoretical roots of the collaborative economy described as “a big catch-all that sees young web shoots with long teeth come together, companies that are worth millions on the stock market and Neobabas with both political and social ambitions” (Turcan and Sudry-le-Dû, 2015, *cited in* Acquier *et al.*, 2016). Their research revealed four theoretical roots. The first root, functional economy, is the transition from property to use. The value of a given object is not in its proprietary possession but in one that optimizes its use or function. The concept is closely tied to circular economy (McDonough & Braungart, 2010) and to collaborative consumption and production (Bostman & Rogers, 2010). The second root, the gift economy, is defined as a transfer free from compensation. Citing the works of Anthropologist Marcel Mauss (1924), who studied gift giving in Polynesia, Melanasia and the Americas, the notion of ‘gift’ supposes the triple function of “giving, receiving and returning”. In our current society, the authors state that it enables recovering lost conviviality or comradeship as well as the opportunity of renewing and strengthening social bonds, as demonstrated by the *Repair Cafes* where, in a certain public location, tools and competences are freely given in order to repair objects. The third theoretical root is that of the commons, and digital commons. The fourth and last root identified is that of the counter-culture movement based on individual freedom of action in a free, unregulated market, rid of monopolies and of state intervention. The rise of the internet and the hacker movement have pushed this ideology forward by using decentralized technology, by questioning established hierarchies and stipulating the freedom for anyone to build new organizational forms based on participation and collaboration (e.g. Hackerspaces) (Troxler 2010, p. 3).

The downside of collaborative commons is a parallel process of winner-take-all dynamics, also in play. The Internet's strong network effects have transformed individual providers like Google, YouTube, Apple, Facebook, eBay, PayPal... into digital monopolies (i.e. Unicorn models) that sit at the heart of the network society. "They are now effectively running the global social commons in the interest of their own commercial ventures, while aggressively arming themselves with patents to guard that privilege. The global governance to regulate these divisive dynamics is still sorely lacking yet is clearly going to be essential in order to reverse this rapid enclosure of the twenty first century's most creative commons" (Raworth, 2017, p. 192).

Morell & Espelt (2018), see the progression from open commons, to the Unicorn model, to platform cooperativism as chronological. In contemplating the progression, one is reminded of Hockerts & Wüstenhagen's article (2010) on the role of incumbents and new entrants in sustainable entrepreneurship. They describe a cyclical process wherein *Emerging Davids* propose a niche offer that attracts *Greening Goliaths* wishing to white wash (green wash, or in this case open-wash) their products and services as soon as they perceive a market response. Such endeavors tend to lessen the environmental and social standards of the *Emerging Davids*, but have the benefit of broader reach due to established market presence. In turn, new Davids with more business acumen will combine product and process innovation and raise the standards once again. The benefit of this process is that sustainable innovation becomes quasi-industry-standard.

By transposing the progression to platform economy models (Figure 7), we see how Open Commons, such as Wikipedia or Goteo first emerged with an economic model adapted to maintaining community governance.








	 Open Commons  	Unicorn  	Platform coops  
GOVERNANCE, DEMOCRATIC ECONOMY, ECONOMICAL SUSTAINABILITY AND PURPOSE EMBEDDED IN THE ECONOMIC MODEL	Foundations, with systems of community participation Economic models adapted to keep community governance	International company Economic models driving governance	SMEs & cooperatives
POWER DISTRIBUTION; FREEDOM ALLOCATIONS AND OWNERSHIP EMBEDDED IN THE TECN AND KNOWLEDGE POLICY	Collective and public ownership Open software (replicable) Open data Open licenses (eg Creative Commons)	Private ownership Proprietary software Closed data Restricted Copyright	Open software (replicable) Data policy depend
IMPACT ON VALUE CREATION AND SOCIAL RESPONSIBILITY TOWARDS EXTERNALITIES	Social value Circular economy - environmental impact Gender active policies	Economic value Gender discrimination complaints Environmental discrepancies	Social and economic value Circular economy - environmental impact Gender active policies

Figure 7: Models of the platform economy (Fuster & Espelt 2018)

In such a model, policies are co-created involving all agents and not only the core-group. Public partnerships are common as an alternative to privatizing and seeking to close the common. Next, Unicorn models appeared with economic models driving their governance and restricted software, causing disempowerment of both customers and administrators. Their disruptive impact via platforms such as Uber and Airbnb, has provoked huge controversy¹⁴ as users provide knowledge, properties or services, while only intermediaries truly profit financially. Finally, the cooperative platform model appeared with sustainability and purpose embedded in the economic model giving rise to hybrid forms merging SMEs and cooperatives. These are successful alternatives and truly collaborative models with decentralized organization based on social economy and open knowledge.

Despite certain confusion in objectives, collaborative economies are growing rapidly, even exponentially, bringing high sustainability expectations with their potential contribution to democratizing the economy. The authors explain that the term “collaborative economy” or “collaborative economy platforms” (which can only be considered commons-oriented under a particular set of conditions), refer to exchange, sharing, and collaboration in the consumption

¹⁴ Codagnone, C., Biagi, F., & Abadie, F. The Passions and the Interests: Unpacking the 'Sharing Economy'. Institute for Prospective Technological Studies, JRC Science for Policy Report 2016.

and production of capital and labor among distributed groups, supported by a digital platform. They introduce the key concept of “platform cooperativism” coined by Scholz in 2016. According to whom, “a digital platform must be based on collective ownership, decent payment and income security for its workers, the transparency and portability of data created, appreciation and recognition of the value generated by the platform’s activity, collective decision-making, a protective legal framework, transferable protection of workers and of their social benefits, protection against arbitrary conduct in the rating system, rejection of excessive supervision in the workplace, and, finally, on the right of the workers to disconnect”.

As stated by Scholz (2016), on one hand the platforms must be shaped around the values of cooperativism, on the other hand digital tools must amplify the scalability and the social and economic impact of cooperative organizations. At the same time, Fuster Morell (2016) indicated that the very construction of technology platforms is not a minor issue, and that cooperative platforms should adopt open software and licenses. In short, creating self-managed governance allowing the articulation of community development around the digital commons, must be approached as “open cooperativism”, the antithesis of the Unicorn and corporate platforms” (Fuster & Espelt 2018).

1.4.2. A FRAMEWORK FOR COLLABORATIVE ECONOMY PLATFORMS

In response to the confusion concerning platforms which present themselves as collaborative but are not, Fuster & Espelt (2018) have created a holistic framework to assess the sustainability and pro-democratizing qualities of these platforms. This framework is the result of earlier work on over a hundred cases of commons-based collaborative platforms that showcase how open technological and knowledge practices reinforce each other (Morell & Espelt 2018). Their Sharing Star Framework¹⁵ articulates around three main dimensions and six subdivisions (see Figure 8).

¹⁵ <http://www.sharingcitiesaction.net/sharing-star/>

STAR OF DEMOCRATIC QUALITIES OF DIGITAL PLATFORMS

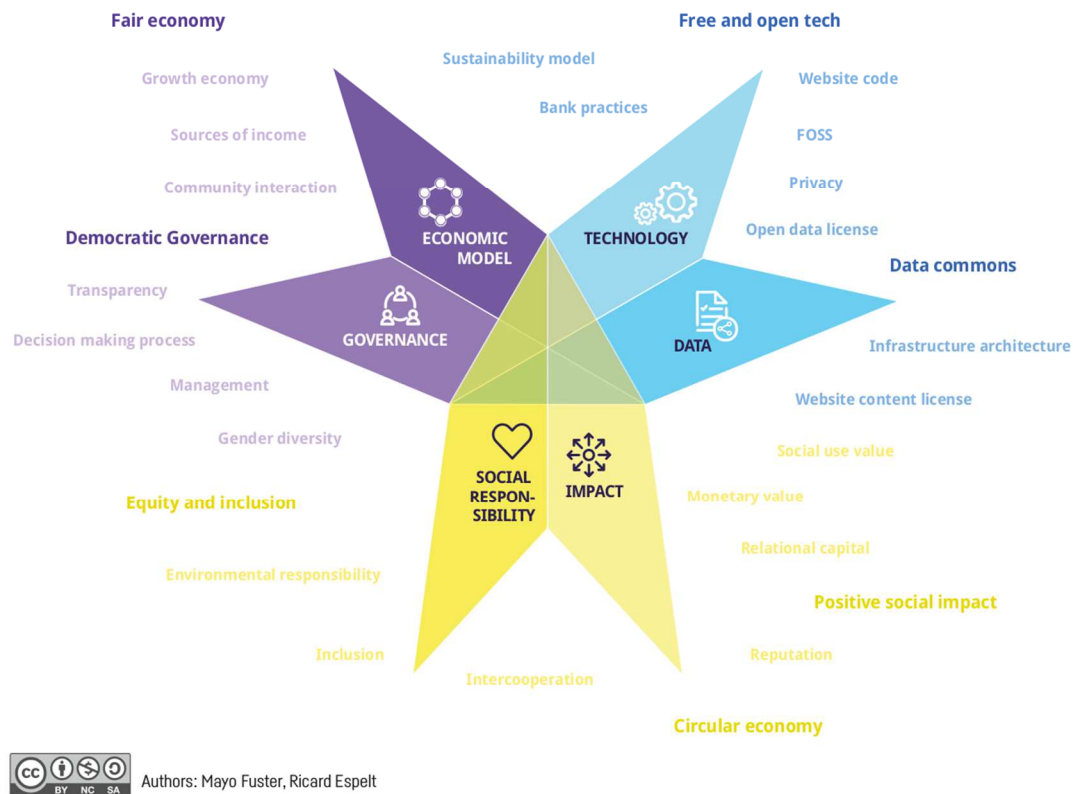


Figure 8: Star of democratic qualities of digital platforms (Fuster & Espelt 2018)

The *first dimension* relates to governance and the economic model, which are clearly interlinked as the means of platform governance is connected to the underlying economic model. The notion of governance relates to the decision making mechanisms and political rules for participating in the digital platform. The economic model addresses the project's financing model (private capital, match-funding or crowdfunding); how far profitability is driven; distribution of generated value; and the benefits and rights of workers.

The *second dimension* addresses knowledge and technological policies, since the adoption of certain technological tools or licenses will have an impact on the way the platform promotes knowledge. Knowledge policy relates to the type of license used for the content and knowledge generated, the type of data, the ability to download data, the transparency of algorithms and data. This aspect regards privacy awareness, the protection of property including personal data, preventing abuse and data collection or sharing without consent. Technological policy regards the mode of property and freedom associated with the type of

software used and its license (free or proprietary) as well as the model of technology architecture: distributed (using blockchain, for example) or centralized (software as a service).

The *third dimension* is the social responsibility and impact which often not been integrated, even though platform collaborative economy holds high sustainability expectations. “These dimensions relate to any source of awareness and responsibility regarding the externalities and negative impacts, such as social exclusion and social inequalities, the inclusion of gender, regarding the equal access to the platform of people with all kinds of income and circumstances in an equitable and impartial manner (without discrimination). This includes compliance with health and safety standards protecting the public, and the environmental impact (promoting sustainable practices that reduce emissions and waste, taking into account the rebound effect they can generate and the most efficient use of resources, the origin and production conditions of the goods and services they offer, minimizing resource use, and the recycling capacity), as well as the impact in the policy arena, and the preservation of the right to the city of its inhabitants and the common good of the city. This aspect also regards the protection of the general interest, public space, and basic human rights such as access to housing” (Fuster & Espelt 2018).

1.5. WORKING WITH OSH COMMUNITIES

The resulting tension between a firm’s perspective on open innovation and a bottom-up community-based perspective is further exacerbated by the role porosity of OSH practitioners. Given the open-access nature of OSH, OSH communities members, providing they have the skills to participate, can be members of a civil society, the government, as well as firms or non-profits, while individually or collectively participating in OSH initiatives.

For this research we define OSH communities as hybrid innovation communities with local-global reach. To begin, we will clarify the scope of innovation communities (Sarazin *et al.*, 2017), and hybrid communities (Evrard Samuel & Carré 2018) blending aspects of Communities of Practice (CoPs) and epistemic communities.

The innovation communities practicing open source hardware can be external to firms, internal or mixed. Researchers use the term “innovation communities” to regroup with communities of practice (Lave and Wenger, 1991); user communities (von Hippel 1986; Parmentier & Mangematin 2014) communities of interest (Fischer 2001); virtual communities; epistemic

communities (Cowan *et al.*, 2000), and communities either internal or external to an organization (Parmentier 2015; Parmentier & Mangematin 2014; Sarazin, Cohendet, Simon *et al.*, (2017). According to Sarazin *et al.*, (2017) innovation communities are an informal group, uniting internal and external actors in an organization (users of products of services, or informal virtual groups sharing a similar interest), who have come to play an active role in innovation processes by developing creative ideas to be validated, tested and put into practice. Till now, they haven't weighed much in organizing innovation dynamics. This has changed, thus the need to group them under the label of "innovation communities".

Open source hardware communities, being composed of diverse communities of practice (CoPs), each Maker Space or Fab Lab within may share knowledge on a given trade (Capdevila 2017). Like communities of practice, the aim of the community is to increase the technical expertise of its members. Members in communities of practice, develop a common repertory of problems and solutions through which collective intelligence and learning emerge (Sonntag, 2009, p.44). Communities of practice were thus defined as "groups of people who share a concern, a set of problems or a passion for a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger *et al.*, 2002, p.4). This research helped firms to see in communities of practice a means of ensuring knowledge sharing, identifying best practices and working together on common solutions. Together, they create new codes, norms, rules or habits resulting in the paradigm shift sought by Fab Cities. What is salient in these community organizations is that they are based on voluntary, free and collaborative relations (Fuster Morell 2014; Mies *et al.*, 2019a). Contributors are not connected through organizational affiliation but rather engaged as individuals (Aksulu & Wade 2010). They proactively self-organize, choosing their own roles (technical, creative, organizational, or administrative) as well as their time periods of involvement. They are "self-motivated, self-selected and self-governed" (Benner & Tushman 2015; Boudreau 2010; Dahlander & Gann 2010). Due to loosely connected community structures and fluid boundaries, participation levels vary over time in terms of quantity as well as contribution. Hence, a person's being considered a community member can be justified by diverse levels of participation (Bonvoisin *et al.*, 2017). Both participation and recognition are based on individual merits described by Ehls and Hertatt (2015) as a *participation lifecycle* where members may progressively become more involved in the community as they hone their technical expertise.

Epistemic communities differ from communities of practice in that they are highly multi-disciplinary. They may be communities of practice, user communities, virtual communities, communities of interest, and all communities either internal or external to an organization. Moreover, research has shown that they translate local knowledge into global innovation by transcending the separations between individuals, communities, and firms (Cohendet *et al.*, 2010; Capdevila 2017). Epistemic communities are the active units forming new knowledge. This happens through a “series of paradigm shifts, which move the system away from established codes, norms, rules or habits” (Cohendet *et al.*, 2014). These communities, defined as “groups of knowledge-driven agents linked together by a common goal, a common cognitive framework and a shared understanding of their work”, build a common declaration of purpose or manifesto that expressly states breaking rules. Their “deviant or non-standard ideas have been identified at the origins of many radical innovations” in the fields of art, technology and science. Movements such as Cubism, or the Cirque du Soleil, Marie Curie or Einstein all reinvented their industries and advocated multiple disciplines. According to (Hass 1992), the three elements characterizing epistemic communities are: 1) the presence of renowned experts who legitimize and give strength to the community; 2) a common goal or concern that federates and mobilizes their diverse competencies; 3) a shared set of beliefs for establishing links with more macro, or political, action.

Open source hardware communities are epistemic by nature. Members are individuals from heterogeneous backgrounds with “maker” or “tinkering” tendencies, whose dissatisfaction with government or market solutions, such as programmed obsolescence, spark the desire to address issues of often social or environmental importance (Li *et al.*, 2017; Unterfrauner & Voigt 2017). These individuals (enthusiasts, company employees, voluntary domain experts, artists, or scientists) choose to take matters into their own hands and collaborate to gain technological empowerment in order to address issues. The resulting innovations are shared publicly under a Commons license, which does not mean they do not need to be protected, but that these innovations will form a rich pool of information and resources which thousands will be able to filter, “allowing them to identify productive opportunities and the creative individuals who can best use these resources. This capacity is the primary means of increasing productivity gains that peer production offers our economy.” (Benkler 2013).

Moreover, unlike communities of practice, the virtual notion of OSH means that they transcend localized learning. Research suggests that knowledge is “sticky” (Von Hippel 1994).

Stickiness refers to the ease at which information can become usable to a given information seeker. The particularity of immaterial commons communities is that they are large and often geographically dispersed. Knowledge may be created locally, but its virtual nature enables it to be extracted and reapplied in new settings around the globe. This ties into the concept of both local and global pipelines characteristic of Makerspaces and Fab Lab networks (Capdevila 2017; Gershenfeld, 2018). Linked to the new production model of the Fourth Industrial Revolution, the Maker Movement has shifted from a DIY-bricolage phenomenon to a global ecosystem of over 1200 Fab Labs in more than a 100 countries, offering the potential for on-site production of the items people consume (Lassiter, 2018; Gaudron & Mouline 2017), and working at sharing files and processes in order to speed up this process.

In line with research on epistemic communities, authors writing about community-based literature argue that relational proximity might be more important than geographic proximity in order to effectively create knowledge (Amin and Cohendet, 2004; Brown and Duguid, 2000). Relational proximity refers to different aspects such as shared values, shared visions, shared vocabulary, or to common institutional environments including norms, regulations and legal frames (Boschma, 2005; Torre and Rallet, 2005, *cited in* Capdevila 2017). As such Capdevila and Cohendet's research is pertinent as they explain how local dynamics influence global dynamics through the interaction of epistemic communities.

1.5.1. HOW AND WHEN TO WORK WITH INNOVATION COMMUNITIES

Community impacts or contributions to innovation require requires understanding what communities are, how they work and how they interact with firms. Firms came to realize that competitive advantage lies in being the most welcoming possible to communities, both internal and external to the firm (Parmentier 2015; Parmentier & Mangematin 2014). This section treats the interactions between the different actors, the tensions between firms and innovation communities, and of course the conditions under which collaboration with communities may be useful.

Numerous authors have documented the importance of innovation communities for innovation. The communities feed a firm with a stream of new ideas from passionate users, as indicated by the cases of Lego, Rossignol and Ubisoft (Sarazin *et al.*, 2017). But leveraging communities is no easy task. In fact, for incumbent firms, community-based innovation modes, radically decentralized, cooperative, and self-organized in terms of problem solving and production,

stand in sharp contrast to their historically-based, hierarchy-based, control-oriented innovation modes (Lauritzen 2017; Sarazin *et al.*, 2017; Parmentier 2015; Benner & Tushman 2015; Lakhani & von Hippel 2003). Tensions arise because firms and communities “*pursue different, non-aligned goals*” (Parmentier & Mangematin 2014). Firms seek to improve their profitability, generating turnover and benefits by making the best market offer. Communities seek to organize matters to increase and facilitate “*the pleasure of using the product, of exchanging and sharing ideas, as well as of being involved in product innovation, with the chance of achieving recognition for their efforts*” (Parmentier & Mangematin 2014). This divide is arguably a rather traditional view of firms; the difference between the modes of operation is illustrated in Figure 9. What we can say is that the operation modes on the left, better translate into to motivation drivers than those on the right, which we will develop.

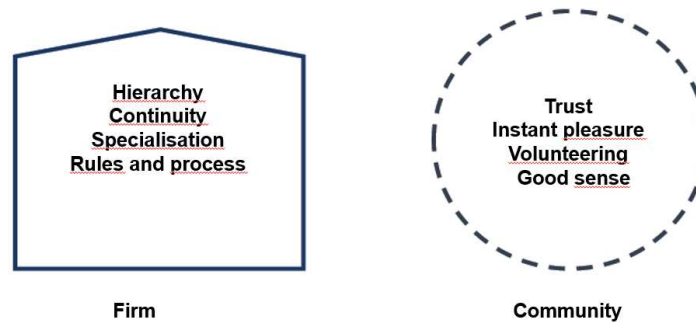


Figure 9: The difficult relationship between firms and communities (Parmentier, 2015)

Firms’ efforts to directly control innovation communities are not often well perceived: they create conflicts and user involvement decreases (Dahlander & Magnusson 2005). Moreover, the type of community dictates the structure of a relationship. For instance, in trying to establish relationships with external communities, firms may choose among three relationship types and identify the most appropriate. They may seek to establish relations with community leaders, such as well-known athletes in the case of Salomon or Free, who will relay information to other community members. They may establish crowdsourcing platforms to benefit directly from the larger array of user communities with many members and few identified lead-users. Finally, research reveals that best results come when firms orchestrate community activities, providing animation and tools for co-creation rather than focusing on hierarchical control. A co-creation space often takes the form of an online forum “hosted in part or fully by the company, and equipped with tools that encourage creativity and innovation” (Parmentier 2015; Sarazin *et al.*, 2017).

Benner & Tushman (2015) and Lakhani *et al.*, (2013) suggest that the variables relevant when selecting innovation modes and associated boundaries, are the “extent to which the product/service is integrated (versus modular) in nature, and the extent to which problem solving knowledge is distributed”. According to the authors, co-development with a community is only strategically useful when costs of collaboration are low, when the given product can be “decomposed or modularized, and when problem-solving knowledge is broadly dispersed [...], such a shift of innovation locus requires incumbent firms to engage with external communities in open, democratic, collaborative relations”. From their model (see Figure 10), the lower left quadrant represents situations where more traditional intrafirm innovation logic applies: core tasks are integrated, and problem solving knowledge is concentrated within the firm.

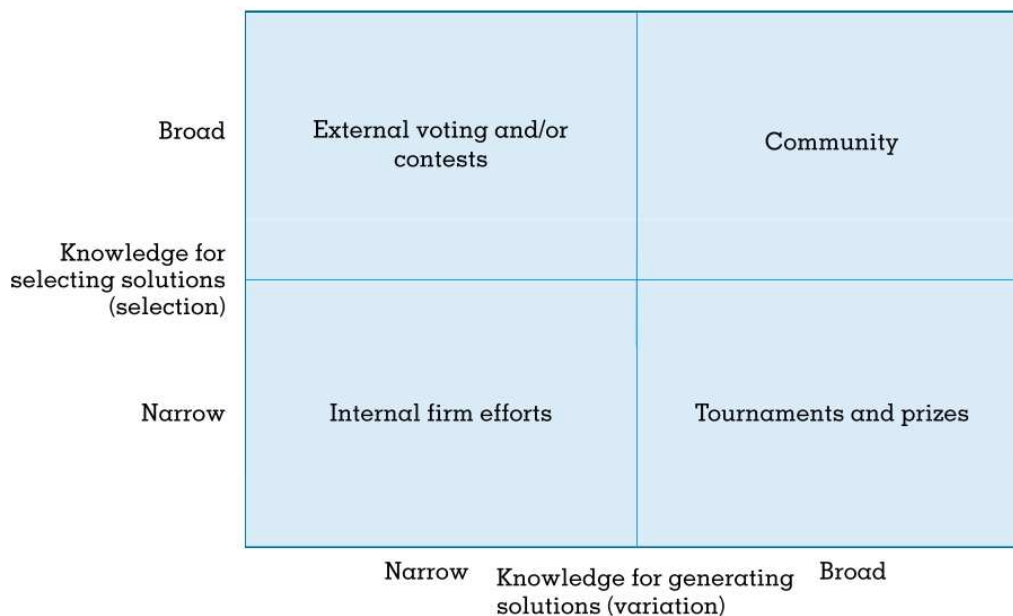


Figure 10: The locus of innovation (Benner and Tushman, 2013; Lakhani *et al.*, 2013)

“Under these conditions, firms internalize R&D and build an innovative culture, capabilities, absorptive capacities and processes that locate solution search within the firm and/or with trusted partners”. This concurs with Benkler (2006), who stated that firm and community innovation can be complementary. A broad base of heterogeneous actors is useful for generating and selecting solutions. However, if the problem is more specific, and its solutions lie within the firm’s key resources or activities, the firm can better optimize and productize results. When the firm detains the knowledge generating solutions, but needs a broad base to

validate them, (as, for instance, in the world of fashion with firms like Zara), in order to determine demand and associated production runs, external voting and or contests may be a good alternative. Types of crowdsourcing such as tournaments and prizes are useful when, as in the case of NASA, solution generation can be broadly distributed, but the knowledge required to select and implement it is very specific (Lifshitz-Assaf 2014).

Co-creation spaces such virtual platforms associated with tools that encourage creativity and innovation, are the means by which firms can establish cross-over points with innovation communities and involve them in the innovation process (Parmentier & Mangematin 2014; Parmentier 2015; Bonvoisin *et al.*, 2016).

1.5.2. INNOVATION ECOSYSTEMS

The porosity of roles of OSH community members, and in commons boundaries is further translated in the porosity of layers in innovation ecosystems literature. Bogers *et al.*, (2016) contend that academic research concerning open innovation has covered intra-organizational levels, inter-organizational levels, but for the moment has not covered broader territorial, or ecosystemic levels.

Scaringella & Radziwon's recent work (2018) provides a useful framework to bridge business and territorial approaches to ecosystem innovation literature. Briefly stated, ecosystems represent the set of conditions that sustain life (Moore, 1993), which when applied to business, are complex (Jackson, 2011), and a vital source of dynamics and innovation for many technologies, products, and services (Adner & Kapoor, 2016; Hekkert *et al.*, 2007). The term “innovation ecosystems” describes all actors and resources of the ecosystem.

Scaringella & Radziwon's (2018) integrated framework proves a particularly relevant basis for studying OSH. Based on a systematic literature review of 383 articles and 10 books, they identify the common invariants of the diverging research streams concerning business ecosystems, innovation ecosystems, entrepreneurial ecosystems and knowledge ecosystems.

Their model reveals the permeability between an inner territorial, territorial ecosystem and an external ecosystem in approaching in the quest for value creation and capture among various sets of actors. Complex relationship interactions among sets of actors (when concerning academia, industry and governments) are illustrated as a triple helix (Caprotti *et al.*, 2014), and a quadruple helix when bottom-up initiatives stemming from civil society are included. When

the environment becomes an actor, a quintuple helix is needed to illustrate relationship interactions.

1.5.3. ORCHESTRATION THROUGH THE MIDDLEGROUND

Because the interactions between the sets of actors in an ecosystem are complex, we choose to use the *middleground* concept to dimension the innovation mechanisms at play and between different ecosystems layers. Innovation mechanisms are “the wheelwork or agency by which an effect is produced” supporting the social phenomenon of innovation (Hernes, 1998, p. 74; Parmentier, 2015, p.80). In essence, in order to understand value creation and capturing processes in OSH, one needs to understand the roles of OSH community members and the larger set of stakeholders supporting them, and to be able to describe the dynamics of their interactions.

The *middleground* concept (Cornella, 2010; (Cohendet *et al.*, 2010; 2014; Sarazin *et al.*, 2017) provides an analytical tool to describe interactions and possible tensions occurring among formal mainstream entities, such as government and firms, and “greenfield” emerging initiatives arriving from grass-root innovation communities (see Figure 11). The concept has been developed to describe the dynamics of how radical, deviant or creative initiatives spread in specific milieus.

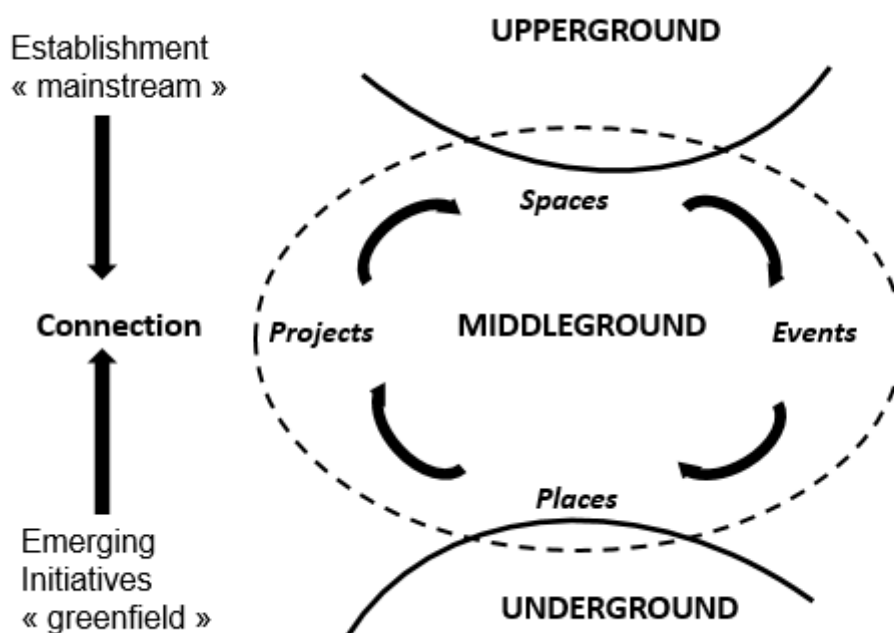


Figure 11: The middleground adapted from Sarazin, Cohendet, Simon *et al.*, 2017, and Cornella 2010

The concept of the *middleground* defines a three level structure of innovation processes that meld and connect formal and informal entities. The metaphor used is that of the tree. The informal, creative grassroots, the *underground*, need to go through the trunk, (the *middleground*), to access the oxygen, or funding flowing from the branches. Conversely, the formal *upperground* entities need the creativity of the *underground* in order to access and refuel their processes with more creativity. Amusingly, this is an old metaphor used to describe the need for bottom-up innovation. In 1751, the Marquis de Mirabeau wrote: “from the roots come the vivifying sap drawn up by multitudinous fibres from the soil [...] To the roots must the remedy go, to let them expand and recover. If not, the tree will perish” (Leibniz, 1768, cited in Higgs 1897, p27).

Cohendet *et al.*, (2010) explain that each level, underground, middleground and upperground intervenes with specific characteristics in the creative process, enabling new ideas to transit from an informal micro-level to a formal macro-level, through the accumulation, the combination, the enrichment and the renewal of bits of knowledge”. The co-constructed *middleground* is where the formal and informal entities will meet and blend their pervading logics through the orchestration of *places*, either physical or virtual, where people can gather in incongruous, happenstance encounters; of *events*, such as Ubisoft’s cool Tuesdays or hot Fridays, which are organized sessions where employees share insights, or hackathons that can attract a global audience and enrich innovation dynamics; of *projects*, on which people work together and of *spaces*, which are cognitive themes that help build and spread ideas such as open technologies, or digital fabrication.

The concept is close to Everett Rogers’ diffusion of innovation theory, which addresses how new ideas and innovation spread (1962), and are communicated over time among the participants in a social system. The *middleground* concept particularly addresses the mechanisms in social system interaction. The concept also resembles that of Eglash’s basins of attraction for generative justice, requiring “bottom-up circulation of nature’s agency in a mangle with human intentionality”, and Elinor Ostrom’s Common Pool Resources (CPR) (Ostrom 2010) “that persistently demonstrate how bottom-up, self-organized governance systems, properly implemented, can offer gains in both human and ecological productivity, sustainability and biodiversity” (Eglash 2016); 2018). We retain the notion of a purposeful, bottom-up top-down engagement to energize a co-constructed *middleground*. The words “purposeful” and “engagement” need to be qualified since, as Sarazin *et al.*, (2017) suggest,

formal entities composing the *upperground* need to radically shift their traditional operation modes and their priorities (Benner & Tushman 2015; Sarazin *et al.*, 2017; Parmentier & Mangematin 2014) when working with innovation communities. In sum, the intention stems from the need to bolster interest in a topic that is sufficiently motivating to engage both *upperground* and *underground* parties.

1.5.4. MAPPING THE FABGING WORLD

The elements of the paradigm shift described earlier, are reconfiguring production from a centralized to a decentralized model and have enabled the democratizing of design, through digital manufacturing (such as additive manufacturing, 3D printing and laser cutting), and the digitization of the design process (via computer aided design CAD, manufacturing CAM, and engineering CAE). Neil Gershenfeld called the Maker Movement the next digital revolution as it placed the means of fabrication on peoples' desks (Unterfrauner & Voigt 2017). Democratizing with these factors means that it is no longer necessary to master craftsmanship or to rely on specialized skills to produce things.

This democratizing occurs through new infrastructures such as Fab Labs (fabrication laboratories), Techshops, Makerspaces and Hackerspaces, dedicated to personal digital fabrication free or for a limited fee (Boisseau *et al.*, 2018). Such collaborative spaces, including incubators, co-working spaces and chambers of commerce, hold a pivotal role (Capdevila 2017). They serve as think tanks, able to funnel projects originating from the different entities to the Fab Labs for prototyping, and to match them with start-ups and firms having appropriate competencies.

At this point, it could be useful to revisit the attempt of “mapping the fabbing world” that Peter Troxler published in 2010. Fabbing refers to our topic, as the third stage of the digital revolution affecting the field of manufactured goods, with the emergence of digital, personal fabrication or ‘fabbing’ (Troxler 2010a, Gershenfeld, 2005). Associated with *middleground* innovation dynamics, OSH can be either or both a cognitive theme, or a *space* for people to work, and a source of single-aim or single-product *projects*. Therefore, in our revised map (Figure 12) it is not featured as an initiative in itself.

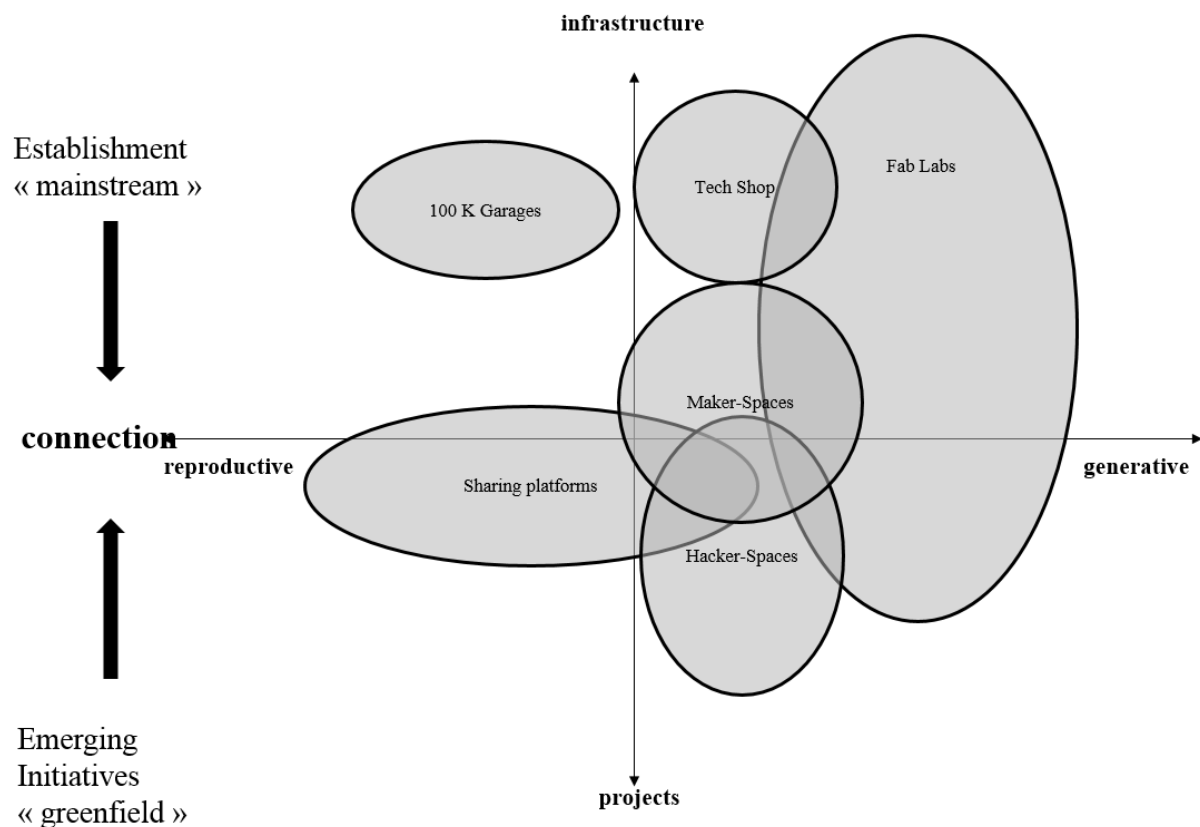


Figure 12: Revision of the map of the fabbing world (adapted from Troxler 2010a, p.4)

The reason OSH is progressing from epistemic communities to cities is because of more or less structured initiatives, which Troxler classified as the “*innovation support model*” and “*the facility model*”, both of which can be seen as “commons based peer production” (Troxler 2010a, p. 9). The innovation support model occurs when the infrastructures of Fab Labs, Hackerspaces and Makerspaces, provide peer support enabling fast, effective innovation for participating peers: i.e. I think the ‘Love Box’ idea is great, I live in Grenoble and head over to the Casemate Fab Lab to connect with other people who can help me build mine.

The facility approach supports users primarily during their stay at the lab when using equipment and manufacturing processes. For example, I’m interested in learning how to make organic insulation for my home using mycelium grown in casts, therefore I head on over to my local bio lab for a workshop and mentoring on which processes and tools to use¹⁶.

¹⁶ <http://greenfablab.org/machines/>

In Figure 12, we have rearranged these initiatives and infrastructures according to the *upperground*, *middleground* and *underground* concepts. More established infrastructures relate to the *upperground* such as 100K Garages and Techshops, while more ad hoc and greenfield (Hackerspaces) correspond to the *underground*. *Middleground* initiatives, such as Makerspaces and Fab Labs form the connection between the two. The sharing platforms are the virtual spaces (Instructables, Github, Thingiverse) through which people can access projects they would like to contribute to, to replicate or fork.

CHAPTER 1: KEY TAKEAWAY

The OSH phenomena is part of a larger business and societal transformation, which is indicative of a decentralized and collaborative trend in innovation. OSH is situated at the confluence of research fields such as enterprise-led open innovation, and community-led bottom-up innovation. OSH fits with Digital Commons and the Commons theory because the innovation is not limited to selected partners but is open to society at large for anyone to replicate, modify and distribute (Bonvoisin *et al.*, 2018), and is thus available for “the common good”. We present the Open–O-Meter and the Sharing Star as conceptual means of assessing the openness of OSH initiatives and their associated governance and knowledge policies.

The second part of this chapter reviews literature on innovation communities and defines OSH communities as hybrid. They are part Communities of Practice, because people sharing similar trades combine their collective intelligence to work together on common solutions using common repertoires. They are also epistemic communities because multidisciplinary actors translate local knowledge into global innovation. The physical and virtual nature of OSH implies pipelines of local and global knowledge exchange and of value creation crucial to innovation dynamics. Through the sharing of values, visions, and vocabulary, they work towards building a common declaration of purpose or manifesto breaking the established rules. The difficulties companies face when working with innovation communities and the particular instances when such interactions are most beneficial, are explained.

Because the roles of OSH communities are blurred and the impact of OSH is spreading globally, it is difficult to select a unit of analysis. To clarify the roles and interactions of actors partaking in OSH, we present the *middleground* concept to illustrate the dynamics of emerging bottom-up greenfield initiatives and their interactions with more established milieus. We identify the commons, market and state, as equally important players in fostering the *middleground* dynamics required for the OSH phenomenon to spread.

How to monetize innovations stemming from an OSH approach, or how the notion of value capture is somehow broadened in Commons based peer production, remains unclear. These notions are a key to the eventual success of such initiatives. The success of OSH endeavors depends on the ability of community members to properly harness the concept of business models to make their projects grow in scope which we will present in the next chapter.

CHAPTER 2: FROM BUSINESS MODELS TO OPEN BUSINESS MODELS

CHAPTER 2: FROM BUSINESS MODELS TO OPEN BUSINESS MODELS**CONTENT**

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CHAPTER 2 SUMMARY

Objective – The strategic use of a business model is traced up to the phenomenon of openness where collaboration of a firm with its wider ecosystem becomes a decisive element of value creation and capture. The components of business models and open business models are reviewed. Next, a state of the art of the current understanding of OSH BMs is provided.

Methodology/approach – A review of literature concerning business models, open business model and open source hardware business models is provided.

Results – The landscape of current understanding of OSH BMs crossing academic and practitioners perspective is both overlapping and disparate.

Limits – As this is qualitative research, the findings reveal what the researcher considered important, that is the elements cementing stakeholder participation in commons-based peer production.

Managerial implications – This literature review reveals that for the moment, the understanding of what is an OSH BM is disparate and not easily actionable for practitioners. The question of how to capture value remains elusive as is the notion of value sharing with others.

Theoretical implications – This chapter leads us to seek to understand how the business model concept can be associated with commons-based peer production.

Originality/value – Through the literature review presented in this chapter, it becomes apparent that a focus on components of business models is too static. To apprehend the dynamic nature of openness and collaboration, the nature of the interactions and the type of value sought need to be investigated.

Before the internet, business conducting methods were comparatively linear and simple. The digital revolution has produced digital goods and sales channels with novel and unconventional exchange mechanisms. These have provoked managerial and academic reflection on the business models themselves.

Business models have come to be the means of describing the dynamic and complex manner of how an organization does business, that is, creates, delivers and captures value existing between the firm and its numerous stakeholders (Teece 2010; Massa *et al.*, 2016; Foss & Saebi 2018). The concept addresses three phenomena: (1) e-business and the use of information technology in organizations; (2) strategic issues, such as value creation, competitive advantage, and firm performance; (3) innovation and technology management (Zott *et al.*, 2011b). Through the internet, a broader base of customers is reached than ever before, altering price scales and the relationship to hyper-connected customers, who as never before, engage with brands or with each other through virtual forums (Parmentier 2015; Bendell & Thomas 2013, p.16). As Tom Goodwin noted, something interesting has happened: Uber, the world's largest taxi company owns no vehicles; Facebook, the world's most popular media owner creates no content; Alibaba, the most valuable retailer, has no inventory; and companies such as Airbnb or Bookings, have radically altered the Hotel industry.

Accordingly, these changes brought about new forms of organizations requiring explanation for potential investors. The idea being that today, product or service innovation alone is no longer sufficient today to guarantee competitive advantage or even viability. In his seminal work on Open Business Models, Chesbrough (2006) explains how "innovation is a core business necessity. In the current environment, you must increasingly innovate openly. And to innovate openly you must do more than search externally for new ideas or license out more of your own ideas. You must also innovate your business model, so that you create value and capture a portion of that value for yourself" (Chesbrough, 2006, pp. 2-3). Some claim that increasing costs of product development in industries such as pharmaceuticals and biosciences, have forced firms to consider alternative ways of making money (Chesbrough, 2007). Others argue that the decreasing costs of product development, especially in software and internet-related industries, have supplied the oxygen for a Cambrian explosion of new business models (Ries, 2011). On a more general level, expanding global competition (Dicken, 2003, *cited in* Berglund & Sandström 2013), the development of flexible manufacturing technologies, and

increasing industrial and technological convergence (Amit & Zott 2001), speak to the importance of business model innovation.

2.1. THE EMERGENCE OF BUSINESS MODEL RESEARCH

The porosity of a firm's boundaries through open innovation, is closely intertwined with the concepts of open innovation and business models. Although the idea has spread like wildfire among both scholars and practitioners, who have understood this relationship as a key to competitiveness, there is no coherent definition today of what a business model is. For Teece (2010) a business model "articulates the logic and provides data and other evidence that demonstrates how a business creates and delivers value to its customers. It also outlines the architecture of revenues, costs and profits associated with the business enterprise delivering that value". For Amit & Zott (2001) a business model depicts "the content, structure and governance of transactions designed to create value through the exploitation of business opportunities". Over the years, the discourse has broadened substantially, and today business models are frequently discussed by technology and innovation management scholars as a conceptual means of relating a firm's technological and market domains (Chesbrough & Rosenbloom 2002; Calia *et al.*, 2007; Björkdahl 2009), and by strategy scholars who use the concept to discuss the creation of sustainable competitive advantage (Christensen 2001; Teece 2010).

Recently, Massa *et al.*, (2016) provided a critical assessment of business model research to clarify the confusion arising from different interpretations of what a business model actually is. They identified three main research themes describing business models, i.e. "an attribute of a real organization; a cognitive/linguistic schema; or a formal conceptual representation of an organization's activities". They argue that further work is needed to broaden the boundaries of innovation-related phenomena beyond product-process-organization to include value creation for all stakeholders. They encourage further research to design business models that realign the organization's profit quest with innovations beneficial to the environment and society.

2.1.1. A CONSENSUAL DEFINITION OF A BUSINESS MODEL?

There is high-level agreement on a number of issues. First, business models describe how firms, or business units, create, deliver and appropriate value (Magretta 2002, Osterwalder and Pigneur, 2004; Shafer *et al.*, 2005; Zott *et al.*, 2011). Second, it is common to define business models in terms of sets of components and their interrelationships, e.g. customer segment, value

proposition, revenue model and key partners (Chesbrough & Rosenbloom 2002; Osterwalder & Pigneur, 2004; Johnson *et al.*, 2008). Finally, there is an emerging consensus that business models transcend the boundaries of any one firm (Amit & Zott 2001; Afuah, 2004; Itami & Nishino 2010; Casadesus-Masanell & Ricart 2010; Zott *et al.*, 2011). Zott & Amit (2010) explicitly make this point when they define a business model as “a system of interdependent activities that in transcending the focal firm exceed its boundaries” (p.216). Building on this emerging consensus, we define a business model as: (a) a high-level description of how a firm (or part of a firm) creates, delivers and appropriates value, that is (b) centered on a focal firm, but that also (c) transcends the boundaries of the focal firm. Business model innovation can thus be considered of as the introduction of a new business model destined to create commercial value (Berglund & Sandström 2013). Finally, the notion of the business model is d) highly dynamic. Jouison & Verstraete (2008) the founders of GRP Business models, explain that the relationships among the venture carriers, the stakeholders and the holders of the key activities as well as the resources necessary for the viability of the business idea, are as dynamic as a spider web. Tweak one relationship, and all the others will have to readapt.

Before listing some of the most common patterns observed, we wish to distinguish among the revenue streams types an organization can activate, which can be numerous, and a firm's overarching business model, simplified by the Gassman *et al.*, (2014) “magic triangle” (2014, see Figure 13). In essence, a business model answers the following questions: What do you offer the customer? What is your customer segment? How is the value proposition created? Why does the business model generate profit? (Gassman *et al.*, 2014). According to the authors, business model innovation occurs when at least two of these are changed.

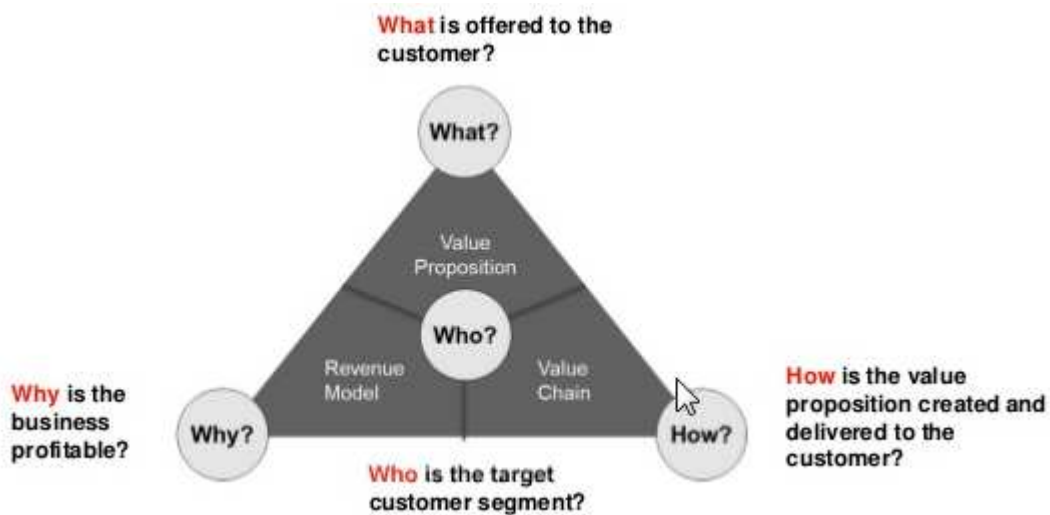


Figure 13: Business model innovation (Gassman *et al.*, 2014)

In practice, the tools of the business model canvas (2010) and value proposition (2015) design by Osterwalder and Pigneur are the most widely used to map out the interplay between customers and key partners for value creation and capture. Critics find that such tools fail to adequately capture the business model of collaborative communities because often “Open Source and P2P distributed systems have fuzzier boundaries and more units” (Menichinelli, 2015, *cited in* Wolf & Troxler 2016, p.3).

Schematically, we observe a shift in management science and business from the focus on a lonely inventor working on a single product or new technology; to corporate innovation driving forward new processes; to open innovation. Chesbrough (2012) explains that “open innovation processes combine internal and external ideas together in platforms, architectures, and systems.” Competitive advantage lies in reconfiguring value creation, capture and delivery, and the entire logic behind of how to address target customers’ most important needs, conducted in a cost effective manner; through novel exchange channels, to ensure the best customer relationships over time, while leveraging key activities and resources in order to manage risk and optimize supply chains.

2.1.2. BUSINESS MODEL COMPONENTS AND PATTERNS

Most business model canvases from Osterwalder & Pigneur (2010), to Jouison-Lafitte and Verstraete (2008) to Gassman, Frankenberger, including Cscik’s Business Model Navigator, are creativity tools, developed to get prospective companies to think outside the box, to overcome mental barriers and the dominant firm or industry logic that may block the road to

new ideas. Gassman *et al.*, (2014) developed their business model navigator, inspired by the engineering methodology for product development, TRIZ, the Russian acronym for the “theory of inventive problem solving”. An analysis of 40 000 patents indicated that the technical problems found in various industries could be solved by using elementary principles. The authors therefore analyzed the business models of successful companies over the past 50 years, plus a number of pioneering companies from the past 150 years, and identified 55 recurring patterns. “To our surprise, we discovered that over 90 percent of all business model innovations simply recombine existing ideas and concepts from other industries”. The authors caution: “creative imitation and recombination require deep comprehension, as imitation does not mean pure copying. Rather a business model must be applied to one’s own situation and be thereby understood with regard to overall meaning, key success factors and to the situation’s peculiarities. Only then, the power of recombination and creative imitation may be released”. Thus, a firm is not confined to a single business model but is potentially open to many. Most new business models are in reality inspired by those of other industries; some basic models can be found in several industries.

The modular nature of business model patterns means that, based on the specifics of the context and resources of a given organization, the patterns may be combined to obtain multiple revenue streams. They are therefore *malleable* in that they can stand for themselves and be regrouped under different categories. Thinking in terms of categories can be a struggle for companies because “they require a more abstract approach than physical products” (Gassman, Frankenberger and Csik, 2014). Neuro-economists, such as Berns, argue in favor of such an approach. He contends (2008) that in order to get a different perspective on an issue, we need to confront our brain with ideas that it has never considered before, to push the brain to re-categorize information to enable us to break free from our habitual patterns of thought, and ultimately begin to develop entirely new ideas”.

Out of the 55 models discussed by Gassman *et al.*, (2014), some of the basic can be found in an assortment of industries. For instance the *razor & blade* model serves to “bait and hook” customers by lowering the barriers for purchasing the basic product. The model offers a cheap or free basic product that will create a lock-in effect. Consumables such as Gillette razors, HP ink jet printers, Nespresso capsules are sold with a high margin. Indeed, 10 years ago, most of us would never have been willing to buy Nespresso coffee capsules from Nestle for 80 euros per kilo. To capitalize on the potential of this model, effort is placed in preventing customers

from purchasing similar products from competitors. Another successful model is the *subscription model*, which essentially shifts the offer from a product to a service. The business engages a contract with its customers, defining the frequency and length of service provided. Customers either pay for the service in advance or at regular intervals. This is similar to the *rent instead of buy* model that is becoming common in the access economy, where “access is the new ownership”¹⁷. Under these models, companies such as Blacksocks offer fresh pairs of socks on a seasonal basis; wedding gowns go from being used once in a lifetime to generating revenue through rentals; and Xerox, instead of capturing value through the sale of photocopiers, has introduced the now famous pay-per-copy model.

2.1.3. OPEN BUSINESS MODELS AND THEIR ATTRIBUTES

Henry Chesbrough in 2006 was one of the first researchers to conceive of the open business model as an independent pattern in contrast to a closed business model (Gassman *et al.*, p.231). In open innovation, the locus of innovation is no longer inside the firm. Therefore open business models are “a subclass of business models in which collaboration of the focal firm with its ecosystem is a decisive or novel element of value creation and capturing”. The key characteristics of open business models are value creation and capture beyond the firm’s boundaries (Tech *et al.*, 2017; Frankenberger *et al.*, 2014; Chesbrough, 2006). Here, openness refers to the inclusion of outside partners in normally closed value creation processes such as R&D.

Research shows that open business models (OBM) have new and amplified attributes regarding the closed internal and open external activities and resources of a focal firm (Frankenberger *et al.*, 2014). Part of the OPEN! research team Tech *et al.* (2017) conducted a literature review of 35 articles on business models and 38 articles on OBMs from 2003 to 2016. Findings included: 1) *The management and generation of IP and communities*, was identified as an integral part of an OBM. 2) There is a *blurring of boundaries between partners and customers* as collaborators now appear to extend beyond formal organizations and communities, to individual and private agents who enjoy the same level of importance for value creation. Precise collaboration is not set in stone but, it differs vastly from classic, customer-supplier relationships. 3) There is also evidence that the mode of collaboration through openness is becoming more *short-term and problem-driven*. Therefore, embracing an open business model involves the *systematic and*

¹⁷ ...also falls under the shared economy umbrella: (Acquier *et al.*, 2017)

purposive identification of areas in the value creation processes where other parties can contribute their own resources, or use existing resources in new and innovative ways. 4) However, while the review clearly showed that openness-driven value creation is well discussed, value capturing that benefits more than a focal firm is not. (Fjeldsted *et al.*, 2012 pp. 8); Soloviev *et al.*, (2010, pp. 692-693) add that “the open and proprietary business models cannot exist in pure form [because] the proprietary business model gives very little space for innovation, while the open business model gives too weak opportunities for collecting profits.”

Companies pursuing an OBM strategy leave profitable niches open to potential partners. This attribute is similar to the notion of the innovation ecosystem where a healthy system is one in which firms co-exist peacefully using different business models that thrive on collaboration. In business model literature, the interrelations among diverse stakeholders in an ecosystem vary over time, according to conventions based on subjective values aiming to improve living and working standards (Jouison-Lafitte, 2008; Coissard & Kachour, 2016).

The reason for opening up a business is to improve efficiency, gain a share of new markets, and or secure strategic advantage. The design of open business models thus requires special consideration on two counts: first, the original business model, and particularly its value chain, must be both internally coherent and attuned to the business model of future partners. Second, it is important to ensure that the added value created also benefits the original business. The conflict of interests existing between one’s own profitability and a partner’s objectives must permit a win-win solution. OBMs do not follow the unidirectional value processing of general business models. Rather, the now blurred roles between users, customers, and co-creators contribute to the value creation activities and consequently gain from the increased quality of the final product. Gassman *et al.*, (2014, p. 235) explain that “opening up your business model and integrating partners into the value creation process is a key element for future growth and competitive advantage. In an increasingly connected world where industries are converging, you will need to open up to stay successful. Consider developing an entire ecosystem to create the kind of value for your customers that none of the participating companies could provide independently. In order for such ecosystems to function, all partners must generate sufficient revenue and benefit from collaboration”.

Two different streams of literature on open business models can be distinguished. The community-oriented stream concerns a focal firm striving to “find an appropriate revenue model (...) that would be acceptable to their (...) clients while allowing them to maximize their

profits.” (Zott & Amit 2010, *cited in* Wolf & Troxler 2016). This model of profit maximizing creates tensions with open user communities which “frequently resist the very types of (...) formal contracting mechanisms that might otherwise serve to protect them from expropriation. They tend to favor self-organization, informal relationships and transactions based on reciprocity and fairness instead” (Boudreau & Lakhani 2009, 74). A second stream of literature on community-based business models has received less scholarly attention. Here, models do not begin with a focal firm aiming to create its community. Rather, they “are concerned with a focal firm that emerges from the context of some collaborative - often online - user community” (Wolf & Troxler 2016, p.3). Considering the distinction we have established on open innovation and commons-based peer production, and the difference between the release of a final product, versus focus on a collaborative process of product development, from the OPEN! Project perspective, we are particularly interested in community-based Open Source Hardware Business models.

2.2. OPEN SOURCE HARDWARE BUSINESS MODELS

In innovation management literature, business models related to open source hardware are still considered a new frontier. We may assume that open source hardware business models (OSHBM) would add layers of complexity to OBM and to business models in general. Indeed, in the continuum from open innovation, open source software and open source hardware, the latter is the most complex to implement. Despite the “exponential rise in designs for open hardware released under open source”, few authors discuss open innovation with a focus on OSH (Pearce 2017, p.1). Even fewer explicitly treat the field of business models.

Early views of open source software specifically excluded business ambitions (Stallman, 2009). The idea being that the users’ essential freedoms of running, studying, changing and redistributing copies are ethical questions needing to be proclaimed and defended from business interests. Proponents of this view claim that “similar to the technical architecture of classic colonialism, digital colonialism is rooted in the design of the tech ecosystem for the purposes of profit and plunder” (Kwet, 2019). The difference between free and open source is that free software ensures freedom and accountability. In open source, community input only serves as a means to make more robust and reliable output, even if in the end it serves to chain users. "A non-free program is a yoke, an instrument of unjust power," Stallman reasoned. for which community input only serves as a means of making more robust and reliable output, even if in the end it serves to chain users.

In spite of this, commons-based peer production kept growing. The non-monetary focus of commons-based peer production baffled researchers like Chesbrough (2003), who called it the “the puzzle of open source software”. How can a business model be built around intellectual property rights? How can value creation be based on a collective good? In 2006, he introduced the term “open source business models”, stating that ‘while open source was created in ways that sought to deliberately eschew the creation of IP rights over technology, alert companies have nonetheless developed business models that are propelling the [software] technology forward into the market’ (Chesbrough, 2006a, p. 45). Slowly the business model concept evolved to consider open source, community-based and non-monetary interaction approaches.

Dahlander & Gann (2010) opened new perspectives by describing open innovation as engaging both monetary and non-monetary interactions. First, Chesbrough (2012) describes these as having an amplification effect on innovation. The blurring of boundaries between customers and key partners means that these actors will benefit from the improved quality of the final product acquired through constant iteration (Bonvoisin *et al.*, 2016 pp. 4-6). Second, Osterwalder & Pigneur (2002) go beyond the inflow and sale of intellectual property to define open source business models as those in which value creation relies on systematic collaboration with outside partners. The third approach is to consider the models in the context of market entry (Bonaccorsi *et al.*, 2006; Davey 2011). However, as put forth by Osterloh *et al.*, (2001), firms wishing to choose a proprietary business model face difficulties if they have relied heavily on external, open source contributions.

Gradually, researchers began trying to describe how OSH platforms capture value, but the descriptions appear to overlap and a comprehensive approach linking academic and practitioner perspectives is absent. Pearce (2017) describes how different open source hardware platforms, like Adafruit and others, have been managed to commercialize knowledge and expertise in services around hardware products. In other words, as the platforms grew, they came up with new ways of capturing value from their hardware through consulting, teaching, speaking, or assembling services. Meanwhile, they experienced the start-up’s need to design a business model to capture value (Saebi & Foss 2015; Berglund & Sandström 2013; Chanal & Caron-Fasan 2010). Today, several options of building a business around open source software, have been identified as applicable to open source hardware (Gershenfeld, 2007; Troxler 2010). Dual licensing, as in the case of freemium models, offers a version of free, open source software and a second version with added functionalities under a proprietary license with revenue. The

service version is based on revenues from services such as support and system implementation or consulting. The retailer version sees profits from sales of complementary products such as books or materials. Distributors create new value by aggregating and optimizing open source material in order that it become easier for the general public to install and use. Other authors suggest a staged mechanism of value creation and value capture for OSH business models. Wolf & Troxler (2016) have come up with five, community-based business models for OSH. These evolve around core activities and activity-systems that become complementary building blocks for future business model design. The DECODE project (Fuster Morell *et al.*, 2017) identifies six models; Tinck and Benichou (2014) another six; Stacey and Pearson, (2015) five; Tebbens (2017), identifies overlapping models related to the direct and indirect revenue streams that may be mobilized through the OSH platform.

We have made a first attempt to group these in the following figure (Figure 14) color-coded by author. The fact that they are disparate and do not overlap the Gassman *et al.*, (2014), 55 patterns, makes them appear somewhat confusing for both academics and practitioners. Interestingly, among the 55 patterns identified by Gassman *et al.*, (2014), only two refer to “open business” (p. 230) and “open source” (p. 235). Jointly, the models seek to include outside partners in normally closed value creation processes through open sourcing, defined as “working together to create a free solution”, wherein products “are developed by a public community rather than a single company” and as a result, the solution developed belongs to the Commons.

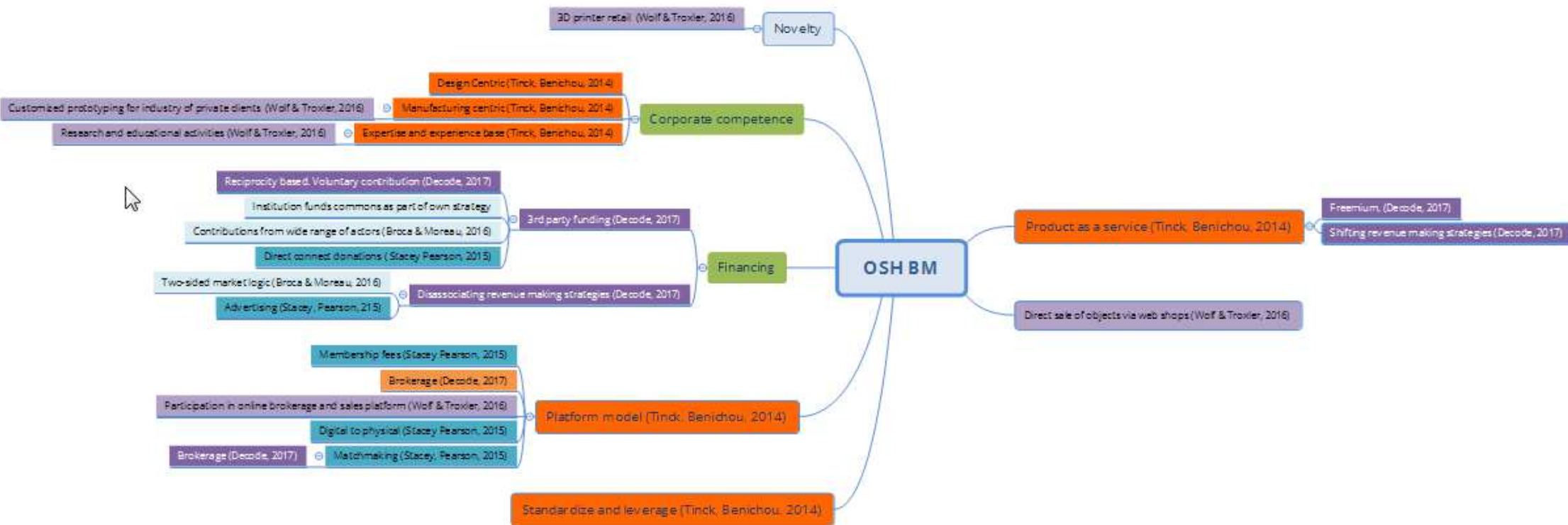


Figure 14: Mapping of OSH business models (author’s categories version 1) see Appendix on transversal analysis (Figure 57; Table 27; Table 28; Table 29; Table 30)

2.2.1. SPECIFICS OF BUSINESS MODELS FOR OSH

In the following discussion we wish to highlight and synthesize what appears singularly novel in OSHBM. In itself, the sharing of design information is not completely new: Lapeyre (2014) explained this using the example of 18th century cooperation and exchanges within the silk industrial community of Lyon (France). However, only in the current context of openness, where digital fabrication technology has become simultaneously better and more accessible, has open source hardware innovation become possible (Blikstein 2013). Scholars argue that OSHW sharing schematics, assembly instructions or procedures, offer cheaper, more efficient and more transparent innovations (Bonvoisin *et al.*, 2016; Pearce 2012; Pearce *et al.*, 2010; Lakhani & von Hippel 2003), resulting in accelerated innovation through collaboration (Boudreau 2010). Hence, new value is created by diversifying knowledge and capabilities.

First we shall review what makes OSH different from free/libre open source software (FLOSS). As open design spreads, there is a push to prototype software-hardware integration, but one needs to be mindful that although some similarities exist between open source software and hardware business models, the former cannot de facto apply to the latter for the following three reasons that will most likely always bear a cost.

First, Rifkin's Zero Marginal Cost theory cannot be applied to hardware. While the marginal cost of producing one unit in software certainly nears zero, it is far from being the reality in hardware. Even if the cost of design drops due to publicly accessible files and digital fabrication, material product development will always incur a cost related to the materials used, personnel, overhead, or the energy running the machines. Hardware startups must make products in-house or outsource their production in small batches. Even with fully automated processes, materials and space will always bear a cost (Tink, Benichou, 2014).

Second, OSHW remains dependent on supply chain logistics, even though it has the potential of radically altering global supply chains, especially with the present, 30 year-trend of delocalizing. Software supply chains are easy: you build a product, distribute it online and users access it from anywhere. In hardware, you may manage multiple suppliers and third party manufacturers who organize and coordinate several organization functions with specific skill sets: R&D, product design, electronics, mechanics, distribution, services. Vertical integration is outdated in many industries which now rely on tiers of suppliers that may themselves, opt for

growth strategies in direct competition with a given company. For instance, the automobile industry is under considerable pressure. New entrants, both big and small, such as Telsa, Local Motors, Wikispeed, Open Source Vehicles, and Baidu, are challenging what was previously “la chasse gardée” of an oligopoly of a handful of global firms.

Third, though it is hard to hurt yourself with software, but it is easier with a hardware product. Hardware products sold to the public, must abide by regulations; safety norms, labels and quality certifications. Establishing the quality and safety testing required to sell a hardware product can be tough and expensive, especially for products such as cars and machine tools. In sum, what we see here is that there are dimensions in OSH that make it a very novel phenomenon. It fits into a platform economy and multi-sided markets where users may have many roles.

2.2.2. THE BINDING ELEMENTS IN OSHBM

In this section we will return to what research has already established concerning the key elements of OSHBM and the dynamic qualities that characterize them. In considering what OSHBMs take from key elements, attributes and components of BM and OBM, we may also question what holds them together, as perhaps a focus on business model components misses out on the dynamic nature of open source hardware.

What has been established is that projects resulting from OSH and OSPD are described as a combination of four factors, according to Fjeldsted *et al.*, (2012), who analyzed the main elements of the open source design process (see Figure 15). They are, (1) *A virtual platform* through which a network of symbiotic connections is created among stakeholders. The platform, is a meeting place either physical or virtual, for contributors, facilitating and empowering interaction “through protocols, processes and infrastructures that enable multi-actor collaboration” (p.734). (2) *A shared drive* motivating participation, which in the case of *online communities of volunteers*, often seeks to support societal development, through “networked social capital”. Research suggests multidimensional incentives for open source project contribution ranging from “intrinsic, hedonistic motives: such as enjoyment, amusement, fulfilment, satisfaction, sense of scientific discovery and creativity, and challenge, exist beside extrinsic (reputation, signaling incentives), political-ideological (anti-commercial, hacker culture) and social motives like the sense of belonging, altruism, contribution to public good and generalized reciprocity” (Wolf & Troxler 2016, 4). (3) *A community* is composed of

a core group and an extended community which will serve to iterate the product development, making an improved product. The actors in the community have the capabilities and values to self-organize. (4) *The business aspects rendering the project viable.* This factor, often not established in the early stages, gradually becomes necessary. As Chesbrough & Bogers (2014) explain, “After the initial inventions by users, business models help to further advance the relevant products and processes by capturing some good knowledge from the public, by attracting capital, scaling the innovations, and thereby creating an economically sustainable business or industry”. To these four factors, research has identified a fifth: (5) *the commons*, where actors accumulate and share resources (Troxler, 2010).

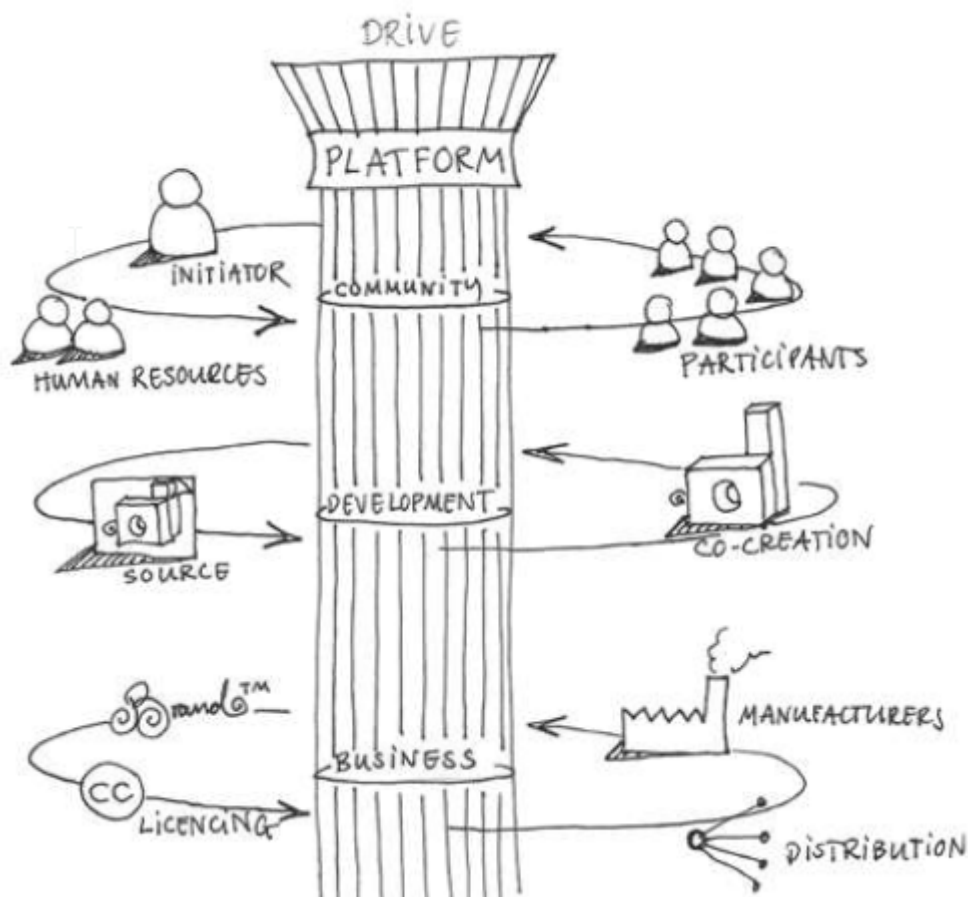


Figure 15: The Open Source Hardware Design process model (Fjeldsted *et al.*, 2012)

The less obvious reflection is what links the elements of OSHBM together in a dynamic manner? That is, seeking to understand and map out not only what the components and

attributes of OSHBM are, but also their dynamic relationships: the soft links among stakeholders, and the mechanisms that foster value creation and capture.

Mechanisms are “the wheelwork or agency by which an effect is produced” (Hernes 1998, p. 74). Identifying them is interesting because they provide an intermediary level of analysis between pure description and social phenomenon, allowing one to understand how organizations act as the wheelwork in producing a social outcome (Davis & Marquis 2005). Here we seek to understand what ties OSH business together beyond key elements and identified components.

Indeed just like recent research¹⁸ highlights the importance of fascia as a connective tissue supporting the skeleton (Stecco *et al.*, 2006; Schleip *et al.*, 2005), focus on business model research should not only study the bones -- the components – of the business model (Osterwalder & Pigneur, 2010), or the subconstructs of business model innovation (Claus 2017) – but the connective tissue joining all the different parts together. To make a risky analogy with medicine, just like fascia is an entire system and a newly defined organ that merits study, similarly more research would be welcome on the connections between business model components and their relationships to one another. In this sense existing business model literature is normative and doesn’t delve into the rich interactions producing open source hardware.

Research on business models conducted by Jouison & Verstraete (2008)¹⁹ in parallel to Osterwalder & Pigneur (2010), addresses these links (see Figure 16), when they explain that business models are as dynamic as a spider web, but we feel that further detail would be interesting. These researchers, on their representation of business models, add the components of who the project holders are, and in which environment they operate. Echoing Raworth (2014,) this stance has the benefit of not viewing business models as written figures on a blank page, but deeply embedded in their operational context and tied to the strengths and shortcomings of their governance.

¹⁸ <https://www.arte.tv/fr/videos/070788-000-A/les-allies-caches-de-notre-organisme/>

¹⁹ <http://www.grp-lab.com/>

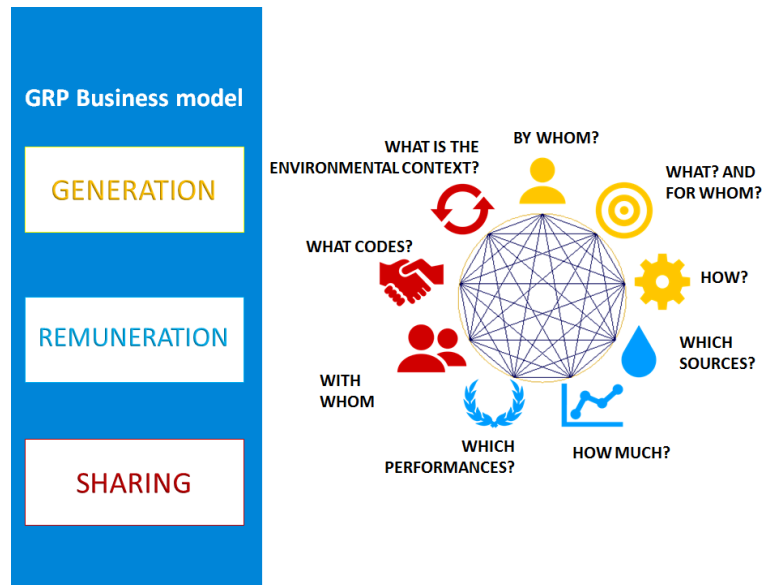


Figure 16: Links between business model parts. Adapted from Jouison-Lafitte GRP business models. (2010)

The dynamic nature of business models is a topic that has been addressed in terms of the value and knowledge capture questions being an antecedent to value creation. For firms engaging in open innovation with innovation communities, it becomes necessary to further define business models, and specifically the interface of value creation and value capture. This crucial factor was addressed by the director of the Danish Design Center, Christian Bason in his keynote speech at the REMODEL conference (2018) on business models for open source hardware²⁰. “The key competitive factor of today, is the velocity by which you learn [...] The faster you find out which are the elements of your business model that work, or don’t work, or are somewhere in between, the faster you can reach scale”.

In a seminal work, Cohen and Levinthal (1990) described how a firm’s prior knowledge determines to which degree the firm is able to “recognize the value of new, external information, assimilate it, and apply it to commercial ends”. This observation has echoed in the scientific community and is also relevant to open innovation because, here too, a firm needs prior knowledge to realize the value of external knowledge and resources. In open innovation research, it is well established that contributions by a firm to communities are essential to establishing the long lasting and strategic relationships that enable firms to continually access external information resources (Dahlander *et al.*, 2005).

²⁰ <https://danskdesigncenter.dk/en/designing-open-business-day-celebrating-open-source-based-business-development>

Research has determined that organizations will move through cycles of openness when they wish to upscale growth, and will revert to proprietary strategies when they seek to profit from the innovation, or to iron-out the quality and safety regulatory framework around their OSHW innovation (Tinck & Bénichou, 2014; Appleyard & Chesbrough 2017). The co-creation network necessary for OSH involves multiple stakeholders (Chanal & Caron-Fasan 2010; Lauritzen 2017; Sarazin *et al.*, 2017). Co-creation is a “joint, collaborative, concurrent, peer-like process of producing new value” (Galvagno & Dalli 2014, p. 644). Thus, it requires the participation of external parties in value creation, and a re-designing of internal processes to make external involvement possible (Hienerth *et al.*, 2011). The knowledge flows from this network interaction result in innovation (Chesbrough 2007), and value creation for all parties.

Saebi & Foss (2015) devised a contingency model explaining that the success of open innovation initiatives is directly linked to aligning initiative with the firm’s business model and its elements of content, structure, and governance (see also: Shafer *et al.*, 2005). In line with Chesbrough (2007) who argues that open innovation and business models are deeply intertwined, Saebi & Foss (2015) suggest the following: (1) openness of the business model is described by the “level of co-creation” and linked to the business model content, which refers to the set of elemental activities (Figure 15 above). They associate openness to (2) the “type of knowledge flow”, and to the business model structure, defining structure as “the organizational units performing those activities and the ways in which the units are linked” (p.4). In particular, openness is a crucial factor for the possible level of co-creation and knowledge sharing within a business model (Storbacka *et al.*, 2012). Yet, in order to benefit from external knowledge flows, a company needs to know how to integrate them. Literature is only beginning to understand the means of moderating these knowledge flows.

Finally, Saebi & Foss (2015) define openness capture by (3) the “level of collaborative capability” and relate this to business model governance; that is, “the mechanisms for controlling the organizational units and the linkages between the units” (p.4). In other words, if a firm attempts to fully benefit from open innovation potential, it needs to adopt suitable organizational and managerial practices, which help to both assess and integrate external knowledge (Salge *et al.*, 2012; Foss *et al.*, 2011), as well as the ability to decide when and what to open or close in a dynamic process (Appleyard & Chesbrough 2017). To do so, the business model should be carefully designed (Hienerth *et al.*, 2011b). Despite the fact that innovation literature has illustrated innovation practices at length (Cantarello *et al.*, 2011; Van De Vrande

et al., 2006), not many authors have looked at how openness within a business model leverages the creation and capturing of value through collaboration with external partners (Holm *et al.*, 2013; Chesbrough 2007).

2.3. THE IMPORTANCE OF VALUE(S) IN OSHBM

The notion of value appears central to open source hardware. Business models seek to create, capture, and deliver value, and in OSH this is done with the consort of a community. In the following section we will clarify the distinction between the singular and plural forms of value and discuss the strategic role they play in federating OSH communities.

First, however it is important to distinguish between the singular and plural forms of value when addressing OSHBM. Breuer & Lüdeke-Freund (2017) qualify “values” as a subjective notion of the desirable and normative orientation of “value” referring to economic value. The terms “value” and “values” are regularly used in inconsistent ways.

These authors are among a stream of authors presently doing groundbreaking work on the importance of values in organizations. Richard Barrett’s most profound finding, as a researcher who has spent a lifetime studying and teaching values, is that *values unite* and *beliefs separate*. He explains that one of the reasons why decision making based on values is so important at this time of history is that it “allows us to throw away our rule books. When a group of people espouse an agreed set of values, then you no longer need to rely on bureaucratic procedures setting out what people should or should not do in specific situations. All the rules reduce to one – live the values” (Barrett, 2006).

Breuer and Ludeke-Freund explain that values are an important part of the tool-set for business model reflection. They argue that values are needed to develop and maintain shared visions and missions” (p.3) in order to create the synergies between different actors to collectively address the “wicked problems” of our time: “seemingly insoluble, poorly formulated, confusing ... involv[ing] different actors with conflicting values” (p.2). These essentially refer to the Tragedy of the Commons addressed in Chapter 1 and to what is new in management science today: that never before in human history have we had the perspective of clearly witnessing the damage our current economic and industrial systems are wreaking on our planet (Elworthy, 2014, p. 25). Value derived from collective problem solving, is what Wolf & Troxler (2016) refer to as the creation “of something of value based on new, jointly generated ideas that emerge from the sharing of information and knowledge” (p.4)

Basing their work on research concerning how leading, innovative organizations determine core values and beliefs as basis for innovation performance, Breuer and Lüdeke-Freund developed a framework to address the shared values of a values-based network (see Figure 17). The aim of the framework is to integrate different business models through the exploration of the common vision of the different actors of an industry or region.

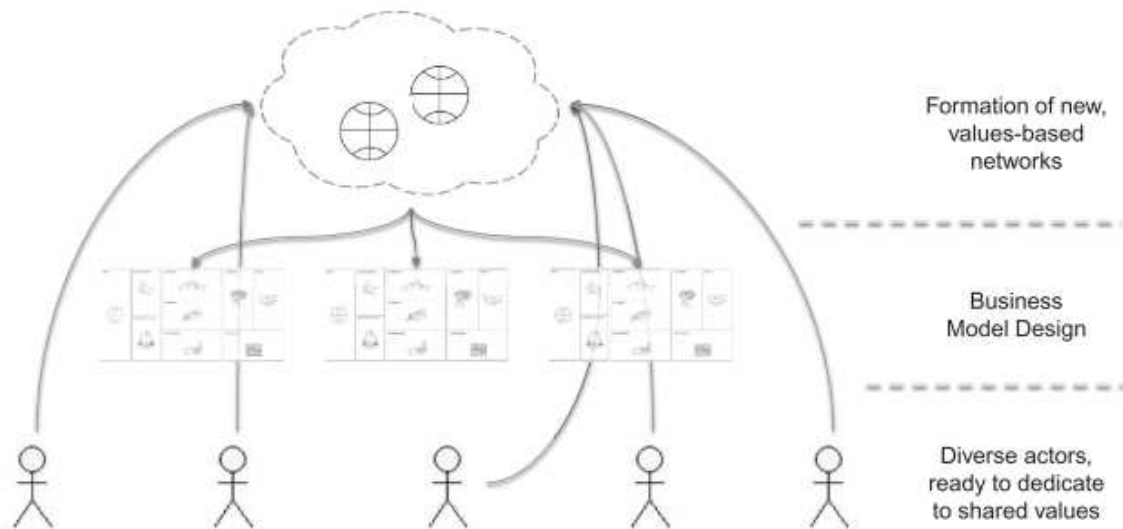


Figure 17: Values-based innovation framework and method (Breuer & Lüdeke-Freund 2017, p.28)

This work is wonderful as research has shown that peer-production governed community-based business models practice multi-dimensional value creation enabling open knowledge sharing, and commons development (Wolf & Troxler 2016, p.5)

Secondly, the ability to motivate, foster commitment and build trust are pivotal activities for OSHBM and community-based business models. Tension exists between the ethical, free software approach that generates open source hardware, and the more practical, process-oriented approaches working to improve the robustness and reliability of product development through community co-development. Businesses seeking to capture value and generate revenue, need to respect community practices and settings (Fjeldsted *et al.*, 2012, pp. 5-6; Parmentier & Mangematin 2014). Moreover, “wicked problems” or barriers to sustainably-oriented innovation “cannot be understood and tackled sufficiently from an egocentric, single-actor perspective that follows rather narrow definitions of (financial) value” (Upward & Jones 2016, *cited in* Breuer & Lüdeke-Freund 2017, p. 29).

Thirdly, research suggests that both value creation and capture have an enhanced meaning within open source hardware (Moritz *et al.*, 2018a; Thomas & Samuel 2017; Unterfrauner & Voigt 2017). The elements, of product-process-organization and financial revenue alone, miss the point of the value creation mechanism underplay in OSPD communities. Unterfrauner & Voigt (2017, pp.2-7), in their recent conference paper: “Makers’ ambitions to do socially valuable things”, analyze the social value and impact of Making. They explain that Makers often use open design with a social innovation, and even a “grassroots anti-establishment heroism” mindset, reflecting “awareness of [the] societal problems in the first place, and the means of developing a solution acceptable to most of the actors involved”. Their findings reveal that the values and expectations that Makers bring to the design process, have educational, inclusion and environmental ambitions.

Finally, OSH value pertains to common collaborative economy defined as a tendency, a set of qualities, and a modality of collaborative platform economy - regarding both the design and the performance of the process - characterized by a commons approach concerning the dimensions of governance, and economic strategy, the technological base and knowledge policies as well as the social responsibility of the externalizations’ impacts of the platforms.

Therefore OSHBM relate to research and sustainable business models as they include triple bottom line considerations. These models differ from the traditional in three ways: (1) business is viewed as an engine of societal progress, (2) the notion of value is broadened, and (3) a multi-stakeholder perspective on value creation is offered. Businesses have the potential to create positive change by turning environmental or social problems into market opportunities (Lüdeke-freund *et al.*, 2016, *cited in* Massa *et al.*, 2016 pp.96; Bendell & Thomas 2013 p. 21). Adopting a sustainable business model approach helps understand how businesses can create value, not only for customers, but also for other stakeholders: society and/or the natural environment, and how this value is captured or distributed across a broad set of stakeholders. Sustainable business models are those that integrate economically relevant sustainability concerns with business success or competitive advantages (Schaltegger *et al.*, 2012, *cited in* Inigo *et al.*, 2017 p. 2).

2.3.1. OSH MECHANISMS FOR VALUE CREATION AND CAPTURE

In an epistemic fashion, theorists and visionary thinkers of Commons-based peer-production inspire. We can cite Neil Gershenfeld, Kate Raworth, Ron Eglash, Michael Bauwens and

economist/artist Lars Zimmerman, can be cited among many others. While working with Lars as a consulting partner in the OPEN! Project, it was most interesting to see how, in a trial-by-error design approach, his ideas were shared and taken up by the larger OSH community. For instance, his open platform design flowchart²¹ was adopted by the Danish Design Center for their REMODEL program, an 8 week process during which companies participated in a formatted, design-driven sprint taking them on a journey of change toward the development of a financially sustainable and innovative open source hardware business model²².

Lars Zimmerman explains that our mind is set to understand how a closed, proprietary system works, but has a harder time conceiving how an open model works. In order to do this he explains that an organization must first imagine how to go open (see: Figure 18).

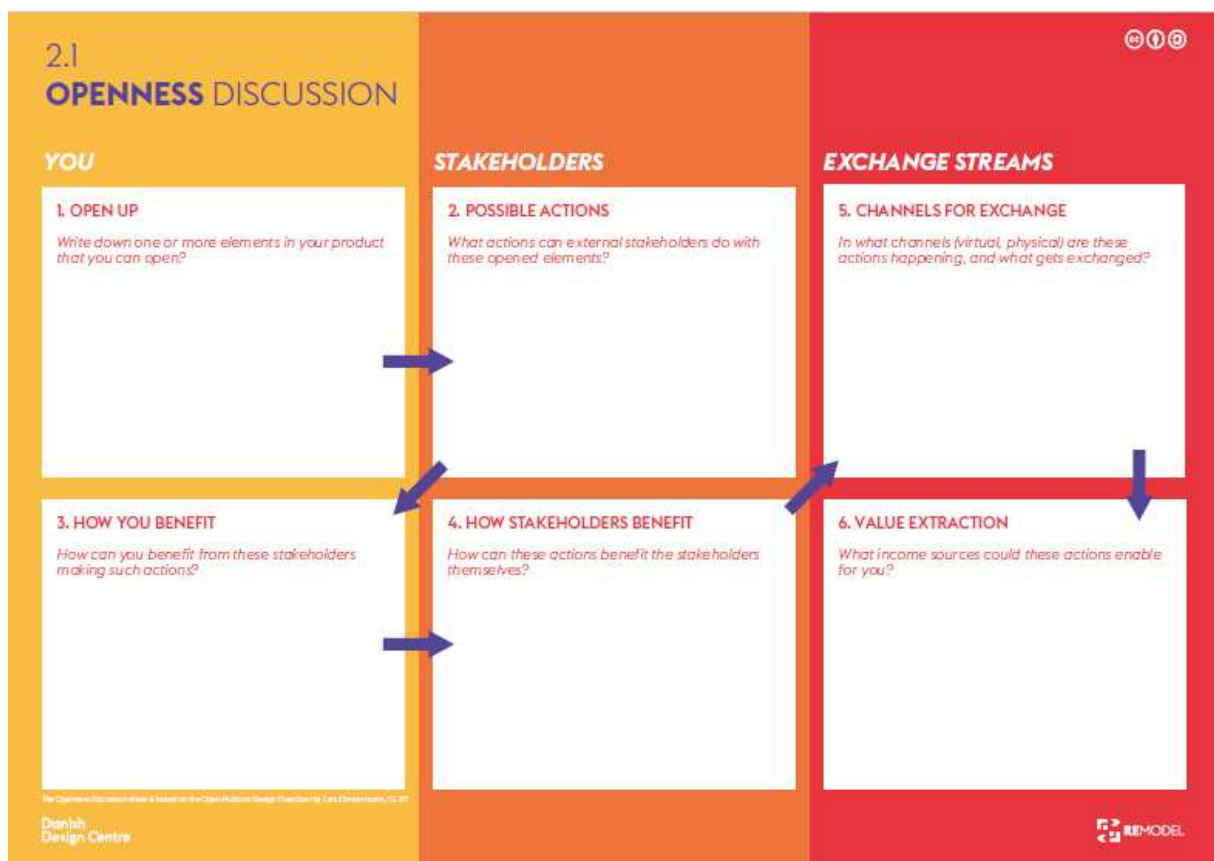


Figure 18: The openness discussion (Danish Design Center, 2018; Zimmerman, 2016)

²¹ <https://community.oscedays.org/t/workshop-tutorial-business-models-for-open-source-circular-economy/4709>

²² <https://remodel.dk/>

The first step, is to identify the assets the organization has and could open. Taking the example of a desk manufacturer, assets are: desks, building plans and a workshop. Imagine what actions external stakeholders could take with these elements opened. What roles would they have once your assets were opened-up to them? In this case, a desk manufacturer can continue to sell desks to consumers and resellers. If he opens his plans publicly, perhaps he would attract the interest of teachers and designers who would be interested either in using the designs for ready-made material, or perhaps in improving or modifying the designs to better fit their needs. From opening up the workshop, he could gain traffic from an entire new network of DIY hobbyists, interested in using the firm's equipment to build their own desks. From there, Steps #3 and #4 would seek to identify what his benefits from these stakeholder actions might be, and how these actions would benefit the stakeholders themselves? Going back to our example, the focal organization would still benefit from selling desks, but with open innovation, it would gain almost passive R&D from teams of people testing and improving their designs. Since this approach is novel, it would benefit from marketing attention and media coverage, and also, à-la-techshop, from an entire new network creating more traffic in its workshop. Stakeholders, on the other hand, would benefit from the facilities and the space provided by the workshop, along with the expertise of those who know how to use them as well as from designs they could sell or use for educational purposes. Step #5 refers to the channels for both physical and virtual exchange that are now activated. The shop will continue to sell desks, a website forum may be the place where a community of teachers and designers can converge to share design files. And the workshop may now become a place for training or events. The organization will now be able to capture value from selling desks, from training sessions, from usage fees and tools, and from subscriptions to use certain types of machinery. It may also ask for membership fees from firm employees who benefit from the bustling activity generated by the workshop. These may also chose to host events, from corporate events, to design sprints to birthday parties. What is described here is essentially a move from a product and service logic to a platform logic where value is created and captured by the organization and by a wider set of stakeholders.

This essentially describes how the Techshop Leroy Merlin (Ivry) and Fab Cafés operate²³, through what Peter Troxler identified as the innovation support model and the facility model (Troxler 2010a). Their physical spaces become bustling centers serving as coworking spaces

²³ Techshop in the US filed for bankruptcy in 2018, but is still running successfully in France in partnership with Leroy Merlin and in Japan. <https://www.techshoplm.fr/>

for roaming employees who need to have a feel for the local innovation scene (Capdevila 2015; 2017), and a talent pool for building projects. Formerly underused office space is rented out while a boutique and a café attract passers-by who would like to try their hands at the tantalizing projects on display. Roughly one third of the revenues generated come from memberships and subscriptions, one third from events, and one third from training. Many other businesses are following similarly inspired open strategies. In the furniture sector Open Desk²⁴ serves as a marketplace for open design office furniture. Interested parties may either download source files and make the product themselves in a DIY fashion, or have it made in a local Makerspace. REMODEL participant, Stykka, seeks to become a springboard for upcoming designers and “be the Spotify” of furniture design. The Lars Zimmerman approach is how the model should work in theory, the Open Desk and Stykka represent how it works in practice and the The Fab Market platform, which is currently a prototype²⁵, seeks to create an economy around open source hardware in order that the designers be correctly remunerated for their work. The idea of the platform is to create multisided-markets where makers, designers, manufacturers, and buyers interact. A user will purchase a design and part of his money (a third) will go to the designer for the design, (a third), to the Fab Lab where he/she will produce the design, and the remainder, to supporting the platform.

2.3.2. OSH MECHANISMS FOR VALUE SHARING

In regard to business models for OSHW, an area of research remaining to be studied concerns the mechanisms for value sharing. Shared value, coined by Porter & Kramer (2011) is “the creation of economic value in a way that also creates value for society by addressing its needs and challenges”. Research on Open Innovation identified the processes of (1) inside-out, (2) outside-in and (3) coupled innovation, with which firms will exploit and leverage knowledge internally, externally or jointly with other firms. The *coupled innovation process* facilitates co-creation with trusted partners while relying on external resources to develop innovation and create value while also creating new revenue streams by externalizing knowledge. According to Enkel *et al.*, (2009) and Sandulli & Chesbrough (2009), it is through these coupled processes that truly open business models emerge.

²⁴ <https://www.opendesk.cc/>

²⁵ Stemming from the IAAC (the Catalan Institute for Advanced Architecture in Barcelona)
<http://market.fablab.io/>

As the open source, collaborative economy and commons philosophy permeates our society, what would mechanisms for value sharing be?

2.4. THE RESEARCH GAP

From the OPEN! Project proposal, the initial research question to which WP4 work relates, has been formulated as follow:

What are the guidelines that entrepreneurs using open source based development should put in place in order to ensure the sustainability of their endeavors and to reduce risk?

In light of the literature reviewed in the previous chapters, we consider an OSH ecosystem as a space, a cognitive framework, upon which hybrid, epistemic & practice communities interested in open design, digital commons, and peer-production, explore as yet unknown needs and solutions voluntarily and collaboratively to create new projects that feed both the local economy and the global pipeline. When the core team of such projects is coached through incubators and accelerators, these projects should become viable.

We have identified critical gaps in the literature including an egocentric focus on single firms and profit maximizing described as community-oriented business models, as well as a lack of understanding concerning the interaction mechanism and “binding factors” of community-based types of business models. A number of different gaps to better understanding value creation, distribution and capture processes in the context of OSPD and OSH, have also been identified. A main gap is the notion that business models and business model components are too restrictive to apply to community based product development. Key elements described by (Fjeldsted *et al.*, 2012) need to be empirically tested. The business model concept needs to be developed to include a broader set of stakeholders (Massa *et al.*, 2016).

Therefore, we proposed to reformulate the research question as follows:

How do innovation communities practicing OSHW create and capture value with firms and with a broader ecosystem?

This research question has been made more specific by the following questions:

- RQ1: How to **monetize** value created through OSH?

There needs to be a guiding framework for shared value in the context of commons based cooperative platforms, as is the case of OSH, in order to map out “the actual way triple-bottom-line value creation happens” (Inigo *et al.*, 2017, p.2).

- RQ2: How can the **business model framework** be developed to include *value creation and sharing* for all **stakeholders**?

Here, we also believe that more empirical work needs to be done so as to understand the dynamics functioning in open source hardware business models, meaning the soft links and mechanisms among the stakeholders binding a business model together, and that are necessary for value creation, distribution and capture (Saebi & Foss 2015; Jouison & Verstraete 2008; Breuer & Lüdeke-Freund 2017; Davis & Marquis 2005)

- RQ3: In the context of OSH, **how does a business model hold together**?

A comprehensive approach linking academic and practitioner perspectives on the revenue capture mechanisms and patterns of OSH Business Models is lacking (Tech *et al.*, 2017; Fjeldsted *et al.*, 2012 pp. 8; Soloviev *et al.*, 2010, pp. 692-693). This needs to be reviewed in light of the Gassman *et al.*, (2014) 55 business model patterns. This approach should be useful in shifting from a revenue stream perspective to one comprehending the multitude of activities and their dynamics, as expressed in the magic triangle (Figure 13).

CHAPTER 2: KEY TAKEAWAYS

What are currently understood as business models and open business models is described. Previous research has identified the following elements to be novel in open business models: 1) the management and generation of IP and communities, 2) the blurring of boundaries between partners and customers, 3) and evidence that the mode of collaboration appears to be short-term and problem-driven.

The current state of the art regarding OSHBM lacks a comprehensive approach linking back to academic research on business model innovation. The result is a disparate stream of literature that is not easily actionable for practitioners.

The fact that OSH communities voluntarily collaborate indicates that the economic notion of value is not the binding factor in OSHBM. The open source hardware phenomena potentially allows exploring “coupled innovation processes” aiming at shared value where truly open business models emerge.

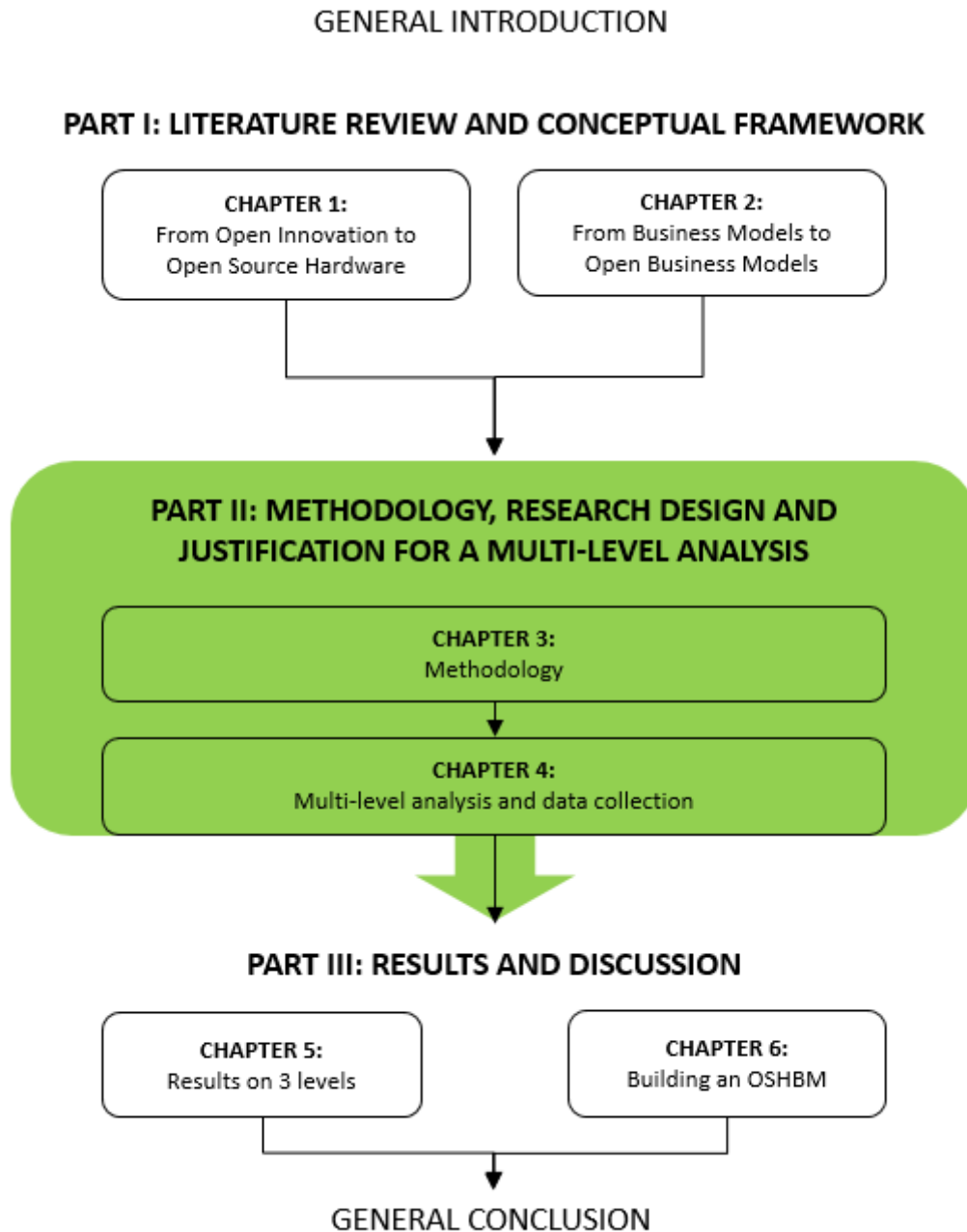
This chapter concludes on the research gap identified from our literature review. Namely that there is currently no strategic understanding of how to make money through Commons-based OSH, and how this value creation is shared with others. Therefore, for this study the research questions are the following:

- RQ1: How to monetize value created through OSH?
- RQ2: How can the business model framework be developed to include *value creation and sharing* for all stakeholders?
- RQ3: In the context of OSH, how does a business model hold together?

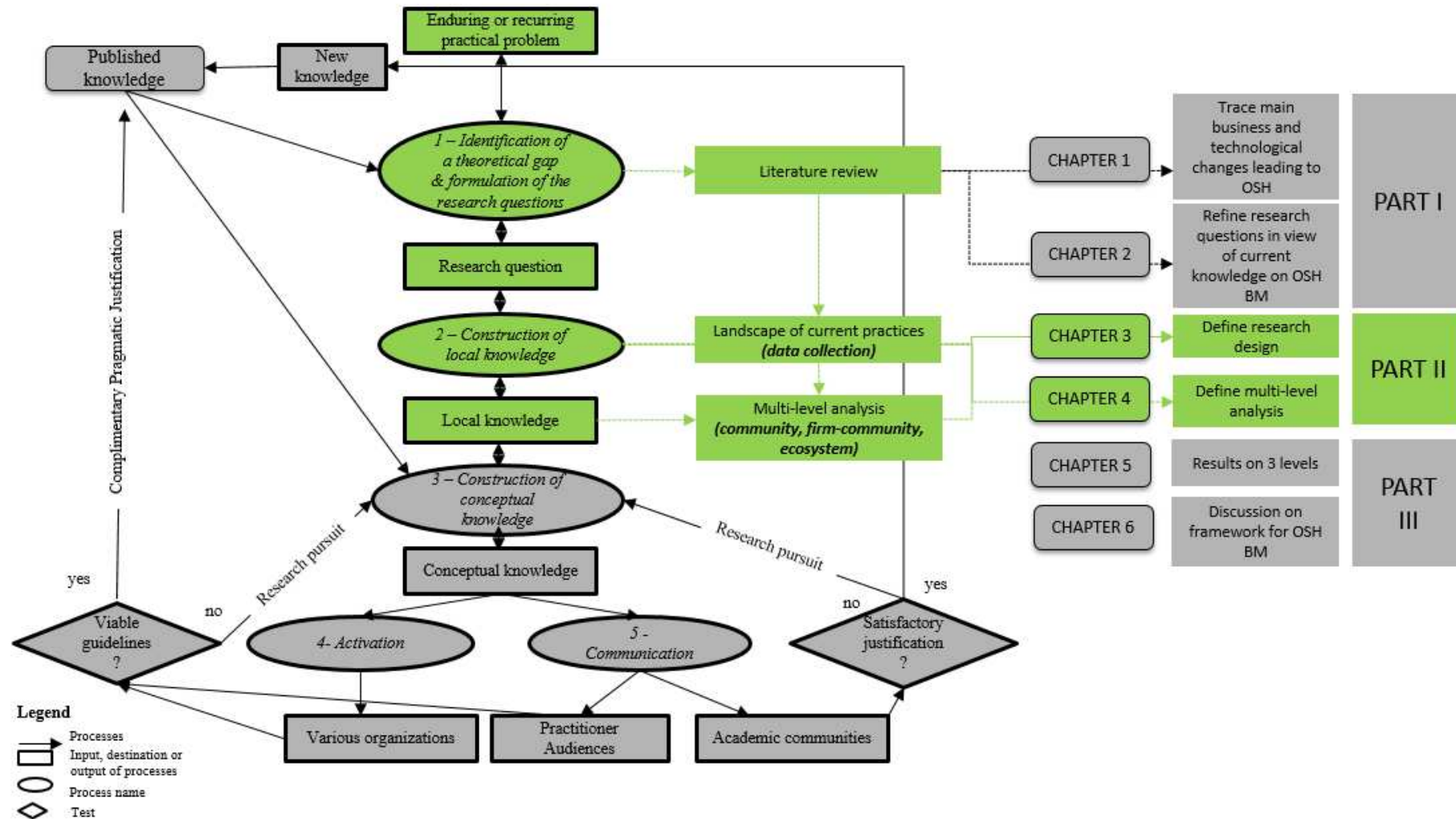
In the next chapter, we will discuss the methodology used to study empirically the phenomenon of open source hardware, and the business models used to sustain it.

PART II:
METHODOLOGY,
RESEARCH DESIGN AND
JUSTIFICATION FOR A
MULTI-LEVEL
ANALYSIS

PART II: METHODOLOGY, RESEARCH DESIGN AND JUSTIFICATION FOR A MULTI-LEVEL ANALYSIS



Part II



CHAPTER 3: METHODOLOGY

CHAPTER 3: METHODOLOGY

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CHAPTER 3 SUMMARY

Objective - We present the methodological basis for the research: qualitative, exploratory research, framed under the PECP (epistemological paradigm: pragmatic constructivism). The theories considered to study OSH BMs are presented as well as the justification for our final choice of the Commons Theory.

Methodology/approach – Based on PECP, the abductive reasoning mode for qualitative exploratory research justifies how the data was collected and analyzed in order to elaborate on the Commons theory from case study research.

Limits – Qualitative research is best conducted in a longitudinal fashion. Field research was run over a span of six months for each analysis level: community, firm-community interaction and ecosystem. Moreover calculating inter-coder reliability on all interviews was not possible for all stages of research.

Methodological implications - The choice of pragmatic constructivism is coherent with the object of our study. We seek to provide knowledge, which is both pertinent and actionable for academics and practitioners, from the perspective that this is the researcher's understanding of the world. From the research questions, we will present our research design. To study the empiric and emerging open source hardware phenomenon, we have chosen a qualitative approach. Data, collected through semi-conducted interviews is thematically analyzed.

Theoretical implications –We seek to elaborate on the Commons theory considering that empirical findings on business models for open source hardware could lead to more theoretical insights. Specifically how to monetize OSH innovation and how to create shared value.

Originality/value – This chapter justifies the methodological approach that appears most coherent to study OSH BMs from a social science perspective.

Our literary review permitted refining the original research questions. This chapter presents the methodology used to develop this thesis in pertinent research architecture according to the process described by Gavard-Perret *et al.* (2012). First we acknowledge the scientific context to which our phenomenon relates, then the epistemological paradigm under which our research falls. We then specify the research design from the objective of our study, thus the ways and the means by which our data is collected.

Our research falls within the pragmatic constructivism paradigm (PECP). A qualitative method has been employed to study the emerging, artificially constructed phenomena of open source hardware, using abductive reasoning and a multi-scalar perspective for the interactions within OSH communities, between firms and OSH communities, and in OSH ecosystems. Our research seeks to refine and elaborate upon the theoretical frameworks of the Commons theory (Fisher & Aguinis 2017). Using the Avenier & Cajaiba (2012) dialogical model, we have studied the empirical phenomena of OSH business models through interactions with actors at every level chosen for analysis. These correspond to the intra- and inter-organization levels, the broader industry, regional innovation systems and the society levels, called “OSH ecosystems”, as offered by Bogers *et al.*, (2016) in their “Open innovation research landscape”.

3.1. EPISTEMOLOGICAL POSITIONING

Epistemology is the philosophical discipline that seeks to establish why we know what we know. For the Swiss psychologist Piaget (1967, p. 6), epistemology is the study of how valid knowledge is built. It's a shared conception of knowledge based upon founding hypotheses that are explicitly formulated, coherent and used among research communities (Avenier & Thomas 2015). Allard-Poesi & Gavard-Perret, (2014) explain epistemology as a reflexive activity underlying how knowledge is produced and justified. As Berger explained in “Ways of Seeing” (1972), all research relies upon a certain vision of the world. Bringing to light the assumptions underlying the research makes the research approach more objective and pertinent in addressing the “research-practice gap”. “Since both what is considered as valid knowledge and the way to justify knowledge validity depend on the epistemological framework; not rendering explicit the epistemological underpinnings of the arguments is a source of enduring misunderstanding” (Avenier & Cajaiba 2012, p.199).

Among assumptions to be clarified are the nature of the reality and of the knowledge we are seeking to understand, as well as the value and the status of such knowledge. Epistemology is

thus directly linked to scientific research (Martinet, 1990, p.9-10) as it enables the researcher to be as coherent and pertinent as possible, and to explain his or her assumptions while justifying the “countless decisions taken in different moments of the research (Avenier 2010).

Table 1 shows the justifications of the research approach, according to the current, main epistemological frameworks.

	EP Scientific Realism – Post Positivism	EP Critical Realism	EP Pragmatic Constructivism	Interpretativism
Ontological assumption	Ontological realism: reality exist prior to and independently from human attention. There exist a unique immutable « real-as-is »	Ontological realism: reality exists independently from human attention. Reality is both intransitive and stratified and is composed of three overlapping domains. The real, the actual and the empirical. Generative mechanisms (GM) reside in the real domain. Observable events occur in the actual domain. Experienced events lie in the empirical domain	Human experience resistance to their actions; No founding assumption on whatever resists human action. Whatever resists human action possibly exists independently of human attention.	Ontological relativism: there exists multiple socially constructed realities not governed by any natural laws causal or otherwise. The agreed meanings about a situation constitute the objective, inter-subjective reality of this situation
Epistemic founding assumptions	Epistemic realism: Real-as-is knowable (with possible faillability of measuring instruments)	Epistemic relativism, but not judgmental relativism. The real domain is not observable. Events (actual domain) are observable. Experienced (empirical domain) events are knowable.	Epistemic relativism in the sense that human experience is knowable and in the knowledge process, whatever stems from a situation is inseparably intertwined with whatever stems from the inquirer, and affects the inquirer's experience of the situation.	Epistemic relativism. Facts are produced as part and parcel of the social interaction for the researchers with the participants and knowledge is gained only through social constructions.
Goal of knowledge generation process	Record constant conjunctions of observable events. Identify surface regularities and patterns	Identify the GMs that are responsible for the events and patterns of events observed.	Build intelligible models of human active experience, which provide insights for organizing the world of experience	Understand how human beings make individual and/or collective sense of their particular world and engage in situations.
Status and shape of knowledge	Correspondence conception of knowledge. Iconic representation of real-as-is. Falsifiable statements	Towards a correspondence conception of GMs, and a pragmatic conception of the manner they are activated. Field testable statements concerning GMs and activable propositions	Plausible interpretations that fit experience and are viable for intentionally acting. Generic models and activable propositions.	Plausible interpretations that fit lived experience. Narratives supported by thick descriptions, and generic statements.

Table 1: Founding assumptions concerning knowledge's origin and nature in alternative epistemological frameworks (Avenier & Thomas 2015)

After having studied the present, main, epistemological paradigms: positivism (Eisenhardt & Graebner 1989; Dubé & Paré 2003, Yin, 2003); critical realism (Wynn Jr & Williams 2012); pragmatic constructivism (Avenier 2010; Avenier & Cajaiba 2012) and interpretivism (Myers & Klein 2011), this research is in line with pragmatic constructivism (PECP), as described by Avenier & Thomas (2015).

The four dimensions of epistemology are *ontological*: questioning the reality which we are seeking to understand; *epistemic*: questioning the nature of the knowledge produced; *methodological*: relating to the tools used to produce and justify the knowledge and finally, *axiological*: relating to the status, shape and ethics inherent to this knowledge creation. Table 2 explains the main assumptions behind the choice of pragmatic constructivism as the epistemological framework for our research.

PRAGMATIC CONSTRUCTIVISM	
What is reality (ontology)	Non-essential. No founding assumptions on reality. The empiric material is rich and dependent on its context, and includes a great number of viewpoints
What is the type of knowledge? (epistemology)	Pragmatic Constructivism.
What is the validity of the knowledge? (methodology)	Build intelligible models of human active experience, which provide insights for organizing the world of experience
What are its effects on knowledge (axiology)	Plausible interpretations that fit experience and are viable for intentional acting Generic models and activable propositions

Table 2: Founding assumptions concerning knowledge's origin and nature in pragmatic constructivism (adapted from Avenier & Thomas 2015)

3.1.1. DIALOGICAL MODEL

The Dialogical Model, introduced earlier, is the backbone of our research. It allows articulating the research flow while creating and maintaining the right amount of tension between academic value and practical relevance. We chose this model because it is coherent with Avenier & Cajaiba's (2012) PECP. The model offers guidelines to conducting rigorous research aimed at generating relevant academic knowledge for practitioners' use. According to Parmentier Cajaiba & Avenier (2013), the model is distinctive for the following two reasons: First, for the ongoing and productive dialogues between the researchers and the practitioners during the span of the research, as described by (Tsoukas 2009a). Second, for the ongoing tension between two antagonistic and complimentary objectives: that is, generating useful knowledge from the perspectives of both the academic and the practitioner. The goal of this model and the objective of PECP, is to arrive at this by detailing and explicitly integrating practitioners' knowledge and experience.

3.1.2. ONTOLOGICAL HYPOTHESIS OF PECP

To begin, the ontology or frame of reference pertaining to social sciences is a human construction process. Social sciences are artificial because they are a process of human and social construction. The phenomenon under study is an artefact, which needs to be understood in its complex and flawed context. Therefore, a positivist approach, assuming to study reality as immutable or everlasting, or "essential" and independent from human activity, does not apply. The PECP approach, as described by Pr. Avenier, posits that we can only understand our own experience of the world, therefore we cannot deduce anything of reality itself. According to PECP, scientific knowledge is based on our own understanding of reality "this is my understanding of the world", a completely different point of view from the positivist approach which would claim, "this is how the world functions". According to Avenier (2010), physical sciences cannot be models for organization research. The PECP approach doesn't seek to describe how reality functions. Open source hardware and digital commons platforms are fundamentally different from a natural science phenomena, such as the movement of planets, or geological structures, which, when observed will always remain the same. What we are studying is "non-essential", and is dependent on human activity, conscience and the intention and interaction of its actors. Therefore, it is "mutable": subject to change.

Our assumption is that "modern society is complex". Benkler (2013) gives at least three reasons for this. 1. Social behaviors at the scales of the interconnected systems we inhabit, that

we rely on, and that structure our capabilities and susceptibilities, are "complex" in the technical sense that they display nonlinear emergent properties and are sensitive to initial conditions and small perturbations. 2. They exhibit stochasticity (p.5), or a random element, even where we think that the dynamics we observe, such as a set of institutions and the behaviors we anticipate in response to them, are linear. 3. The tools, techniques and models we use for managing our understanding of the world, "require a level of simplification for tractability and that the information lost in the process of rendering the problem tractable creates systemic error that is not itself susceptible to solution within the techniques we possess". Describing Digital Commons and Knowledge Commons, to which our phenomenon of OSH belongs, Benkler explains:

"Like markets, commons are necessarily imperfect. What commons offer is a space for experimentation, learning, and adaptation whose limitations are not correlated with the limitations of the property system. They offer another degree of freedom in the exploration of solution spaces to the problems that human existence posits" (Benkler 2013, p. 5).

3.1.3. EPISTEMOLOGICAL HYPOTHESIS OF PECP

The choice of pragmatic constructivism precisely fits the object of our study. As assistant professor at Stanford University, Paulo Blikstein, remarks (2013, p.5), writing about 'Digital fabrication and 'Making in Education', "Seymour Papert's Constructionism builds upon Piaget's Constructivism and claims that the construction of knowledge happens remarkably well when students build, make, and publicly share objects. His theory is at the very core of what "Making" and "Digital fabrication" mean for education, and underlies what many enthusiasts of the "Maker movement" propose -- even if many are not aware of it. -- Papert's words describe precisely the relationship between making and learning: "Construction that takes place 'in the head' often happens, especially felicitously, when it is supported by construction of a more public sort "in the world" -- a sand castle or a cake, a Lego house or a corporation, a computer program, a poem, or a theory of the universe. Part of what I mean by 'in the world' is that the product can be shown, discussed, examined, probed, and admired".

3.1.4. METHODOLOGICAL HYPOTHESIS OF PECP

Next, we will seek to address the validity of the knowledge we seek to address: how it is produced and justified and according to which tools. This leads us to question the value of the knowledge, as well as the procedures guaranteeing that value. The pursuit of scientific

knowledge seeks the “truth”, but this truth differs according to the current main epistemological frameworks (see

Table 1). For instance, in a realism approach, the methodology used will have to be verifiable and confirmable. In Popper’s famous example (1968), the validity of a theory is that “it is considered as provisionally representative, as long as it is falsifiable and has withstood all hypotheses performed on it”. You may surmise that all swans are white, until you meet a black one, which will refute your assumption. Whereas in a constructivist approach, the method used to gather data must be credible and actionable (Allard-Poesi & Perret, 2014). The means of collecting data, must make sense in that given context, so that another researcher could follow the same steps, even though his results may be completely different when set in the new context. The results will be conceptualized but need to be re-contextualized if tested in a different terrain. The goal of the PECP approach is to build intelligible models of human active experience, which provide insights for organizing the world of experience. In such an approach, results do need to be confirmed, but they need to be *adequate* to fit a given situation (Von Glaserfeld, 1988; *cited in* Gavard-Perret *et al.*, 2012). In sum, they must make sense and be actionable, for academics and practitioners alike.

According to (Avenier 2010, p. 1232), the constructivist approach may freely use any method and combination thereof in order to conduct research. Any method, provided it is used interpretively and its implementation is adequate and actionable, is eligible to generate knowledge. Modern hermeneutics: the theory and methodology of interpretation, include both verbal and non-verbal communication. Concerning qualitative data, the approach used in this research includes, for instance:

-primary data collection from interviews or focus groups, or recordings of keynote speakers during conferences.

-secondary data, such as visual and digital data, texts and company reports.

The guiding principles of the methodology are ethics, explicitness and rigor (*ostinato rigore*).

Since the foundation of management studies is based on human interaction, the notion of *ethics* in research means interacting with humans in a “manner respectful of their dignity, their integrity and their privacy” (Guba & Lincoln, 1989 *cited in* Avenier 2010; Miles, Huberman and Saldaña, 2014, p.58-68). This includes respecting the confidential nature of data

collected, the future use of which should be previously established with respondents. For instance, in this research, invitations were sent out to potential respondents asking if they would consent to participating in the research and how they would prefer their information be handled. If they preferred confidentiality, their data was anonymized, and only their job function was listed in the details of the data collected. Once the interview transcript was completed, it was sent it to them for validation and/or additional comments. Ryen (2011) concludes her chapter on ethical issues in qualitative research by saying that such research “calls for moral responsibility in a field scattered with dilemmas not for pre-fixed answers”.

Explicitness refers to “thick description” which is giving more than sufficient detail about an event, person, or interaction to capture context-specific nuances of meaning; leaving an “audit trail”, recording as faithfully as possible various stages of the research process, clarifying the researcher’s decisions, information gathered and inferences drawn.

Trustworthiness, or “*obstinato rigore*”, the favoured motto of Leonardo da Vinci, is “the effort of striving broadly to become more rigorous” in the way information is collected, in the way researchers “read, reread academic literature and field documents and draw inferences” (Avenier 2010, p. 1243). Thus, by following the PECP approach, results can be visualized and rendered useful to practitioners.

3.2. RESEARCH DESIGN SPECIFICATION

The research design of this work ties into the construction of the OPEN! Project as it relates to the fourth work package (WP4) on business models for open source hardware. Following the Dialogical Model, the enduring or recurring practical problem initiated by the OPEN! Project in general, is to understand and model how Open Source Product Development (OSPD) works. For WP4 and for this thesis, it is to understand and model what the business models for open source hardware are.

Two initial phases served to progressively sharpen the research questions for this thesis, beginning with the general question of: “What are business models for open source hardware?” The WP4 partners in the project and the HIIG Institute in Berlin conducted a literature review to specify what makes business models “open”, and what the central components of these business models are (Tech *et al.*, 2017). Concurrently, an empirical assessment of the current practices for the OSPD landscape, was conducted by all partners so as to develop a shared understanding. This phase corresponds to the second process type described by (Avenier &

Cajaiba 2012): the *construction of local knowledge*. This contextualized knowledge “is essentially developed by drawing upon practitioner experience and knowledge about the research question. It serves as a basis for developing conceptual knowledge” (Avenier & Cajaiba 2012, p.202). It is part of the *abductive process*, of going back and forth between the academic’s and the practitioner’s spheres, of empirically validating conceptual knowledge and enriching it with real life experience. Here, as was agreed upon in the project proposal, empirical data was gathered through semi-conducted interviews, so as to test the conceptual elements key to OSPD, as described by Fjeldsted *et al.*, (2012): *the drive; the community; the development process and the business model*.

This preliminary work allowed us to structure the research design (see Figure 19). The principal and secondary research questions were clarified and fine-tuned to:

How do innovation communities practicing OSH create and capture value with firms and with a broader ecosystem?

- RQ1: How can **value** created through Open Source Hardware **be monetized**?
- RQ2: How can the **business model framework** be broadened to include *value creation and sharing* for all **stakeholders**?

A qualitative analysis approach was chosen, based on semi-conductive interviews and thematic data analysis. What also emerged was the necessity to conduct a multi-level analysis. These points will all be developed later.

Goal: develop theories to explain the OSHW phenomena	Extend existing theories to explain OSHW
Research questions	<ol style="list-style-type: none"> 1. How to monetize value created through OSHW? 2. How can how can the business model framework be broadened to include <i>value creation and sharing</i> for all stakeholders?
Epistemological paradigm	Pragmatic constructivism (Avenier & Thomas, 2015)
Theoretical resources	Commons theory
Empirical investigation strategy	Qualitative explorative research <ul style="list-style-type: none"> • Case studies

(Gavard-Perret *et al.*, 2012)Figure 19: Research design (adapted from Gavard-Perret *et al.*, 2012)

3.2.1. CHOOSING A TYPE OF SCIENTIFIC REASONING

The objective of scholarly reasoning is to justify new knowledge in a scientific field. The essence of an argument is proceeding from grounds to claims or from premises to conclusions in a credible manner (Toulmin, 2003). Pierce's (1878) illustration of "beans in a bag" is often the classic reference used to introduce the main forms of reasoning, which are our primary tools of inference: *deductive*, *inductive* and *abductive* reasoning.

1. All the beans in this bag are white (the rule)
2. These beans are from this bag (the explanation)
3. These beans are white (the observation)

In deduction, one takes the rule (1) and the explanation (2) and derives the observation (3). The conclusion about the particular is based on the general. Inductive reasoning combines the observation (3) and the explanation (2) to infer the rule (1). The third mode of reasoning is abduction. "Understanding the role of abduction becomes apparent once we acknowledge the possibility of multiple bags and which bag is the source of the beans observed. In abduction one begins with a number of alternative rules (1) and the observation (3); the explanation (2) is inferred by appraising the alternative rules in light of the observation" (Mantere & Ketokivi

2013). Abduction has been suggested as the logic by which new hypotheses are derived and how scientific discoveries are made (Hanson, 1958; Niiniluoto, 1999 *cited in* Mantere & Ketokivi 2013). According to Avenier & Thomas (2011) abductive reasoning doesn't aim to change the theory but to understand the reasons for regularities or disparities observed in the phenomenon studied.

In PECP, a qualitative and abductive approach is necessary to generate new knowledge. This requires moving back and forth between deductive (from already published academic knowledge) and inductive (coming from the field) approaches. Per the Dialogical Model, this process connects local knowledge, “that is essentially developed by drawing upon practitioner experience and knowledge about the research question”, to extant literature (Avenier & Cajaiba 2012). Local or field knowledge is the basis for developing conceptual knowledge. Conversely, conceptual knowledge can be contextualised, tested and validated through rich local or field knowledge.

3.2.2. QUALITATIVE, EXPLORATORY RESEARCH

Since the phenomenon under study is novel, we opted for a qualitative approach for collecting empirical evidence and validating previously established conceptual knowledge of open source hardware communities. A qualitative approach is used when little is known of a given phenomenon. Unlike quantitative research, which tests formulated hypotheses and requires certain conditions such as representability of data and validity of test items, qualitative research methods are best used to explore complex phenomena where statistical data is not yet available (Silverman, 2018). Both approaches are complementary: the qualitative generally comes first, going into more depth and following up on topics that seem to have rich interpretations. The quantitative approach allows confirming the findings and the hypotheses formulated. In accordance to Ketokivi & Choi (2014, p233), we chose to adopt the definitions of qualitative and quantitative research based on the meanings of the words themselves:

“Qualitative research = research approach that examines concepts in terms of their meaning and interpretation in specific contexts of inquiry.

Quantitative = research approach that examines concepts in terms of amount, intensity of frequency.”

The strength of qualitative data is its holistic approach to accumulating local knowledge through the experience and knowledge of real people in real settings. Miles, Huberman and

Saldaña (2014, p.11), explain: “The fact that the data is collected in close proximity to a specific situation” ensures confidence in its local *groundedness*. They add that another advantage of qualitative data is the richness and holism revealing complexity. Such data provide “thick descriptions that are vivid, nested in real context, and that have a ring of truth with a strong impact on the reader”. Such data, carried over a *sustained period*, makes a powerful means of *studying a process*, and even *assessing causation*. Lastly, the authors explain that qualitative data, “with emphasis on people’s lived experience, are well suited for locating the meanings people place on the events, processes and structures of their lives”

Qualitative data in this research is mainly in the form of words. The words collected and analyzed are based on observation, interviews, documents and artefacts. Such data are not usually, immediately accessible for analysis but require some type of processing: raw field notes need to be expanded and typed up, audio recordings need to be transcribed and corrected (Miles, Huberman and Saldaña, 2014, p.11).

In this work, data gathered comes mainly from semi-constructive interviews, a method widely used in management science because it ensures both flexibility and structure. On one hand, an interview guide is composed of topics identified from the literature as pertinent to deepening the research question. Having respondents reply to every single item permits analyzing their responses systematically and easing a *horizontal analysis*. The horizontal approach enables studying multiple interviews transversally in order to identify salient themes and patterns. Individual discourses are deconstructed and their common parts extracted. Coherence is thereby not determined by the structure of each individual document, but rather by reuniting similar elements in the different interviews transcribed (Gavard-Perret *et al.*, 2012, p.291). In this manner, the researcher was free to progress through each topic of the interview guide in a compliant fashion, fluidifying the conversation and letting respondents deepen subjects of particular interest according to their own logic. The interviews were predominantly done by two interviewers in order to systematically refocus on the interview guide prepared.

For a quicker and more concentrated approach, the objective of the research was explained to those interviewed. Indeed, the goal was to assemble the respondents’ knowledge and experience concerning the research questions to the point of saturation on the topic given, ensuring the researchers that they had gathered enough data from enough respondents to understand most facets of the respective questions.

Other means of primary data collection included field notes from observation during workshops, roundtables, seminars, and recordings of keynote speakers during conferences. Secondary data was collected through company websites and reports.

3.2.3. DATA ANALYSIS PROCEDURE

All knowledge collected locally was structured and submitted to the same research method.

Prior to each stage of our research, (i.e. the fields of study which progressively became different levels of analysis), an interview guide was composed of topics collectively identified in academic literature and felt to be the most conducive to answering our research questions. As mentioned above, the aim of the interview guide was to provide both flexibility and structure (Gavard-Perret *et al.*, 2012, p.113). Interviewers were free to concentrate on one subject then spontaneously ask other questions in order to grasp new ideas as long as all the interview themes were treated. Thus, respondents were able to address each topic according to their own logic while unplanned subjects emerged.

Each interview was recorded so as to maximize the potential of post analyses. The interviews were conducted in English, French and German. After each interview, both interviewers collaborated in summarizing their findings in English and in identifying the most pertinent. The interviews were then entirely transcribed, and if needed, translated into English.

Coding

Next, using the data analysis software (Nvivo and Sphinx), data resulting from French and English interviews, was coded. The initial topics in the interview guide composed the first-cycle codes, or knots (Miles, Huberman and Saldaña, 2013). Coding was then refined (see Figure 20) through two more coding cycles permitting novel ideas and themes to emerge. Progressively, significant themes were revealed “through the systematic classification process of coding and of identifying themes or patterns” (Hsieh & Shannon 2005, p. 1278; Zhang & Wildemuth 2009)

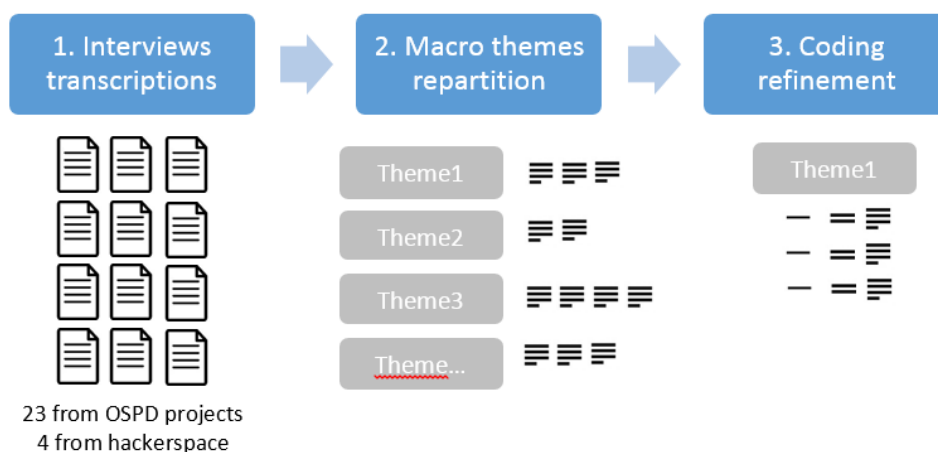


Figure 20: Procedure to refine coding

The interviews were then deconstructed, as explained, in order to run a transversal, horizontal analysis (Gavard-Perret *et al.*, 2012, p.291). Matching the dimensions related to the research questions, major themes were paired with particularly evocative citations and reported on an excel spreadsheet. In additional workshops with OPEN! team colleagues, members were assigned specific projects and asked to write the main insights gathered from the projects, on ‘Post-its’. The ‘Post-its’ were assembled to discover what patterns emerged.

According to the frequency of the themes, and the subjective understanding of the researcher (Miles, Huberman and Saldaña, 2013), the insights gathered in the data analysis were prioritized. The results of our first field research on the “Landscape of current OSPD practices” were discussed in order of importance relating to the different dimensions studied: *the platform, the drive, the community, the development process and the business model*.

From then on, we used either, within-the-case analysis to describe and explain “what has happened in a single, bounded context”: research on the firm-community level using the Raidlight case, and on the ecosystem level using the city of Barcelona case, or cross-case analysis using the study on the automobile sector, in an effort to increase generalizability, (Miles, Huberman and Saldaña, 2013, p. 101).

Intercoder reliability

Intercoder reliability does not ensure validity, but it is a crucial component of qualitative content analysis. When it was possible -- meaning when the people who conducted the interviews were physically close enough to be able to conduct, transcribe, translate and code

them -- we used this. At different stages of the research it was not possible. For instance, the four interviewers attempted to rank the initial project interviews according to nominal scales. The resulting intercoder reliability, using the Fleiss Kappa, was much less accurate than with two coders coding in physical proximity.

In the structure of the OPEN! Project, each partner institution was assigned specific, person-months. Thus, there was a certain turnover of persons available for coding. In the case concerning the automobile industry study, the person-months assigned the HIIG partner were coming to an end and the projects partners attempted to analyse the data in time for the Journal of Product Innovation Management call for papers. As a result, there was no time to be spent on the lengthy process of coding. Furthermore, twelve of the sixteen interviews had been conducted in German and only the summary of findings was translated into English. For the last stage of research on the case of Barcelona, there was only one person conducting the interviews (in English) and coding them, therefore interpretations depended upon the researcher's subjective intelligence and viewpoint alone (Miles, Huberman and Saldaña, 2013).

Considering the (Neuendorf, 2002) statement: "given that a goal of content analysis is to identify and record relatively objective (or at least intersubjective) characteristics of messages, reliability is paramount. Without the establishment of reliability, content analysis measures are useless". With this in mind, at times during our research it was possible to calculate intercoder reliability using a Cohen's Kappa when two coders were used, and a Fleiss Kappa in the case of four coders.

Two methods were generally employed to consider intercoder reliability: the percent agreement and the Cohen's Kappa for two coders. The *percent agreement* is limited to nominal coding and only two coders with the same number of coded units. Although it is the easiest way of achieving computer inter-coder reliability, there are some drawbacks and the use of percentage agreement is not usually recommended. The *Cohen's Kappa* is a popular and widely cited method for estimating the reliability of nominal data. A statistic which measures inter-ranker agreement for qualitative (categorical) items, it is generally thought to provide a more robust measure than simple percent agreement calculation, since κ takes into account the agreement occurring by chance²⁶.

²⁶ https://en.wikipedia.org/wiki/Cohen's_kappa

This was the option chosen for estimating intercoder reliability regarding macro and micro themes in the first stage of our research. As will be discussed in Chapter 4, this was made possible because two of the four people conducting the interviews, were located in Grenoble. At this stage of the research, they conducted half of the 24 interviews and transcribed almost all of them, translating to English those that had been conducted in French. Then they coded all. This close physical and cognitive proximity, explains why the coding was “substantial” in this instance. When the coding reliability was only “moderate”, the researchers went back to the coding book to clarify misunderstandings that had led to coding disagreements. In the Cohen's Kappa measures, the agreement between two raters who each classify N items into C mutually exclusive categories, the equation is:

$$\kappa = \frac{p_o - p_e}{1 - p_e} = 1 - \frac{1 - p_o}{1 - p_e},$$

where p_o is the relative agreement observed among raters, and p_e is the hypothetical probability of chance agreement, using the observed data to calculate the probabilities of each observer randomly qualifying each category. If the raters are in complete agreement then $\kappa = 1$. If there is no agreement among them, other than what would be expected by chance (as given by p_e), $\kappa \leq 0$ ²⁷.

Per Landis & Koch (1977), the Cohen's Kappa result is interpreted as follows:

- $\kappa < 0.00$ Poor
- $0.00 < \kappa < 0.20$ Slight
- $0.21 < \kappa < 0.40$ Fair
- $0.41 < \kappa < 0.60$ Moderate
- $0.61 < \kappa < 0.80$ Substantial
- $0.81 < \kappa < 1.00$ Almost Perfect

The result is acceptable starting from 0.61.

The Fleiss Kappa estimates the reliability for nominal or ranked (ordinal) data for any number of raters. It expresses the extent to which the amount of agreement observed among raters exceeds what would be expected if all raters made their ratings completely randomly²⁸. The

²⁷ https://en.wikipedia.org/wiki/Cohen's_kappa,

²⁸ https://en.wikipedia.org/wiki/Fleiss%27_kappa

interpretation scale is the same as for the Cohen's Kappa. The Fleiss Kappa formula is the following:

$$\kappa = \frac{p_a - p_e}{1 - p_e}$$

The factor $1 - \bar{p}_e$ gives the degree of agreement attainable above chance, and, $\bar{p} - \bar{p}_e$ gives the degree of agreement actually attained above chance. If the raters are in complete agreement then $\kappa = 1$. If there is no agreement among them (other than what would be expected by chance) then $\kappa \leq 0$.

3.2.4. CASE ANALYSIS

Case research, as an output of qualitative data, is destined to create knowledge. In order for this approach to be successful and scientifically transparent, the *methodological approach* of how the study is framed and how the analysis is conducted, needs to be clearly explicated (Ketokivi & Choi 2014).

The case study approach enables highlighting how a decision or a series of decisions were made, how they were implemented and what their results were (Hlady Rispal, 2002).

The point of designing case studies is to “seek the formulation of theoretical insight that can be understood as the outcome of the interaction between a general theory, the extant literature offers, and the empirical context at hand”. Three approaches: theory generation, theory testing and theory elaboration, differ chiefly “in the relative emphases given to theory and empirics”. In Figure 21, arrow thickness denotes degrees of emphasis.

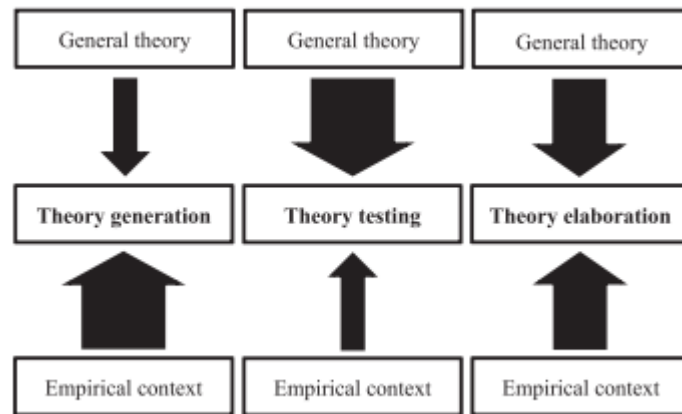


Figure 21: Three modes of conducting case research (from Ketokivi & Choi 2014)

Critics suggest that the problem with qualitative data, is that it is not understandable outside its context (Chanson *et al.*, 2005). Ketokivi & Choi (2014, p. 233) insist that the aim of case research is not to produce theories for others to test. “Theories produced in case research can certainly be subjected to further testing, but as an extension of earlier case research rather than as its validation.” They further explain that the essence of case research is in the *duality criterion* of being situationally grounded, “but at the same time seeking a sense of generality... an attempt to transcend the empirical context and seek broader theoretical understanding through abstraction”. These three research approaches are ideal types although they may not be found in their pure forms in actual research. Figure 22 explains the different logics for each type.

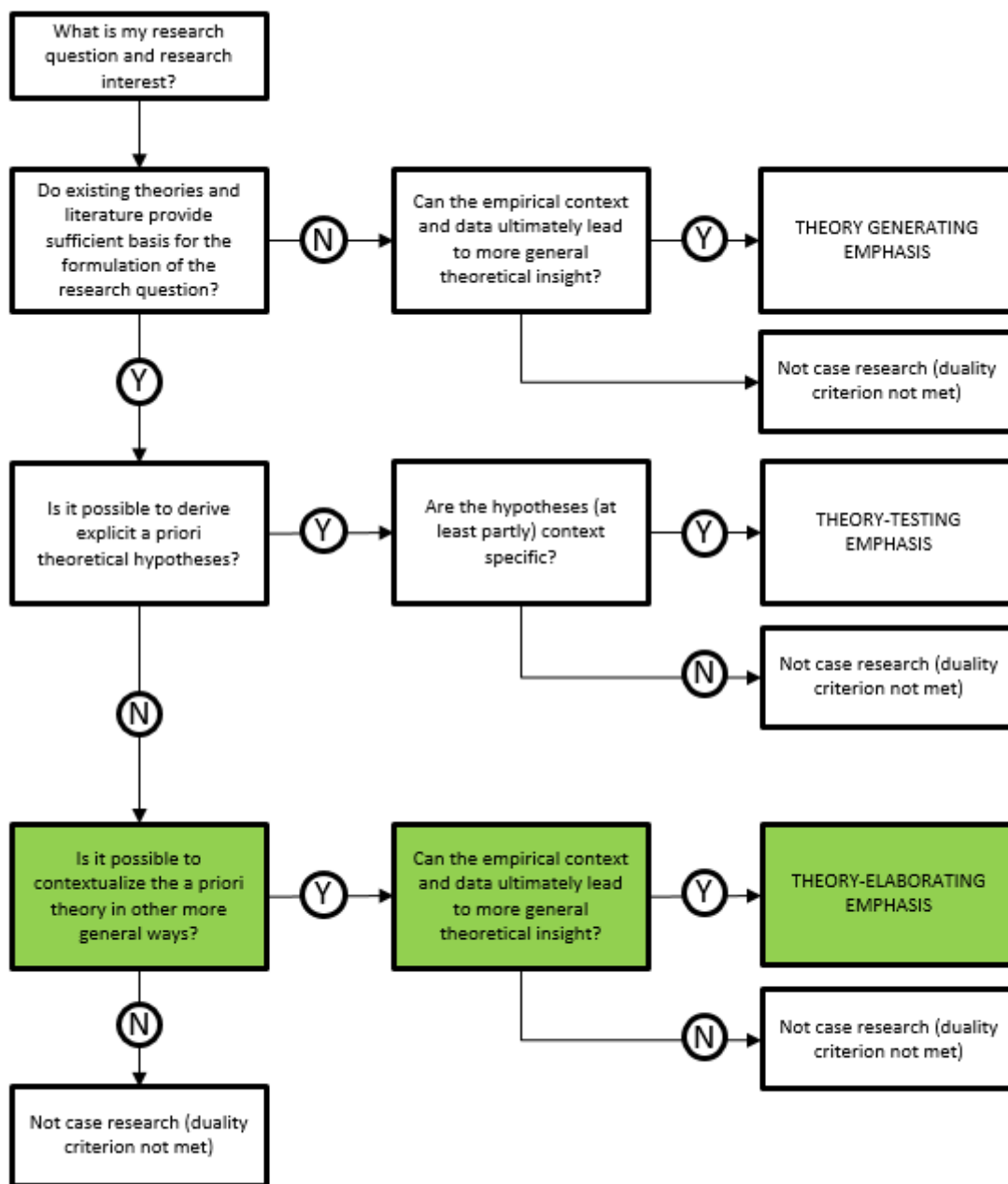


Figure 22: Case research decision tree (from Ketokivi & Choi, 2014)

3.3. THEORY ELABORATION

Our research follows the theory elaboration approach, which focusses on the contextualized logic of a general theory; it does not seek to test its logic, but to elaborate upon it. The general theories are treated as “malleable”. As the researcher may wish “to explore the empirical context with more latitude and serendipity, empirical data are used not only to test a theory but also to challenge it” (Ketokivi & Choi 2014, p. 236). The role of serendipity is so the researcher

may remain open to unanticipated findings and the possibility that the general theory require considerable reformulation. Theory elaboration “is a disciplined iteration between general theory and empirical data”. It is also a logical extension the of knowledge creation justification linking the epistemological framework PECP with its methodology and abductive reasoning. Theories may be elaborated by introducing new concepts or by conducting an in-depth investigation of the relationships among concepts.

This process meets the double criteria of general theory and empirical context because, “while categories and concepts are ultimately grounded in the [new] data, this process exhibits less emergence as it is guided by a-priori, theoretical considerations” (Ketokivi & Choi 2014, p. 236).

According to Ketokivi & Choi (2014) the elusive concepts central to theory advancement are *generality*, *transparency* and *cognition*. “No matter how we strive to be objective, we never are and objectivity is never an actionable and operational methodological criterion” (Stanovich, 1999, cited in (Ketokivi & Choi 2014). Discussions on *generality* could be improved if researchers examined the role of existing theories and concepts in greater detail. The notion of *transparency* is really about asking whether the conducted research makes sense or not; if the author’s arguments are understandable to the reader. As humans we rely less on computational reasoning (formalized, pre-determined rules and procedures, of which deduction and induction are forms) than we do on cognitive reasoning, which is more idiosyncratic (less formalized and less pre-determined). The bias inherent in such a reasoning impedes true transparency in research. The notion of cognition is the common bias for researchers to see what they expect to see and to fit theory to data or vice versa. They write that “a rigorous case researcher allows all theoretical predispositions and emerging theoretical insights to remain challenged by the data... and to be open to be surprised by it” (p. 238).

Given such high methodological standards, we will do our best to describe the logic behind our process of theory elaboration at this stage of the research.

3.3.1. EXTANT THEORIES IN ORGANIZATIONAL MANAGEMENT

Theories describe how people or organizations behave. Choosing a research design requires taking a good, hard look at the phenomenon being observed and the current theories in its discipline: in this case organizational management and the methodologies available to describe

the phenomenon. The current, principal theories in management sciences are criticized for missing the changing nature of innovation.

Recently, many authors have decried management theories as too simplistic and static to fully capture the dynamic changes in the size and complexity of modern organizations. We risk knowing more and more about a type of innovation that is displaced. According to Benner & Tushman (2015), extant theories of innovation fail to capture the complexity of the current context in which organizations operate. For them, “open innovation, enabled by low-cost communication and the decreased costs of memory and computation, has transformed markets and social relations”. However, “the impact of this innovation mode on the firm is not well understood”. Management science lacks “a theory of the firm, either for incumbents or new entrants, that takes into account community innovation. The impact of open innovation on the organizational literature, strategy literature, and innovation literature is minimal (for exceptions see Afuah & Tucci 2013)”. They lament that conservative and simplifying theories are used as they fit into the dominant discourse, and are published in journals that barely conceal “exercises in power and resistance” (Gabriel, 2010, p.761, *cited in* Suddaby *et al.*, 2011). Benner & Tushman (2015) suggest a shift from “mature, deductive scholarship to more inductive and phenomena-driven scholarship”.

Moreover, theories in management sciences are often retrofitted from other disciplines, importing but not addressing the founding cognitive biases. Suddaby *et al.*, (2011) explain that theorists are drawn to “fashionable styles of thinking”, and many times (such) theories have been adapted to accommodate the empirical context of organizations, without understanding that “theories generate both ways of seeing and ways of not seeing”. They write “when we import theories from psychology and sociology, we also import core questions, assumptions, and metaphors, each of which has the potential to create blind spots for management researchers”.

Studying the business models for OSH is absolutely, very problem oriented and phenomena-anchored. In line with theory elaboration, we can definitely keep the *duality criterion* of the right amount of tension between general theory and empirical context. To explain how firms respond to innovation streams beyond their organizational boundaries, the current context concepts, such as open innovation, open source hardware, business models and the *middleground*, need to be understood through an overarching theoretical framework. The problem of our thesis research is in its opening statement: There is definitely paradox and

tension between “business models” and “open source hardware”. The goal of our research is to treat that tension. Following an abductive reasoning mode, the way to frame our research thus becomes:

1. Business models for open source hardware (the rule)
2. These business models belong to open source hardware (the explanation)
3. Open source hardware projects have business models (the observation)

In our case, the recurring and empirical observation initiating this research is that “despite deliberately eschewing the creation of IP rights over its technologies” (Chesbrough, 2006a), we can observe business models relying on commons, peer-based production that work, “not despite being open source but because they are open source” (Raworth, 2017, p.230).

The problem is that extant theories (1. the rule), such as absorptive capacity and dynamic capabilities, do not leave room for phenomena transcending the boundaries of the firm, while others are either not strategic or actionable enough. In the meantime (3. the observation) is that the open source hardware phenomenon is progressing and catching on as a trend, from large global players such as Baidu, Tesla and the UNICEF, to the smaller players inventoried in the “open source hardware observatory”²⁹. Therefore, in this research we will seek (2. the explanation) for this occurrence.

For this, we shall review the management science theories that were most considered, and that justify our final choice of the Commons theory.

Our first hypothesis is, since the locus of innovation relies on innovation communities both internal and external to firms, value creation and capture should be broadened to include the 4 freedoms³⁰ at the heart of the open source hardware movement.

The second hypothesis is that the notion of value itself must be broadened and take on new meaning (Breuer & Lüdeke-Freund 2017).

²⁹ <https://opensource.design.cc/observatory/>

³⁰ The freedom to access, the freedom to replicate, to modify and to distribute. These four freedoms are derived from the free software definition (Free Software Foundation 2015), which are: Freedom 0, the freedom to run the program for any purpose; Freedom 1, the freedom to study how the program works; Freedom 2, the freedom to redistribute copies; Freedom 3, the freedom to distribute copies of modified versions

Foss & Saebi (2018, p.10) explain that over the last fifteen years, the following theories have been applied to the understanding of BM and BMI: “Dynamic capabilities (Leih *et al.*, 2015), threat rigidity and prospect theories (see Saebi *et al.*, 2016), entrepreneurship theory (see Foss, Saebi & Stieglitz, 2016; George and Bock, 2011), TCE (Zott and Amit, 2010), RBV or Penrosian view of the firm (Mangematin *et al.*, 2013), applied to the understanding of BM and BMI in the context of learning (e.g. Sosna *et al.*, 2010), managerial cognition (e.g., Tikkanen *et al.*, 2005), performance (e.g., Amit and Zott, 2001; Zott and Amit, 2008; Kim and Min, 2015), innovation (e.g., Chesbrough and Rosenbloom, 2002), replication (e.g., Winter and Szulanski, 2001), and competition (e.g., Casadesus-Masanell and Feng, 2013; Velu and Jacob, 2014)”.

The Paradox theory

The **paradox theory**, indigenous to management sciences, addresses the complexity that current organizations must face globally in an increasingly dynamic and competitive world. Beyond dealing with issues, such as ambidexterity or research exploration/exploitation, organizations are now challenged to be “local and global” (e.g., Marquis & Battilana, 2009), “doing well and doing good” (e.g., Battilana & Lee, 2014; Margolis & Walsh, 2003), “social and commercial” (e.g., Battilana & Dorado, 2010), “artistic or scientific and profitable” (e.g., Glynn, 2000), “high commitment and high performance” (e.g., Beer & Eisenstadt, 2009), and “profitable and sustainable” (e.g., Eccles, Ioannou & Serafeim, 2014; Henderson, Gulati, & Tushman, 2015; Jay, 2013). These contradictions are prevalent, persistent, and consequential. Further, they can be sustained and managed, but not resolved (Smith, 2014).

An additional paradox to be noted is almost an oxymoron: “innovation management”. The management process, as Benner and Tushman suggest, is tied to the productivity dilemma: the tyranny of efficiency and associated inertia “when you value sameness, more than you value creativity”. Innovation, on the contrary, is about creating new products, developing existing products, but also about adopting the latest technology from fundamental research.

The Dynamic Capability theory

The dynamic capability theory was a favored option. This theory connects knowledge management with innovation processes. Tied to a resource-based view and to literature (Barney 1991), the central idea is that to respond to environmental changes, a firm develops a set of higher-order, organizational routines, as well as creative management activities destined to sense threats and opportunities, sizing their internal and external resources and competencies

in response to the environmental changes, and finally implementing the intended transformation (Teece 2014; Teece *et al.* 1997, p. 516). These organizational routines and management activities relate to the firm's capacity to *sense and seize, to transform or reconfigure* the intangible asset that will support superior, long-term business performance (Teece 2007). The ability to innovate one's business model, per se, is a kind of dynamic capability as it involves re-arranging the firm's resource base in addressing the competitive environment.

Janssen *et al.* (2018) have elaborated on this theory while researching the connection between openness and the need to develop dynamic capabilities for distinct phases of knowledge processing. They argue that, as clients and partners contribute to activities, mostly at the beginning and end of the innovation value chain, knowledge intensive business services (KIBS) should develop a "conceptualizing" capability for translating raw ideas into marketable service propositions.

The Absorptive Capacity theory

In today's world, competitive advantage results from business model innovation and how fast firms learn, so the absorptive capacity theory was also considered. Similarly to dynamic capabilities, this theory posits that the ability to exploit external knowledge is a critical component of innovative capabilities. The absorptive capacity of a firm is its ability "to *recognize* the value of new external information, to *assimilate* it and to *apply* it to commercial ends" (Cohen *et al.*, 1990). Such capacity, operating at individual and firm levels, is tied to a firm's previous knowledge base and routine (Zahra & George 2008). This organizational concept appeared very promising in terms of knowledge management specific to a firm, but despite its presence in literature for twenty years, it remains too vague.

In sum, the paradox theory did not seem actionable enough while the dynamic capability and absorptive capacity theories relate mostly to the open innovation mechanisms of outside-in processes, and are not focused on a *coupled process*, where value creation benefits all stakeholders.

The Stakeholder theory

The Stakeholder theory is attractive given the scope of our research on how to monetize value creation through open source hardware, and how to broaden value creation and capture for a wider set of stakeholders, because it directly addresses how to create shared value. According

to Porter & Kramer, (2011) the key ways that companies can create shared value opportunities are by *reconceiving products and markets; by redefining productivity in the value chain; and by enabling local cluster development*. These ways apply directly to open source hardware and to its high sustainability potential, including manufacturing redistribution, and the local-global reach of the Fab Lab network (Capdevila 2017, Gershenfeld, 2018).

The Stakeholder theory establishes that firms have a tacit obligation to create and distribute wealth to all stakeholders, without separating business from ethics (Freeman 1994; Clarkson 1995; Ruf *et al.*, 2001). In turn, their common, social and environmental responsibility, or CSR, gives them advantages. Contrary to any business pursuing its ends at the expense of the society in which it operates then finding success short lived (Porter & Kramer, 2011), here, the firm's triple bottom line is economic, social and environmental. Following this rationale, improved social performance has come to be a potential source of competitive advantage. Among others can be mentioned more efficient products and processes, improvement in productivity, product differentiation and increased pricing premiums (Porter 1991; Porter & van der Linde 1995; Fombrun *et al.*, 2000; McWilliams & Siegel 2011)(Porter, 1991; Porter & van der Linde, 1995, Fombrun *et al.*, 2000; McWilliams & Siegel, 2011). All of which are positive in improving a company's bottom line.

Shared value "highlights" the immense human needs to be met, the large new markets to serve, and the internal costs of social and community deficits – as well as the competitive advantages available from addressing them (Porter & Kramer, 2011). According to the authors, productivity in the value chain is redefined when the *boundaries are blurred between profit and non-profit*. Society's unmet needs are huge while businesses are better positioned "than governments and non-profits are at marketing that motivates customers to embrace products and services creating societal benefits, like healthier food or environmentally friendly packaging". For a company, "the starting point for creating this kind of shared value is to identify all the societal needs, benefits and harms that are or could be embodied in the firm's products... An on-going exploration of societal needs will lead companies to discover new opportunities for differentiation and repositioning within traditional markets, and to recognize the potential of new markets previously overlooked" (Porter & Kramer 2011, p. 68).

The second point Porter & Kramer (2011) make, is that productivity in the value chain is enhanced when it is congruent to societal progress, and invents new ways of operating to address it. They write that so far "few companies have reaped the full productivity benefits in

areas such as health, safety, environmental performance and employee retention and capability”. They give examples of Walmart addressing excess packaging of products and greenhouse gases “by reducing its packaging and rerouting its trucks to cut 100 million miles from its delivery routes in 2009, saving \$200 million even as it shipped more products. Innovation in disposing of plastic used in retail stores has saved millions in lowering disposal costs to landfills”.

Similarly to the discourse on the importance of innovation ecosystems (Adner 2006; Adner & Kapoor 2010) Porter and Kramer’s third point is *enabling local cluster development*. They highlight the key role of government regulations in encouraging companies to pursue shared value by focussing on measures for performance, phase-in periods and support for technologies that would promote innovation, improve the environment and increase competitiveness simultaneously (Porter & Kramer 2011).

The Commons theory

The Commons, whether natural (such as fisheries) or digital, fast becoming one of the most dynamic arenas of the global economy (such as Wikipedia) are improved through the self-organization of clearly defined communities. The Commons theory demonstrates that in certain instances, a hybrid, private-collective-innovation-ecology develops that complements and may even surpass triple bottom line market and state performance (Troxler 2010b; Von Hippel & Von Krogh 2003). Commons introduce a new player to the “cast” of twenty-first century economics (Raworth, 2017) in the figure of the *embedded economy*³¹ (see Figure 23).

³¹ This revision of our economy embeds it within society and within nature and invites new narratives – about the power of the market, the partnership of the state, the core role of the household and the creativity of the commons (Raworth, 2017, p. 28).

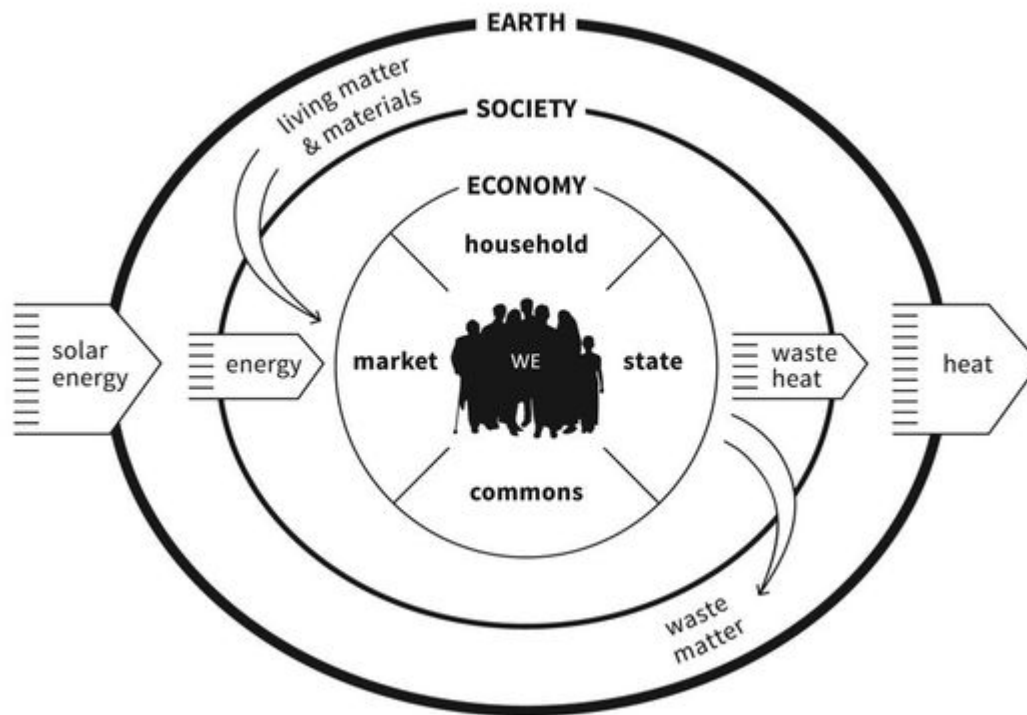


Figure 23: The embedded economy (Raworth, 2017)

Commons challenge the binary choice of market versus state when it comes to controlling technology, and offer an equally powerful alternative able to complement, compete with and even displace the market. The key as described by Ostrom (1990, p21) is that through dialogue, building trust and experimenting, essentially bonding and collaborating, individuals creatively extricate themselves from situations where they are trapped into following self-interested impulses that destroy their own resources.

This process has two implications for our research. On one hand, the process of setting common-agreed upon rules, is similar to the manifesto and associated codes, norms and practices that members of epistemic communities abide (Ostrom, 1990, p90; Cohendet *et al.*, 2014, p. 935). On the other hand this co-creation practice between multi-level actors enables individuals to break free of the restrictive and over-used central-regulations or private-property metaphors. This notion links back to Barrett's work on the three levels of evolutionary intelligence. "Individual members of a group structure that fail to put the needs of the group structure ahead of their own needs threaten the survival of the group structure and may potentially threaten their own survival and the potential survival of every entity that is part of

the group structure [...] when [they] focus on their own self-interest” rather than the good of the whole [the common good] – the viability of the group structure is compromised” (2018, p31).

The Commons are by no means a panacea, and Ostrom clearly pointed out that neither the commons nor the market, nor the state alone can provide an infallible blueprint. “Approaches to distributive land design”, she said, “must fit the people and the place, and may work best when they combine all three of these approaches to provisioning” (Ostrom *et al.*, 2007).

3.3.2. JUSTIFICATION FOR CHOOSING THE COMMONS THEORY

We have chosen the Commons Theory over others because it better fits our phenomenon and goes a step farther in acknowledging the profound shifts underway in our society.

The Commons theory is powerfully disruptive as it addresses novel configurations in value creation and capitalism through distributive design. The digital revolution has unleashed an era of collaborative knowledge creation and distributed capital ownership that could radically decentralise the ownership of wealth. Peer to peer networks and “anyone with an internet connection can entertain, inform, learn and teach worldwide. Every household, school or business rooftop can generate renewable energy and if enabled by blockchain currency can sell the surplus on a microgrid. With access to a 3D printer, anyone can download designs or create their own and print-to-order the very tool or object they need. Such lateral technologies are the essence of distributive design and they blur the divide between producers and consumers, allowing everyone to become a prosumer, both a maker and a user in the peer to peer economy” (Raworth, 2017, p.192).

The other disruption offered by Digital Commons is being regenerative by design. Through what has come to be called the ‘circular economy’, industrial manufacturing has begun the “metamorphosis from degenerative to regenerative design” (Raworth, 2017, p. 220). The idea of the circular economy is to use renewable energy to fuel production in a way that eradicates waste by design. Diverging from the take-make-and-waste mentality, waste equals food: biological and technical nutrients are never used up and thrown away, but circulated again and again through cycles of reuse and renewal (see Figure 24). For instance, businesses are diverting the coffee grounds or cooking oil from waste, to growing mushrooms, or making biodiesel. Used firehoses are recovered from landfills and are used to create sustainable and ethical luxury.

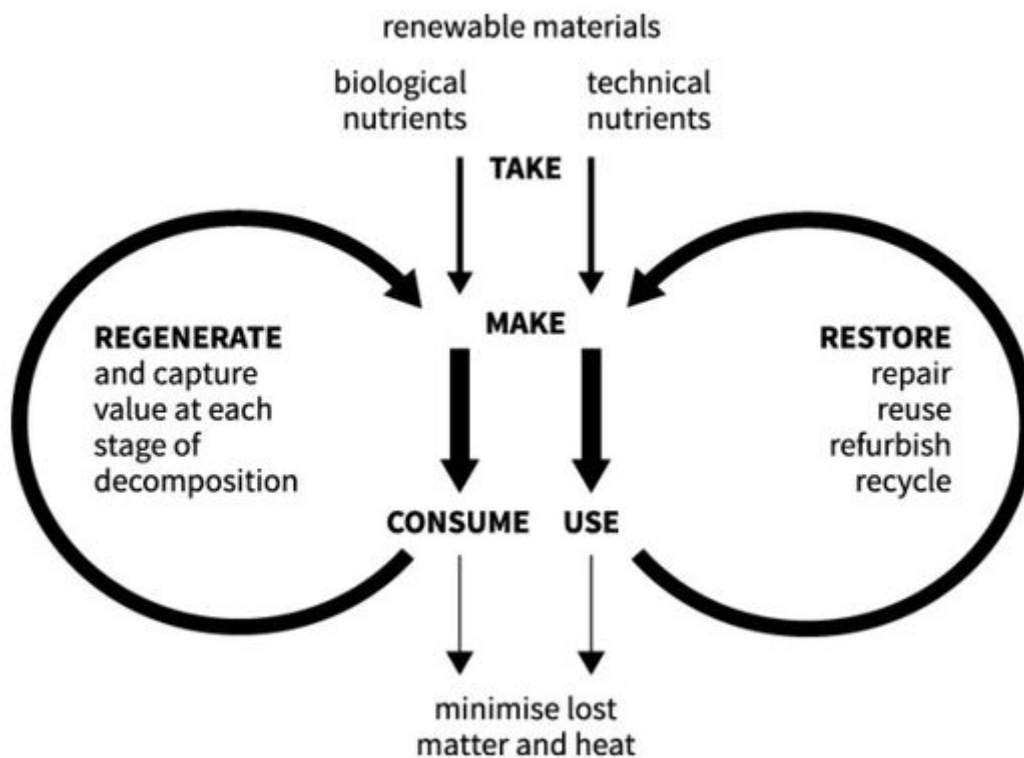


Figure 24: Circular economy: regenerative by design (Raworth, 2017)

This notion of regeneration approaches the concepts of reproduction and generation. Their meaning will be clarified as they add to the disruption potential of the Commons theory. Peter Troxler in his 2010 article uses the “reproductive” and “generative” dimensions. The reproductive dimension coincides with Raworth’s distributive concept: meaning it is easy to copy. Digital fabrication is becoming better and more accessible (easier to copy) to a wider public enabling whoever is interested to learn how to make their own tractor, brickpress, or shower that collects, cleans and reuses the water in real time while you are showering. The advantage is that, rather than just heading down to your local construction material shop and buying a standard product, you can learn how to build your own, which you can endlessly customize and upgrade. Blikstein (2014, p.2), in his article on the "democratization of invention" echoes this idea by saying, “what Logo, [the tool to make programming easier to learn] did for geometry and programming – bringing complex mathematics within the reach of schoolchildren – fabrication labs can do for design and engineering. Digital fabrication is Logo for atoms”. This replication technology is enabling creative sparks in the general public.

The generative notion is slightly different (like the re-signals) from Raworth's and Ellen MacArthur's Circular Economy idea. In essence, it's about creating new things. For Raworth, it's about continuously recycling biological and technical nutrients. For Troxler "it is more about enabling people to create new things, not only by giving them the tools, but also by teaching them how to use the tools, how to use materials, how to design, and how to create". The effect a Fab Lab has on its users, or the "Fab Lab Magic", is putting a twinkle in the eye of someone of any age, who gets an idea, "and all of a sudden, minutes or hours later, he's holding it in his hands. What happens between an idea in mind and holding it, is a big hook" (Troxler 2010a, p.11).

The above ties into Eglash's (2016) basins of attraction for generative justice concept that require "the bottom-up circulation of unalienated value... in a mangle". Among other scholars, Eglash believes that both capitalist and communist ideologies are extractive. They thrive on depleting, extracting and exploiting both human labor, and environmental resources. Labor, the original source of value creation, is made invisible "giving the illusion that money itself generates value" (p. 381). Both systems are therefore alienating. Commons-based generative justice takes the opposite stance. Eglash's definition is "the universal right to generate unalienated value and to directly participate in its benefits; the right of value generators to create their own conditions of production; and the right of communities of value generation to nurture self-sustaining paths for its circulation". The "mangle part" is that this is best achieved using pro-democratic processes, mindful of avoiding gender, race, age, or sexual biases. As described in the literature on the *middleground*, the quality of the innovation will depend on the heterogeneity of the *middleground*, *the mangle*, deliberately inviting and fostering diversity.

In sum the notion of "generation" is broader than that of "regeneration", as it addresses not only cycles of biological and technical nutrients, but how the skills, expertise and competences of human experience can be upcycled as well.

Such processes also need to be open-sourced, as "the full regenerative potential of circular production cannot be reached by individual companies seeking to make it happen within their own factory walls: an illogical and unfeasible basis for creating a circular economy". Sam Muirhead, one of the spokespersons for the open source, circular economy movement, explains that the open-source design principles of modularity (making products with parts that are easy to assemble, disassemble and rearrange), of open standards (designing components to a

common shape and size), of open source (full information on the composition of materials and how to use them), and of open data (documenting the location and availability of materials), are the strongest fit for circular economy needs (Raworth, 2017).

CHAPTER 3: KEY TAKEAWAYS

In this chapter, the choice of a qualitative exploratory approach to cross academic and practitioners' perspectives is discussed.

The PECP positioning appears as the most congruent stance for our object of study. Through trial and error, we will seek to explain, following an abductive reasoning mode, why and how OSH business models exist and work.

The means set to collect and analyse empirical data are justified. Cases studies and transversal analysis elaborate upon the Commons theory as initially developed by Elinor Ostrom (1990), and built upon by Benkler (2016; 2013); Fuster Morell (2014). This theory best fits our phenomenon as it addresses novel configurations in value creation and capture through distributive design, regeneration (the ability to be replicated at low cost) and generation (the ability to inspire and empower people).

The next chapter will present the process by which empirical data was gathered.

CHAPTER 4: MULTI- LEVEL ANALYSIS AND DATA COLLECTION

CHAPTER 4: MULTI-LEVEL ANALYSIS AND DATA COLLECTION

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CHAPTER 4 SUMMARY

Objective - Explains how we apply our chosen methodology to study OSHBM. First, we define OSH ecosystems, the multi-level unit of analysis for our study. Next, we explain how data was collected and analyzed for all three levels of analysis: the intra community level, the inter-organizational level studying firms' interactions with OSH communities, illustrated with cases in the textile and automotive sectors and the larger ecosystem/ territorial level using the specific case of Barcelona.

Methodology/approach - A qualitative exploratory approach was used to study this emerging phenomenon with case studies to elaborate on the Commons theory. We describe how we analyze our data using the works of Fjeldsted *et al.*, (2012) concerning the key elements of Open Source Design, the Open-O-Meter (Bonvoisin *et al.*, 2017), the Sharing Star (Fuster & Espelt 2018), Saebi & Foss's (2015) continuum of open business models, and the dimensions used by Troxler (2010) to analyze Fab Lab business models.

Limits - Qualitative research is best carried out over long periods of time in order to draw upon recurring, or evolving patterns. In the scope of this three-year research project, and given that we chose to view it through multilayer analysis, the analyses were conducted over intervals of a couple months for each layer.

Managerial implications - This section is rich in practical implications as we address the different types of revenue streams OSH projects can leverage, how firms interested in OSH can interact with innovation communities, and finally what cements their participation in OSH and can make them grow in their ecosystems.

Theoretical implications - We are seeking to understand and to model the potential of commons-based business models being a successful, redistributive and regenerative alternative to the linear, extractive models that have underpinned the last industrial revolutions.

Originality/value – This chapter displays our approach of making our qualitative research using thematic analysis as sound as possible.

OSH is a phenomenon that transcends firm boundaries and sends ripple effects spreading like a trend or a virus. Reasoning by using the abductive mode (Mantere & Ketokivi 2013), iterating between previously established knowledge on OSH community joining processes (Aksulu & Wade 2010; Ehls & Herstatt, 2015), our OPEN! project members realized that studying the phenomena by focussing mainly on OSH communities was too narrow.

Understanding the different levels came gradually. The OPEN! Project began with a review of 23 “pure OSH players”, conducted by members of the CERAG & GSCOP labs in France and TU Berlin. Projects. These projects were identified through the Open Source Hardware Observatory³², fulfilling the selection criteria of complex, tangible, goods, labelled “open source” by their surrounding communities. However these OSH projects were deemed “not sufficiently mature to study business models” by other team members.

The next level of research chosen for analysis focussed on the interaction between OSH communities and firms. For this, we chose to study how established sectors, such as the automobile industry and the sport textile sector were responding to these novel product development processes and progressively interacting with internal and external innovation communities.

A visit to Barcelona for a PhD seminar given by Henry Chesbrough at the ESADE Business School, was the opportunity for face-to face meetings with some of the “pure open-source-players” originally interviewed. During these meetings with Mauricio Cordova, the founder of the Fair Cap and Waterzilla projects, architect Jonathan Minchin, the coordinator of the Green Fab Lab and partner of the Open-Source-Behive project, and Guillaume Texier, co-founder of Aquapioneers, – it became clear that along with the drive and efforts of the founders, these projects were receiving extensive support from city-wide institutions. We then decided to expand our analysis to studying the interactions among different stakeholders invested in making OSH projects grow.

The levels of analysis we were able to identify are thus:

³² <https://opensource.design.cc/observatory/>. The product was tangible and discretely manufactured. Food, process industry and software products were excluded. A large panel of technologies was considered from mechanical through electronic hardware to textile. /The product was of minimal complexity containing at least several parts. Products such as business card holders or cell phone cases made of a single, 3D-printed part did not fulfil this criterion, the objective being to focus on a higher part of the complexity range./ The product was labelled “open source” by its community, which satisfies, or aims to satisfy, the transparency criteria, i.e. publicly available blueprints and/or CAD files.

1. The community level of “OSH pure players” corresponds to “community-based business models”, where a focal firm emerges from a collaborative community (Wolf & Troxler 2016).
2. The inter-organizational level on how firms interact with OSH communities, uses specific cases in the textile sport (Raidlight) and automotive industries (with the four cases of Renault, Volkswagen, Local Motors and Kreatize). This level corresponds to “community-oriented business models”, where firms are exploring ways to work with, or to build innovation communities that will generate new products and revenues (Wolf & Troxler 2016).
3. The ecosystem-level is the macro-unit of our analysis as it includes all the other levels. We use the *middleground* concept to study stakeholder interactions within the ecosystem fostering OSH project growth.

In sum, these fields of study progressively became the different units of analysis through which it was possible to treat the phenomenon of open source hardware: the community level, the organization level, and the least studied, the industrial, regional and societal level of analysis (Bogers *et al.*, 2016), which we call the ecosystems level. The idea is to understand how open source hardware enables value creation and sharing through and across these different levels. The goal of our research is therefore an understanding of what a framework might be for OSH business models by focussing on a multi-scalar levels of analysis. This is important because, as Bunnell & Coe (2001) explain, there is a need to study innovation giving “credence to relationships operating between and across different scales”.

For each level we will collate the context justification, the research questions, data collection and analysis of the research we have conducted.

4.1. OPEN SOURCE HARDWARE ECOSYSTEMS

In response to Foss & Saebi's (2018) recommendation to select a unit of analysis to study business models, we chose OSH ecosystems as our multi-level unit of analysis. In this section we will define more precisely what we understand as OSH ecosystems.

In OSH ecosystems, individuals and communities are informal entities congregating voluntarily and collaboratively to develop products and whose culture lies outside standard corporate logic. They represent a bottom-up engagement helping to co-solve common issues.

We worked on a number of different models to illustrate the spread or reach of OSH (Røvik 2011) as we understood OSH ecosystems. As models go, the challenge lies in simplifying a

complex phenomenon, for cross-disciplinary understanding. Figure 25 is by no means perfect, but it attempts to present the OSH phenomenon as a drop, which will progressively interact with wider concentric circles of stakeholders in a broader innovation ecosystem. The drop first sends ripples through the hybrid, epistemic-practice OSH innovation communities described in Chapter 1, then with firms, and progressively through a larger set of stakeholders within a broader innovation ecosystem.

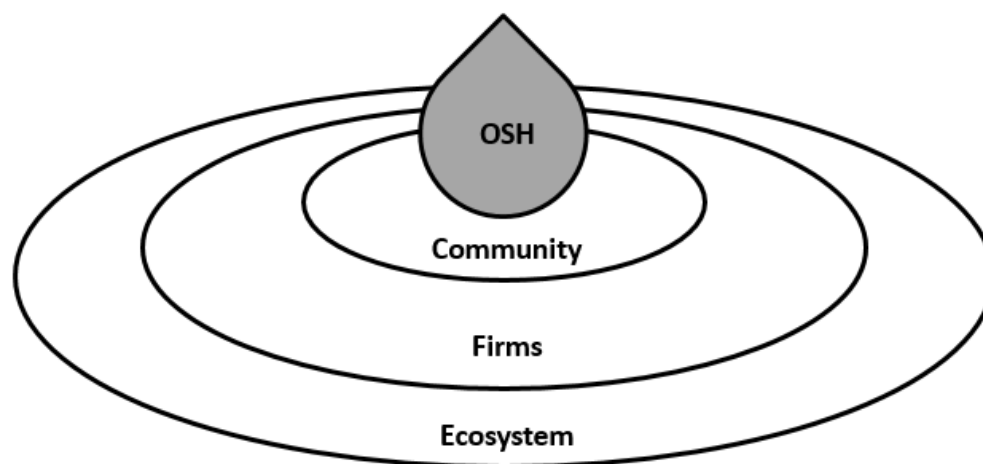


Figure 25: The Open Source Hardware Ecosystem (authors per Aksulu & Wade, 2010)

OSH ecosystems are initially launched by a core group of creative individuals who successfully manage to motivate others to contribute to a given innovation. As their scope progressively spreads, they form communities which will reach out to actors in wider ecosystems for funds and assistance to help them grow (Figure 25).

While the community is the focal point of the open source movement, key knowledge sharing happens on the individual level. A macro view, is nonetheless required to appreciate OSH ecosystems and the impact of their phenomena (Mies *et al.*, 2019). An individual contributes to a project by completing project-related technical, creative, organisational, or administrative tasks. Contributors engage as replicators, developers, or community managers, among other roles (Bonvoisin, Thomas, *et al.*, 2017). The heterogeneous actors in OSH communities proactively self-organize and fluidly choose their own roles as well as their time periods of involvement. Participation levels vary in terms of quantity and content (Bonvoisin, Mies, *et*

al., 2017b). They contribute as individuals and are not connected through organisational affiliation (Aksulu & Wade 2010) but rather through epistemic motivations (Sarazin, *et al.*, 2017). By collaboratively developing OSH products, OSH communities “communitize” technology from private institutions to the public (Bonvoisin, Mies, *et al.*, 2017).

On the ecosystem level, collaboration is described as interactions between the community and various other actors, e.g. from the domains of science (Pearce 2017), medicine (Niezen *et al.*, 2016), education (Mondada *et al.*, 2017), music (Ilan 2011), and business (Li, *et al.*, 2017; Moritz, Redlich, & Wulfsberg, 2018), for example. Furthermore, many open source communities operate as non-profit foundations (Ritvo *et al.*, 2017). OSH government related policy implications are another subject relevant to the framework. Finally, OSH communities are often interconnected, for example, through contributors involved in multiple communities or complementary designs. The ecosystem perspective includes these practises as well. In OSH ecosystems collaborative spaces, including incubators, co-working spaces and chambers of commerce, hold a pivotal role (Capdevila 2017). They serve as think tanks able to funnel projects originating from the different entities to the Fab Labs for prototyping, and to match start-ups with firms and appropriate competencies. Figure 26 maps out the main identified stakeholders in OSH ecosystems, using Fab Labs as a supporting infrastructure.

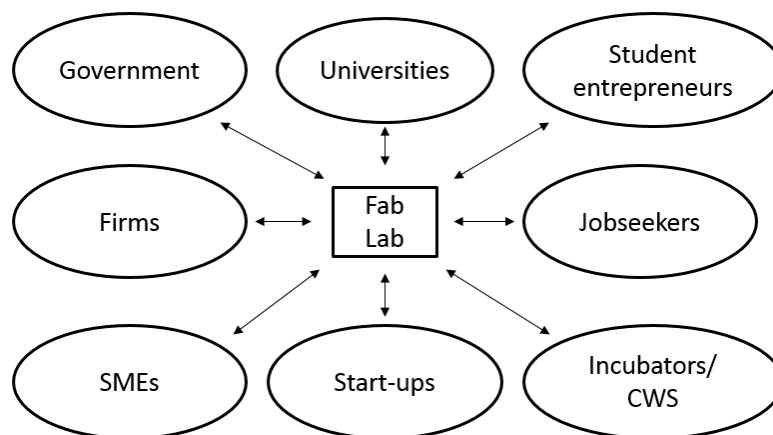


Figure 26: Stakeholder interactions in a Fab Lab innovation ecosystem (adapted from Donaldson and Preston, 1995)

From a geographic perspective, OSH ecosystems can be observed in cities. The city offers a multiscale level of analysis that allows observing localized innovation processes from both global and local perspectives (Capdevila 2017). Locally, stakeholder interactions on a city

(macro) level create a situated ecosystem implicating people and firms (Storper & Venables 2003). This level of analysis, however, has been less studied in OSH literature (Bogers *et al.*, 2016).

4.2. COMMUNITY-LEVEL

In Chapter 1 we defined OSH communities as hybrid communities. Epistemic by nature, they can be defined as “groups of knowledge-driven agents linked together by a common goal, a common cognitive framework and a shared understanding of their work” (Cohendet *et al.*, 2014). Moreover, they are composed of diverse communities of practice (CoPs), as each Makerspace, or Fab Lab may share knowledge on a given trade (Capdevila, 2017). Together, these heterogeneous actors seek to create new codes, norms, rules or habits in operating a paradigm shift: the core intent of the Fab Cities.

4.2.1. OSPD COMMUNITY-BASED PROJECT CONTEXT DESCRIPTION

Given the rare empirical studies on open source product development (OSPD),³³ the initial study sought to deliver a qualitative description of these projects, using the dimensions defined by Fjeldsted *et al.*, (2012): *the platform, the drive, the community, the development process and the business model*.

The goal of the multidisciplinary, OPEN! Project Team collaborating on this phase of the research, was to cross engineering and managerial perspectives. OSPD is defined as the development of open source hardware products in a collaborative process permitting the participation of any person interested. OSPD is a form of open source innovation described by Raasch *et al.*, (2009) as: “free revealing of information on a new design with the intention of collaborative development of a single design or a limited number of related designs for market or non-market exploitation.”

The idea was to gather understanding on the implication of openness for the product development process and subsequent business models of such projects. Building on Balka *et al.*, (2009)’s work, Bonvoisin and Boujut (2015) analysed documentation published on seventy-six, open source, mechanical hardware products, spanning categories from agricultural machinery, machine-tools and transport, to renewable energy technologies and medical

³³ The OPEN! Project differentiates between open source product development (OSPD) where the process of product development is open to contributions, and OSH, where only the final product’s plans are disclosed. For this first stage of research, on the community-level, our focus was specifically on OSPD. For the subsequent stages, we revert to the more commonly used term of open source hardware (OSH).

equipment. This research was the basis for the development of the Open Source Hardware Observatory.

The Research questions for this study were:

- *Q1 – What basic elements characterise OSPD business models?*
- *Q2 - How is the organization of a product development community structured?*
- *Q3 - How is the product development process organized?*
- *Q4 – What are the requirements for appropriate online support platforms?*

4.2.2. DATA COLLECTION

The study ran from May through December 2016. From the initial 76 projects identified by the Observatory, we identified a list of 88 projects through internet search engines, by screening social networks, attending targeted conferences, visiting local Makerspaces and by attending Maker Fairs (Lyon, Nantes 2016). Of these projects, 24 became the subjects of our interviews. The interviews were held via videoconferencing (using skype), and whenever possible with face to face meetings (Qrokee, Arbalet, Ozon Cyclery, OSE Germany) (See Table 3).

Criteria used for selecting the OSPD projects were:

- The product was tangible and discretely manufactured. Food, process industry and software products were excluded. A large panel of technologies was considered from mechanical through electronic hardware to textile.
- The product was of minimal complexity containing at least several parts. Products such as business card holders or cell phone cases made of a single, 3D-printed part did not fulfil this criterion, the objective being to focus on a higher complexity range.
- The product was labelled “open source” by its community, which satisfies, or aims to satisfy, the transparency criteria, i.e. publicly available blueprints and/or CAD files.

Altogether 30 project initiators from the 23 OSPD projects were interviewed (see Table 3): for some projects; more than one person participated. Of those interviewed, 33 was the average age, 23 was the minimum and 64, the maximum; 86% were male, 14% were female. The project initiators interviewed were based in France, Germany, England, the United States, Finland,

Spain, and Estonia. Interview time totalled 28 hours; 20 additional hours were spent in Maker Fairs and gathering data from makerspaces.

# of Projects	1	2	3	4	5	6	7	8	9							
Name of OSPD projects	La Cool Co	Apertus Axiom	Arbalet	EchOpen	E-nable	FairCap	FarmHack	Hovalin	InMoov							
Project founders	2		1	1	1	1	1	2	1							
Contributors		1														
Total interview time in minutes	73	74	73	100	42	60	104	60	20							
Additional primary data: Maker Fairs & Makerspaces	Maker Fair Lyon 360	Maker Fair Nantes 720	Laboratoire Ouvert Grenoblois (LOG) 120													
# of Projects	10	11	12	13	14	15	16	17	18	19	20	21	22	23		
Name of OSPD projects	Knitic	L'Atelier s'adapte	Open Source Ecology	Open Source Beehives	OSE Germany	Ozon Cyclery	Qrokee	Raidlight	Sunzilla	TinkerBike	Waterzilla	Ultrascope	Ludd 21	Acquapioneers		
Project founders	2	2	1	1	1	1	2		1	1	1		1	1		
Contributors								2				1				
Total interview time in minutes	64	61	60	73	130	75	86	101	69	33	94	90	57	50	TOTAL TIME in hours	28,3
Additional primary data: Maker Fairs & Makerspaces															TOTAL TIME in hours	20

Table 3: Details of primary data collection for the community-level analysis

Five interviewers participated in the interviewing campaign: three based in France and two in Germany. The research questions above were addressed through semi-directive interviews with OSPD project initiators or contributors. As mentioned in Chapter 3, interviews were semi-structured, declining the five topics through an interview guide that allowed for both flexibility, and structure (Gavard-Perret *et al.*, 2012, p.113). Interviewers were free to concentrate on one subject then spontaneously ask additional questions in order to grasp new ideas, as long as all interview themes were treated. This allowed respondents to address each topic fluidly according to their own logic and to let unforeseen topics emerge. The interviews were conducted by two people in order to increase the potential of live analysis, and recorded so as to maximize the potential of post analyses. The interviews were conducted in English, French and German. After each interview, both interviewers collaborated in writing the summary of findings in English and identifying the most salient issues. The interviews were then entirely transcribed, and translated into English.

4.2.3. DATA ANALYSIS

The projects were analysed according to the dimensions established by (Fjeldsted *et al.*, 2012) as first-cycle codes (Miles, Huberman and Saldaña, 2013) (see Figure 27). Later, they were analysed using the same criteria that (Troxler 2010) used to analyse the business models of existing Fab Labs: value proposition, revenue model, processes, resources, marketing and innovation partnerships. Transcriptions were classified according to these by two coders. The aim was to agree on this transcription classification, from which a common database was obtained.

The unit of analysis which refers to the basic unit of text to be classified during content analysis was defined. Qualitative content analysis usually uses individual themes as the unit for analysis, rather than the physical linguistic units (e.g., word, sentence, or paragraph) most often used in quantitative content analysis (Zhang & Wildemuth 2009). Then, the coding was refined for each macro theme.

The analysis progressed through additional subcategories of coding in light of emerging themes, either based on the researcher's understanding or on the data itself. Each macro theme was coded by one coder [see Appendix for the codebook procedure].

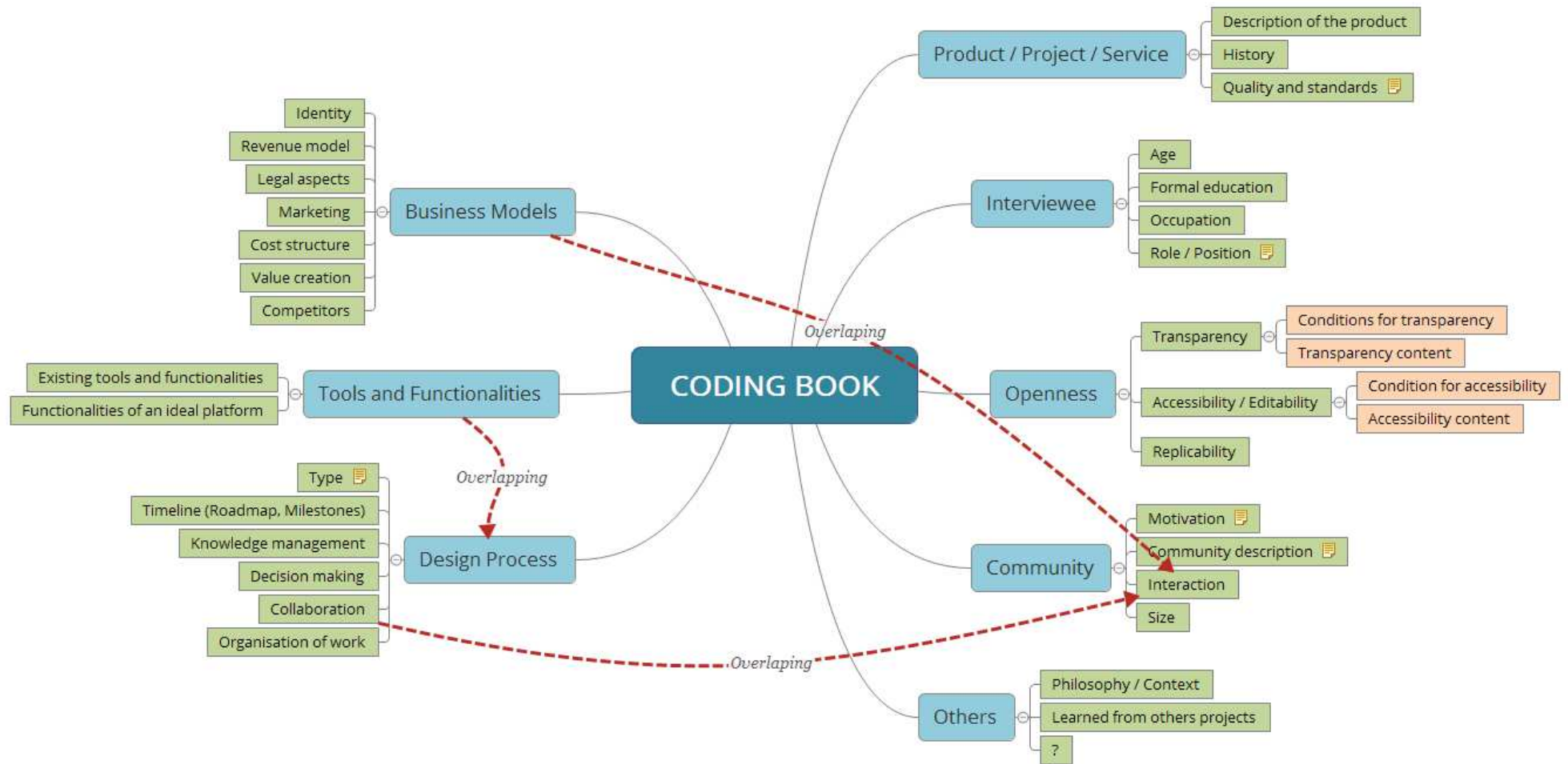


Figure 27: Community level thematic coding

4.2.4. CALCULATING INTERCODER RELIABILITY

Next, we used the intercoder reliability as the indicator of measurement consistency between two coders for the macro and micro themes, according to the Cohen's Kappa method.

Cohen's kappa measures the agreement between two raters who each classify N items into C mutually exclusive categories.

First step

The two coders have coded the same interview (e.g. Knitic). The Table 4 contains a sample of the coding defined by each coder.

	Laetitia	Celine	Agreement / Matching
Extract 1	Interviewee	Business Model	0
Extract 2	Business Model	Business Model	1
Extract 3	Product	Product	1
Extract 4	Others	Others	1
Extract 5	Product	Product	1
Extract 6	Product	Product	1
Extract 7	Product	Product	1
Extract 8	Business Model	Business Model	1
Extract 9	Community	Community	1
Extract 10	Product	Product	1
Extract 11	Community	Community	1
Extract 12	Product	Product	1
Extract 13	Community	Community	1
Extract 14	Business Model	Business Model	1

Table 4: Coding sample

For example, "Extract1" has been coded "Interviewee" by Laetitia and "Business model" by Céline. As a result, we find "0" in the last column meaning that there is no agreement between the coders. For other extracts of this sample, we obtain an agreement between coders e.g. the extract 2 was coded "Business Model" by both coders.

At this stage, we are able to calculate the agreement percentage. 68 extracts were coded. 51 extracts out of 68 were in agreement ("1") meaning that the percentage agreement is **75%** ($51/68*100$).

Second step

The data are arranged in a contingency table in order to be able to calculate the Cohen's Kappa.

To create this table and facilitate completion, the extracts were sorted according to their macro themes (example Table 5).

	Laetitia	Celine	Agreement / Matching
Extract 9	Community	Community	1
Extract 11	Community	Community	1
Extract 13	Community	Community	1
Extract 26	Community	Business Model	0
Extract 40	Community	Community	1
Extract 42	Community	Community	1
Extract 43	Community	Community	1
Extract 62	Community	Community	1
Extract 64	Community	Business Model	0
Sum			7
Count			9

Table 5: Coding sample community

Then the contingency table can be easily completed, (see Tableau 6 below).

		Laetitia								
		Business Model	Community	Design Process	Interviewee	Openness	Other	Product	Tools	Sum
Céline	Business Model	14	2		1		1	1		19
	Community	2	7			1				10
	Design Process			5	1					6
	Interviewee				3	1				4
	Openness					6				6
	Other	1					7			8
	Product	3		1				7		11
	Tools					2			2	4
Sum		20	9	6	5	10	8	8	2	68

Tableau 6: Contingency table

The diagonal in green represents the agreement between coders (i.e. both coded a given extract the same way). Others cells represent a disagreement between coders. For instance, three times, Laetitia coded an extract as “Business model” while Céline coded the same extract “Product”.

Third step

As a reminder, the formula is:

$$\kappa = \frac{p_o - p_e}{1 - p_e} = 1 - \frac{1 - p_o}{1 - p_e},$$

where $p_o = 0.75$

and $p_e = 0.1613$

then $\kappa = 0.70$

According to the interpretation given by Landis & Koch (1977), the intercoder reliability for the macro coding is “Substantial”.

Once the macro coding had been validated, the same procedure was applied to the micro coding. For instance, if we consider the macro theme “Openness”, we have micro-coded all the extracts of one given interview by using sub-categories specific to “Openness”.

For each macro code, both coders coded specific extracts corresponding to the macro theme.

The results are reported in Table 7.

	Percent agreement	Cohen’s Kappa	Interpretation
OPENNESS	1	1	Perfect
INTERVIEWEE	1	1	Perfect
PRODUCT	1	1	Perfect
COMMUNITY	0.75	0.6464	Substantial
DESIGN PROCESS	1	1	Perfect
TOOLS	0.79	0.5116	Moderate
BUSINESS MODELS	0.59	0.4826	Moderate
OTHER	1	1	Perfect

Table 7: Results synthesis for microcoding

Most the results were satisfying. Two macro themes “Tools” and “Business models” had to be redone since the kappa is not high enough: The two coders went back to the coding book to clarify the definitions given each code. Then, new extracts were coded.

Results are presented in the Table 8

	Percent agreement	Cohen’s Kappa	Interpretation
TOOLS	1	1	Perfect
BUSINESS MODELS	0.72	0.6489	Substantial

Table 8: Results synthesis for microcoding - Second test

Next; using the transversal horizontal analyses approach described earlier, the interviews were deconstructed to reveal emerging patterns (Gavard-Perret *et al.*, 2012, p.291). The “Landscape of Current practices” paper (Bonvoisin *et al.*, 2016) prioritises the most salient themes per dimension and offers a view of the current practices and challenge for each dimension.

Later, the four members of the OPEN! team who had conducted the interviews, attempted to rank the projects according to dimensions that appeared of particular importance. Table 9 displays the mean rankings average of the four different coders. The columns highlighted in yellow in Table 9 were particularly relevant to the understanding of OSPD business models.

		Level of quality assurance	Number of replications	Complexity of the design	Pursued level collaborative development	Decentralisation of contributions	Size of development community	Size of overall community	Intended mode of production	Mission/vision /values	OSPD project life cycle stage	Legal Status
1	Apertus Axiom	2	3,0	4,5	4,0	2,8	2,0	2,3	3	4,0	2,5	3,0
2	echOpen	2	1,5	4,3	5,0	3,8	2,3	2,5	3	5,0	2,0	4,0
3	Farm Hack	3	2,5	2,3	4,5	3,5	3,0	3,0	1	5,0	2,8	4,0
4	Hovalin	3	3,5	2,3	3,0	1,0	1,0	1,8	1	2,3	1,5	5,0
5	Knitic	4	3,0	3,5	3,0	1,0	1,0	2,3	1	3,3	1,8	5,0
6	OSE	3	3,0	3,5	4,3	3,0	2,8	3,0	2	5,0	3,0	4,0
7	Ozon cyclery	4	1,0	2,8	2,8	1,5	1,3	2,5	2	4,3	1,5	3,0
8	SunZilla	2	1,0	3,3	4,0	1,5	1,0	1,8	3	4,8	1,5	4,0
9	Ultrascope	3	2,5	3,8	3,5	1,5	1,0	3,0	1	4,0	1,5	3,0
10	Arbalet	2	3,0	2,3	3,8	1,0	1,3	1,8	3	1,0	1,0	5,0
11	Fair cap	5	1,5	1,3	3,5	1,0	1,0	2,3	3	5,0	1,5	2,0
12	InMoov	4	4,0	4,5	1,8	1,0	1,0	3,0	1	3,0	1,8	4,0
13	L'atelier s'adapte	2	1,3	1,8	4,0	1,0	1,3	2,3	4	5,0	1,0	4,0
14	La Cool Co	5	1,8	2,8	3,3	1,5	1,5	2,5	2	3,5	2,3	1,0
15	Open Source Beeh	4	3,5	2,0	4,3	2,3	2,3	3,0	2	5,0	3,3	1,0
16	Qrokee	5	1,3	1,5	1,5	1,0	1,0	2,8	2	1,5	1,5	1,0
17	Waterzilla	2	1,3	3,5	4,5	1,0	1,0	2,3	4	4,8	1,0	2,0
18	Tinker Bike	2	1,0	3,8	1,8	1,0	1,0	1,5	3	3,8	1,5	1,0
19	Ludd21	1	0,5	4,5	4,0	1,0	1,0	1,0	3	4,0	1,0	2,0
20	E-Nable (France)	3	4,0	2,8	4,0	3,3	2,8	3,0	1	5,0	2,5	4,0

Table 9: Project rating based on average mean between 4 coders- community level

To verify reliability of the ranking, a Fleiss Kappa method was used as there were four different coders. This statistical measure calculates the degree of agreement in nominal classification over that which would be expected by random chance, among a fixed number of raters.

Here, the inter-coder reliability was moderate and fair (see Table 10). This is because half of the rankers had only conducted and helped with transcribing of the interviews they had performed. Whereas, the other two rankers, had conducted their interviews, transcribed all 24 of them, translated from French to English those conducted in French, and coded all 24 interviews. Even the percent agreement measured before the Fleiss Kappa, indicated disparity between the French and German teams, and a relative similarity within each team. We can therefore conclude, that even given all the steps to share the data, the understanding of each project was subjective.

<i>Decentralisation of contributions</i>	<i>Intended mode of production</i>	<i>Drive</i>
The share of workload between core-team and volunteers	The type of production environment for the manufacturing of the final product	The overall orientation of the mission/vision statement or description as defined and pursued by the project founders or community
1 - everything done by core-team 2 - some tasks are made by people of the outside they have chosen 3 - design is done by the community (volunteers) but mgt. By core team 4 - design and mgmt activities is done by the community	1 - pure peer-production, i.e. DIY (at least 50 % of value added) 2 - hybrid (i.e. use standardized components and DIY components, commercial workshop production) 3 - clear aim for industrial manufacturing 4 - undefined	1 - purely for fun (geeky, hobby) ... 5 - real life problem-solving (strong driver to serve existing needs and disseminate the project to a broad audience reach this goal; from the initiators point of view)
<i>Fleiss's kappa</i>	0,46	0,30
		0,37

Table 10: Fleiss Kappa inter-coder reliability

4.3. FIRM AND COMMUNITY INTERACTION LEVEL OF ANALYSIS

The selection criteria for the 24 interviewed projects did not include the criteria of well-established projects: attracting a reasonable number of contributors and demonstrating some development progress across time. Neither, in retrospect, was included the criteria of belonging to a Fab Lab network, which “is structurally more developed and better documented than other communities” (Troxler 2010, p.6). As a result, many projects were early-stage projects with as yet unclear organizing structures.

Therefore, the HIIG and CERAG partners decided to shift analyses levels and gather data on how established sectors are seeking to leverage OSHW innovation through dynamic opening and closing strategies (Appleyard & Chesbrough 2017), possibly through co-constructed *middlegrounds* (Sarazin *et al.*, 2017) as research suggests happens in innovative and creative industries.

The following sections will present the justification for the two sectors chosen:

- the textile sport sector with the trail running company Raidlight. case study.
- the automobile sector with a cross-case analysis of two incumbent, original equipment manufacturers (OEM), Renault and Volkswagen and two newcomers, Kreatize and Local Motors.

We will discuss the details of the data collection, and the conceptual frameworks which were used to construct the semi-directed interviews and as a basis for the thematic analysis.

4.3.1. CONTEXT AND JUSTIFICATION FOR THE RAIDLIGHT CASE STUDY

Interviews with Raidlight personnel had been included among those of the first phase: community-level, study. However, since the OSH was already associated with an established company, we chose to fold these interviews as well as subsequent workshops into the second-level study “firm-community interactions”.

In March 2016, the Saint Pierre de Chartreuse based trail running company Raidlight, joined the Open! research project. Raidlight from the creation of the brand and because its founder, Benoit Laval, is a trail-running athlete himself, has always enjoyed an active community of practice. The objective of joining the project was to see if/how Raidlight could possibly co-develop specific items in their product range with the help of their 9000 community members.

In the field of trail running, a community of practice includes a multiplicity of individual experiences that interact on discussion forums around the broad topics of training and health in order to enhance their own athletic performances (Rochat *et al.*, 2017, p. 2). Each month the R&D team and the executive committee select themes that the community manager shares on the company's forum, such as "how do you feel about the straps of this backpack? What could be improved to make your practice more efficient? What problems have you encountered?" The community members react providing their own personal experience. The role of the community manager is to prioritize the most salient themes for feedback to the R&D team.

This first level of forum discussion analyses enables characterizing the significant issues emerging from the trail runners' experience of equipment use. Examination of these contents could be of interest for the R&D engineers who may identify relevant areas of product development. Notably, this inductive approach has already been used to elaborate a field test protocol for carrying and hydration systems in trail running.

This approach can be blanketed as crowdsourcing: outsourcing a task to a "crowd" in the form of an open call (Afuah & Tucci 2012) and arguably, it was in its early stages. But the founder of Raidlight managed to combine a number of factors making this phenomenon much more interesting and a testing ground for potential, strategic advantage. First, he actively sought out collaborations with academics in a number of universities (University of Rouen, University of Lausanne) to work on issues, such as how runners collectively look for solutions that help them adapt to issues emerging during actual practice. Second, in the extremely competitive sector of global sports apparel, Benoit Laval, in collaboration with the Sporaltec cluster and ANT-Tex, a lab for new textile technologies, assumed the unlikely wager of moving part of his production back into the brand's headquarters in Saint-Pierre-de-Chartreuse. A year later, the "made in France" line was a definite success. The number-one rule of the line being: streamline assembly time to be able to keep producing in France, using cutting edge technology and materials.

This new partnership with the members of the Open! Research team, including conception, optimization, production and innovation management labs (GSCOP, CERAG, Berlin TU), grated on his nerves with its scientific jargon. After a three-day workshop in May 2017, Benoit Laval decided to go a step farther than what the Open! Project members asked of him. Rendering the plans of his token backpack line accessible online was not enough (Figure 28);

he decided to leverage the strengths he created around his brand: his trail running stations, his own site factory, and his community. The building plans would be rendered public on the Github platform, but he'd invite the best contributors to come on-site for an immersion day to prototype their innovations with the help of his athletic trainers, designers and factory technicians. In the morning, guests would come, test out the Raidlight equipment and have a run with Raidlight's athletic trainers, and in the afternoon, they'd get to work with stylists and textile technicians to create their prototypes. Innovations, would then be shared online, which would result in benefits greater than just a single product. Here, a planned and integrated product bridged the gap between the ideas from the community and the engineers capable of implementing them.

By extending its offer beyond its successful forum, by focusing on improving runner performance, Raidlight would also become a lab for prototyping and customization.

Re-conception de la gamme "Responsiv"

Bienvenue sur l'espace collaboratif dédié à la re-conception des produits de la gamme "Responsiv - Made in France"!



Figure 28: Raidlight Responsiv trail running vests

4.3.2. DATA COLLECTION

The partnership between Raidlight and the Open! Project implies that the company be present during bi-annual, plenary meetings in order to be in phase with the aims of the research project. Additionally, two, in-depth semi-directed interviews were conducted with the community manager and the R&D manager. In May 2017, a morning-long focus-group was held with the Raidlight Founder, his community manager and 3 members of the Open! Project team, including two academics with senior knowledge on OSH. In this instance, the goal was to study the fit between the OSH value proposition and Raidlight's customer profiles. After an

initial brainstorming with all focus-group members, the community manager, with her 3 years of experience managing the company’s forum, collected and ranked the items.

More data was gathered through a report written by other OPEN! team members responsible for helping to manage the Raidlight / Github portal throughout the process, (September 2017 through 2018). Both of Raidlight’s employees interviewed were female; demographic information such as age was not requested. Table 11 displays the details of data collection for the Raidlight case study.

Name of OSPD projects	Raidlight
R&D manager	1
Community manager	1
Total interview time in minutes	101
Additional primary data	6 3 day Plenary Meetings with OPEN! team members and Raidlight Founder and managers 1 Focus-group session with founder, community manager and OPEN! team members
Secondary data	Report from OPEN! team members on OSH project advancement

Table 11: Details of data collection for the Raidlight case study

4.3.3. CONTEXT AND JUSTIFICATION FOR THE AUTOMOBILE INDUSTRY

The automobile industry is currently facing major challenges. France has declared that by 2040 there are to be no combustion engines on its roads (Ewing, 2017). The so-called “Dieselgate” affair in Germany in 2016/17 could result in prohibiting diesel vehicles in German cities (Tilman, 2017; Der Tagesspiegel, 2017). The evolving Chinese market El Dorado will undergo fierce competition (Zhang, 2016), with the looming ban on gasoline and diesel-powered cars sales (Bradsher, 2017). Autonomous buses are being used in public infrastructures where Berlin and Copenhagen are testing the Olli bus to supplement their transportation offer. Finally, Tesla’s success shows that the industry is permeable to new entrants. Thus the

automobile industry is open to hardware innovation and to open business models able to alleviate its current shortcomings.

With more than 800,000 employees (D Statis, 2017a) and over 31 billion euros in revenue as of July 2017, the German automobile industry is one of the most important contributors to the German GDP with a gross value of 4.5% (D Statis, 2017b). Given such numbers and the preeminent increase of car sales, it cannot be denied that the industry is still growing. However, trends such as platform and sharing economy, Smartphone dissemination and permanent Internet access, as well as changing mobility needs for an aging and growing urbanized society, all pose new challenges for established industry.

In 2015, 46% of the German society had already used shared economy products and services, mostly media and entertainment, consumer goods, and mobility. This number is higher: 82%, with the population under 30 (PwC, 2015a; PwC, 2015b). Motivated by increased mobility comfort, a fraction of the cost of owning a car, safe access both to natural resources and public space, 12.4% of Germans under 30 have already used car sharing and 13.2% have used platform based transportation services (BDA & VDA, 2017). By providing a cost-efficient, environmentally friendly and safe alternative in a demographically changing society, e-mobility and autonomous driving challenge the existing infrastructure. By provoking traditional service providers, they pave the way for new business models. Challenges arise from opening up software as well as hardware. In this sense, especially open source hardware innovation along supply chains, gains importance in unblocking closed systems and accelerating innovation.

As the theoretical background has indicated, research at the interface of business models and open source hardware is in its infancy. So far, the conceptual model delivered by (Saebi *et al.*, 2017) for open business model design offers a useful framework for exploratory research. Since qualitative evidence to support their model has not yet been presented, and following the tradition of open hardware scholars (Svahn *et al.*, 2017; Wolf & Troxler 2016), we have opted for a case study method.

Our research question for this study is:

- *Q1: How do firms design business models around open source hardware?*

4.3.4. DATA COLLECTION FOR AUTOMOBILE INDUSTRY

Our objective was to compare the innovation processes of firms in the automobile industry at different stages of maturity. Based on the Open-Closed strategy continuum (Appleyard & Chesbrough 2017), our case selection was oriented to provide an example of each situation from closed-closed strategy to open-open strategy. The following figure illustrates the four cases chosen (see Table 12).

<i>Ex Post</i>	Open	Renault - POM Twizy	Local Motors -Olli
	Closed	VW-IP	Kreatize- Platform
		Closed	Open
		<i>Ex Ante</i>	

Table 12: Case selection adapted from the dynamics behind the Open-Closed Strategy continuum

In order to better observe how established players open their business models and which approaches they take toward open source hardware innovation, the firms in this study include the established players Renault-Group (Renault) and Volkswagen Group (VW), as well as the startups Kreatize and Local Motors.

The study ran from March to November 2017. We interviewed innovation managers who were involved in beginning open innovation initiatives, project managers responsible for managing communities of open hardware development, and the founder of Kreatize (see Table 13 below).

	VW	Renault	Local Motors	Kreatize	
Innovation managers	4	2			
Project managers	1	2	3		
Founder				1	
Detail of secondary data	Forums (OICA, 2016) Annual Report 2016, 2017	Annual report 2016 Forbes (Schmitt, 2017) Case Studies (Martinez 2011, Hunter & Doz 2016) lesnumériques.com, 2017 treehugger.com, 2017		startupbahrain.com	
Total interviews time in minutes	180	275	300	120	TOTAL INTERVIEWS: TIME 15 hours

Table 13: Details of the data collection for the automotive sector

Demographic information such as age was not requested; out of 13 respondents, only one was female.

Data was gathered during a roundtable on open source hardware conducted by research partners in Berlin with German actors in the automobile industry. Project partners also participated in *La Fabrique des mobilités* workshops in Paris around Renault's Platform Open Mind (*POM*) Twizy project. The interviews provided this study with an in-depth understanding of processes and structures within the case companies. Each interview was recorded and immediately transcribed verbatim. Following this, the transcripts were returned to those interviewed for review and confirmation before any analysis process to develop the case studies was actually begun. The data was then triangulated (Gibbert *et al.*, 2008) with secondary data, which included cross checking publicly available interviews and articles, internal documents provided by the case companies, as well as additional interviews with their employees. In total, we — the research group — interviewed 18 industry representatives. The interviews each lasted around 90 to 120 minutes. Based on the transcripts and secondary data, the case stories were subsequently developed. Researchers worked independently of one another (Miles & Huberman, 1994) as they conducted the iterative analyses. Iterations were basically

oscillations between the data and emerging themes and patterns within the business model dimensions of content, structure, and governance (Locke, 2001; Saebi *et al.*, 2017). The researchers also familiarized themselves with each case before beginning the cross-case analyses (Eisenhardt & Graebner 1989), which employed visualization and tabulation techniques (Miles & Huberman, 1994), in helping to detect differences as well as similarities between the cases. Finally, the researchers iterated using current literature, raw data, and first findings until they arrived at inherently sensible and consistent case stories.

4.3.5. CASE OVERVIEWS FOR AUTOMOBILE INDUSTRY

Case 1: Renault

The Renault Group is a French multinational automobile manufacturer established in 1898. In 1999 it founded the Renault-Nissan Alliance, based on cross-shareholding. This became one of the most effective partnerships in the history of the automobile industry. In 2016, with 36 manufacturing sites, 12,000 points of sales and more than 120,000 employees, it sold over 3.3 million vehicles in 125 countries. The Renault Group is ninth among the largest car manufacturers worldwide (OICA, 2016). Jointly, with Nissan and Mitsubishi, Renault became the largest automobile group globally (Schmitt, 2017), marketing its products under five brands: Renault, Avtovaz, Dacia, Renault Samsung Motors, and Alpine. In 2016, Renault reported a sales volume of 1.805.290 new vehicles registered in Europe and global revenue of 51 billion EUR (Renault, 2016).

The Renault platform investigated in this study is the Platform Open Mind (POM) Twizy, revealed at the Consumer Electronics Show (CES) Las Vegas in collaboration with Open Motors (formerly OSVehicle). The project initiative won the internal Renault Pitch-and-Poc contest in July 2016. POM Twizy's aim is to provide a vector upon which car body makers, start-ups, academics and extended innovation communities can develop and experiment. Thus, it allows third parties to copy and modify existing hardware and software in order to design new adaptations of the electric vehicle, Twizy.

Of particular note in the initial POM collaboration, we find Open Motors, a US-based, B2B company that has developed a ready-to-use hardware platform enabling companies to produce fully electric cars in half the time and 1/6 of the cost. Relying on open source, Open Motors provides core functional parts such as the wheels, chassis, motors, electronics, and batteries

permitting car manufacturers to develop their own models in a modular and open source fashion (Treehugger, 2017).

Case 2: Volkswagen Group

The Volkswagen Group (VW) was founded in 1937 under the name “Gesellschaft zur Vorbereitung des Volkswagens mbH”. Initially, VW’s main objective was to market a car at an affordable price. To achieve that goal, VW built a completely new industrial settlement in the town of Wolfsburg. Today, VW is the second most important automobile manufacturer in the world. In 2015, VW was selling more than 9.8 million vehicles per year and generating annual revenues of 217 billion EUR with around 630,000 employees (VW AG, 2016). In 2016, the corporation overtook Toyota and became the world's largest automaker by sales. With more than 12 brands, VW’s main business area remains automobile manufacturing, however the service sector has grown considerably with strong expertise in finance, including leasing, insurance, and fleet management.

Recently, VW has taken an important strategic step, moving from being a pure automobile manufacturer to becoming a provider of new mobility concepts. In other words, VW’s future strategy, TOGETHER, is no longer only about selling physical cars (VW AG, 2017). Beyond its goal to launch 30+ fully electric vehicles by 2025, VW has initiated *MOIA*. The spin-off is focusing on mobility services for urban areas at affordable prices in collaboration with different stakeholders: public transport companies, tech firms and mobility service providers. *MOIA* particularly changes VW’s customer focus. Instead of concentrating on the car owner, the corporation now considers the needs of the flexible, urban, and digital traveller. In designing new services, big data analysis helps to investigate data points provided by cities and navigation systems, and merges these with VW know-how.

Despite internal collaboration on platforms for various models, (A0, A, B, C, D series), the VW group itself has thus far only opened two joint venture platforms: (B-VX62 with Ford Motor Company and LT/T1N with Daimler AG).

Case 3: Kreatize

Kreatize is a Berlin based start-up founded in 2015 by Simon Tuchelmann and Daniel Garcia. Before launching Kreatize, Tuchelmann was CEO of the family-owned TSF Tübinger Stahlfeinguss, a steel casting enterprise, and Garcia had founded rapidApe, a realtime monitoring board for TV and analytics.

Early in 2016, Kreatize attracted its first seed money of half a million euros. By mid-2017, it closed its series A funding with around five million Euros from the *Atlantic Internet* investor fund. To improve its network, Kreatize joined the Berlin-based accelerator program, *Start-up-Autobahn*, created by Daimler AG, Porsche, and Axel Springer Plug and Play.

The start-up developed a matching system based on machine learning that combines manufacturers' requirements with suppliers' capacities and techniques. To do so, the manufacturer uploads a CAD design file and in few seconds the system displays the best offers by price and manufacturing technique. The matching process itself, however, happens in a black box, which is preferable for the manufacturer and the supplier due to cost and timesaving. Thus, suppliers do not have to go through the eternal, long sign up processes with the manufacturer, who only signs Kreatize as supplier once. For the matching service, Kreatize charges the manufacturer a service fee as well as a surcharge on the supplier's price, then takes a share of the final cost.

Currently, Kreatize is building on a database of more than 200 suppliers, 1,000 materials, and 12 manufacturing techniques. The average order value is between 5 - 10K euros (June 2017).

Case 4: Local Motors

In 2008, Jay Rogers, CEO and co-founder, launched the US-based open platform called Local Motors. His intent was to redefine the development of connected hardware by pairing micro-manufacturing with co-creation. Basically, the Local Motors platform connects brands and their customers in order to work together in so-called challenges. Thus, central firms, designers, engineers and other platform contributors, jointly accelerate product and technology development. Currently, Local Motors reports 75,000+ contributors to its platform where the term 'platform' relates to varying instruments that enable brainstorming an idea and product development through co-creation. For instance, *LM Labs* refers to Local Motors' open innovation platform for vehicle development. *Launch forth* is a community-powered SaaS platform to unite the world's largest engineering and design community with companies to design and bring products to light faster. *Fuse* supports co-creation and micro manufacturing for external companies. Finally, *HP Mars Home Planet* is a platform to model urban space for the future inhabitants on Mars.

Local Motors was the first company to rely on direct, digital manufacturing. The first product evidence to emerge from its collaborative innovation, was the *Rally Fighter*, the world's first co-created production car (2008) and *Strati*, the world's first 3D-printed car (2014).

Since its creation, Local Motors has realized projects together with partners such as GE, Airbus, and the US Army. In other words, it has contributed not only to areas like aeronautics, space solutions, and automotive but also has addressed societal issues such as environmental protection, mobility, defense and security, and safety. The company has especially gained critical expertise in co-creating open source hardware.

The cases selected for this study have confirmed evidence relative to OSHW and business models. The studies were chosen to compare industry and business' interest in the project. To replicate different finding patterns (Yin 2006), the research group chose firms acting within one industry — the automotive — with differently closed and open business models (Appleyard & Chesbrough 2017). To ensure validity, these represent different levels of maturity ranging from the start-up Kreatize, on the market for about two years to the more mature, nine-year-old start-up, Local Motors, and the two established corporations, Volkswagen and Renault.

4.3.6. MULTIPLE CASE DATA ANALYSIS

For this section we therefore have a single case in the textile industry and four cases in the automobile sector.

For the Raidlight case, we initially intended to study the match between the proposed OSH value-proposition and the expectations of the existing user community, matching the item ranking established during the roundtable with the OPEN! team and with the community's through an online survey. However, the online survey, produced very few responses. Eight community members answered while we were conducting the study and 32 at the end of the project. We considered that number of responses insufficient for our analysis and therefore we chose to apply the same contingency framework used to assess the automobile cases.

We formalized the elements described in Saebi & Foss's (2015) "continuum of open business model" in a reading grid qualifying each dimension according to business model design, that

is content, structure, and governance (see Table 14). We used these dimensions to construct our interview guide and to analyze our cases (see appendice).

	LEVEL OF VALUE CO-CREATION: <i>The breadth and depth of innovation occurring with external partners or communities.</i>	LEVEL OF KNOWLEDGE FLOW: <i>The permeability of information in the company's business model structure</i>	LEVEL OF COLLABORATIVE CAPABILITY: <i>The capacity to govern interaction with external knowledge providers</i>
Lower	Efficiency centric: Refers to the company resources readily available and knowledge with little potential for co-creation between the focal company and an external knowledge provider.	Unilateral: In efficiency centric and user-centric business models the knowledge flow is unilateral. Hence, the business model structure needs to allow only for the inflow and integration of external knowledge into the company's internal R&D system.	Kick off capabilities: The degree to which the company needs to develop collaborative capability to govern its interactions with external knowledge.
Medium	User-centric: Refers to the open business model in which the potential for co-creation increases, as the company is able to integrate user communities ideas into its value proposition, and thus create additional value	Dyadic: In a collaborative open business model, knowledge flows need to be jointly developed. They require a higher degree of permeability.	Incentivizing capabilities: Incentive is given to overcome the not-invented-here syndrome.
High	Collaborative: business model in which the potential for co-creation rises in parallel with the co-development of knowledge and technologies. Open platform business model: This level creates the highest potential for co-creation, resulting in a business model that acts as an open innovation platform for a multitude of different stakeholders.	Multilateral: The level of permeability of the company's business model structure needs to be high in case of open platform business models as knowledge flows multilaterally between varieties of knowledge partners.	Open platform capabilities: Collaborative capabilities geared toward mutual knowledge exchange, development and management of long-term partnerships.

Table 14: Rating dimensions per Saebi and Foss (2015)

4.4. ECOSYSTEM LEVEL: CONTEXT DESCRIPTION AND THE CHOICE OF BARCELONA

Among other pertinent OSH ecosystems, Barcelona was chosen for this study for the following reasons: First, a concentration of OSH projects from the city have received considerable stakeholder support: namely projects such as The Fair Cap, Open Source Beehives and Aquapioneers, among others. Second, earlier research in ecosystems confirms the importance of its *middlegrounds* in fostering innovation (Capdevila 2015). Third, Barcelona holds a pivotal role in the Fab City network (Guallart, 2018; Diez and Armstrong, 2018), leading the engagement to locally produce 50% of the city's consumption by 2054. Finally, it boasts the highest concentration of commons-based cooperative platforms (Fuster & Espelt 2018), placing it at the heart of global trends like open technology and circular economy.

Barcelona is pioneering open, participative technology initiatives to make itself self-sufficient in terms of energy, industry, mobility and even food. The Fab Lab Barcelona established in 2007, as the first EU-based fab lab, is central to the nervous system of global Fab Labs. The

Barcelona Fab Lab is a place of experimentation where numerous European research projects are carried out. The Fab City project was born there, and today the Global Fab Academy Distributed Master, is coordinated from there as well. The Fab Lab founding team integrated the city's leadership, which helped to establish a public network of Fab Labs per district. This resulted in the FAB10 conference in 2014, during which the Mayor of the city, Xavier Trias, publicly committed to the goal of locally producing at least 50% of the city's consumption by 2054.

Digging deeper, Barcelona is an interesting case study because it has a history of technological and urban innovation centered on human values and on people striving to live in harmony within their environment. Barcelona is often cited as a palimpsest of innovation: a manuscript continually rewritten (Barril, 2008) with innovations serving to make the city more agreeable. Perhaps this is due to its geographical situation -- the sea on one side, the mountains and two rivers on the others-- the notion of exponential growth was never an option.

4.4.1. DATA COLLECTION

A qualitative methodology was chosen to explore the dynamics of this living phenomenon. Data was collected during four, one-week stays in Barcelona over a four-month period from March to June 2018. We were co-hosted by the Digital Commons Institute (Dimmons) at the UOC (Universitat Oberta de Catalunya) and the Free Knowledge Institute. Beginning with three previously identified local OSH startups (Bonvoisin, Thomas, *et al.*, 2017), namely Open Source Beehives, Aquapioneers and Fair Cap, a snowball sampling was conducted to find key stakeholders in the Barcelona ecosystem working in the field of digital production and open technology (see Table 15).

	Start-ups		Crowdfunding	Incubator accelerator Makerspaces Coworking spaces	Firms	Non-profits	Barcelona City Council	University	Fablab		
	Aquapioneers	OS Beehives	Fair cap	Ulule	Ship2B, Apocapoc, Makers of Barcelona	Ideas for Change, Infonomia	Free- Knowledge Institute	Office of Digital Technology and Innovation	Dimmons	Fablab Barcelona, IAAC	
CEO					1	1					
Program managers					1					1	
Project managers		1		1	1		1			1	
Founder	1		1		1	1	1		1	1	
Total interviews time in minutes	50	73	60	38	117	55	50	48		103	TOTAL INTERVIEWS TIME: 10 hours
Additional primary data: Workshop and conferences	Aquapioneer Workshop at Apocapoc, CWS						Workshop on Platform Cooperativism	14th Fab City Summit, Paris	14th International conference on internet, law and politics: Collaborative Economy challenges and opportunities	Design Anything Make Anywhere Launch Event	
	180						180	960	960	180	TOTAL TIME: 41 hours

Table 15: Details of primary data collection on Ecosystem level analysis

Primary data collection includes ten hours of semi-directed interviews and face-to-face interviews focused on the stakeholders' own scope of activities relating to OSH, the nature of their interactions with other stakeholders, their understanding of Barcelona specifics conducive to OSH, including PESTLE trends, and finally, their understanding of the value created by OSH initiatives. As support for discussion, those interviewed were given a visual of the Innovation Fab Lab Ecosystem (Figure 26) and of the *middleground* concept.

Demographic information such as age was not requested. Of those interviewed 75% were male, 25% were female.

Additional data was gathered during workshops and conferences organized by the stakeholders. This allowed for direct interaction with extremely busy people, such as the founders of the start-ups, and keynote recordings of influential stakeholders, such as Barcelona's Chief Technology and Digital Innovation Officer and the Dimmons Director of Research on Collaborative Economy (see Table 15).

4.4.2. OBJECTIVE OF THE DATA ANALYSIS

Recordings were transcribed and coded using Sphinx Quali software for a thematic analysis (Hsieh & Shannon 2005; Miles *et al.*, 2014). Seven deductive macro themes were defined corresponding to the categories in the interview guide. These were subsequently refined into sub-categories, both deductive and inductive, in order to provide for new, emerging understanding (Figure 29).

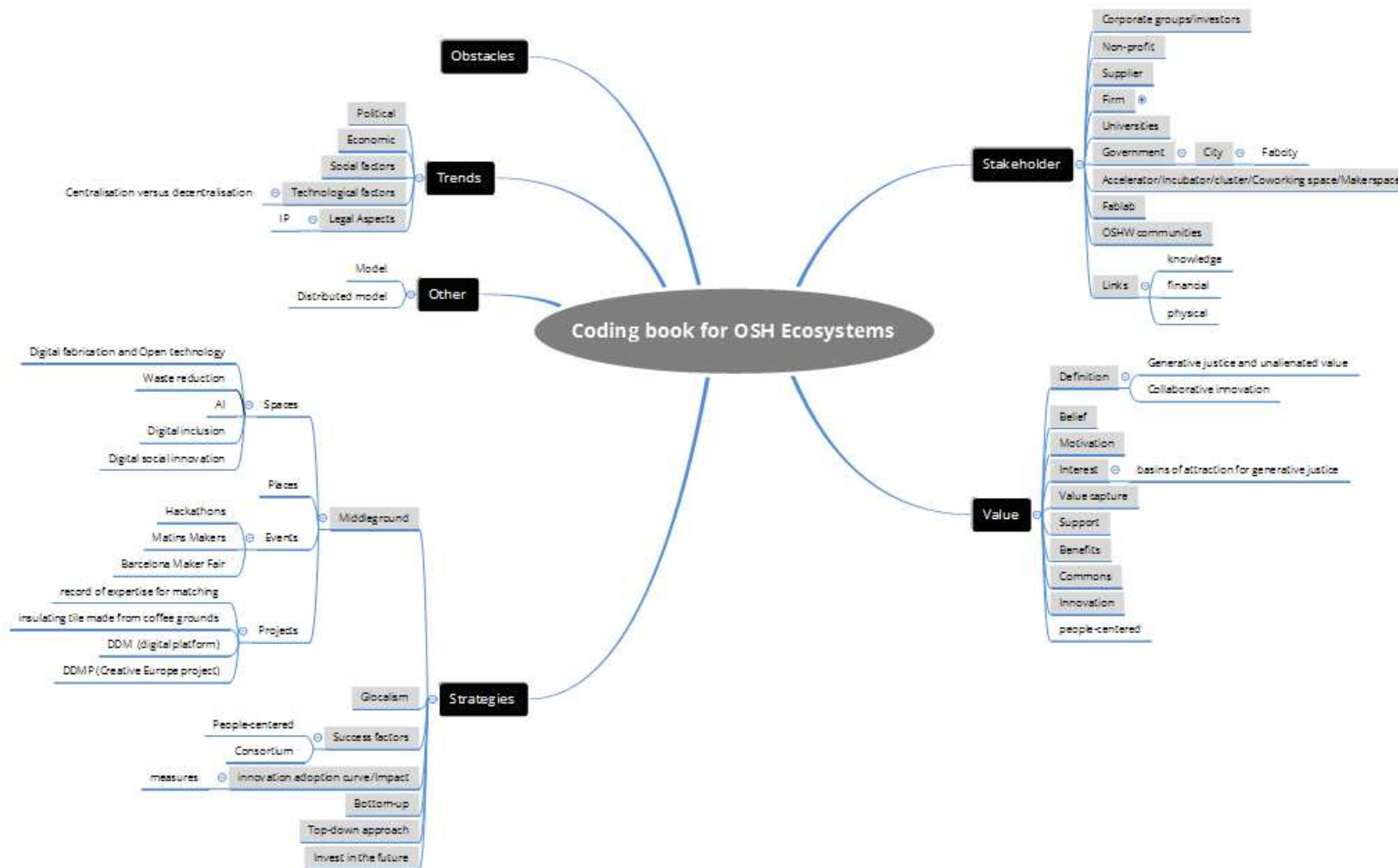


Figure 29: Detail of macro themes and subcategories for the Barcelona case study

The purpose of the analysis was to identify the most salient themes appearing in the data collected, as well as the words used most frequently for each theme. The software functions on lemmatization, meaning that it sorts words from the transcriptions based on their common semantic roots. To simplify the analysis, common lemmas are grouped and further associated with synonyms.

CHAPTER 4: KEY TAKEAWAYS

In line with the methodology choice presented in Chapter 3, Chapter 4 presents the justification for a multi-level analysis, and establishes OSH ecosystems as the unit of analysis for our research. We suggest that studying OSH through the prism of communities alone is too narrow in scope, as the phenomenon transcends the boundaries of any given organization. As our research progressed, we observed how firms were reacting to OSH, and how stakeholders in a broader ecosystem were instrumental in helping sustain OSH endeavors.

This chapter provides the details data collection for each level of analysis as well as the dimensions used to analyze the data. For example, for the community level of analysis, with a core group as the main contributors to the product development process, our analysis empirically tests the five key elements of OSH identified by (Fjeldsted *et al.*, 2012): the drive, platform, process, community and business model.

For the firm community-interaction level we present our single case analysis of the trail running company Raidlight, and the justification for the multiple case analyses of the actors in the automobile industry. The dimensions used are based on Saebi & Foss's (2015) contingency model for the success of open innovation initiatives, namely, the level of value co-creation, the level of knowledge flow and the level of collaborative capability.

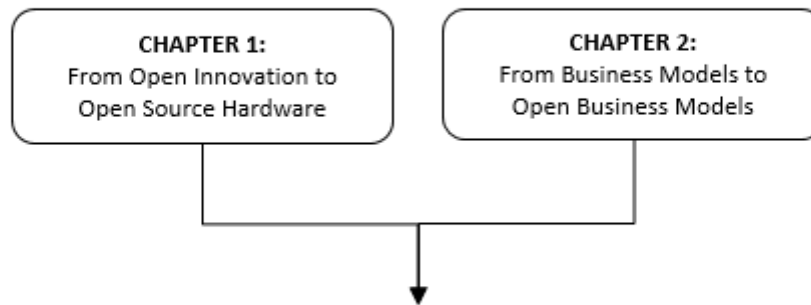
For the ecosystem level of analysis, the main stakeholders susceptible to supporting OSH were mapped. Semi directive interviews focused on their understanding of the type of value created by OSH and how and why such endeavors were nurtured in Barcelona.

PART III: RESULTS ON THREE LEVELS AND DISCUSSION

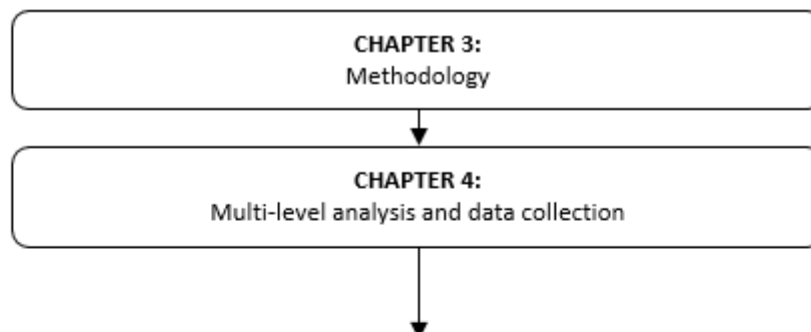
PART III: RESULTS ON THREE LEVELS AND DISCUSSION

GENERAL INTRODUCTION

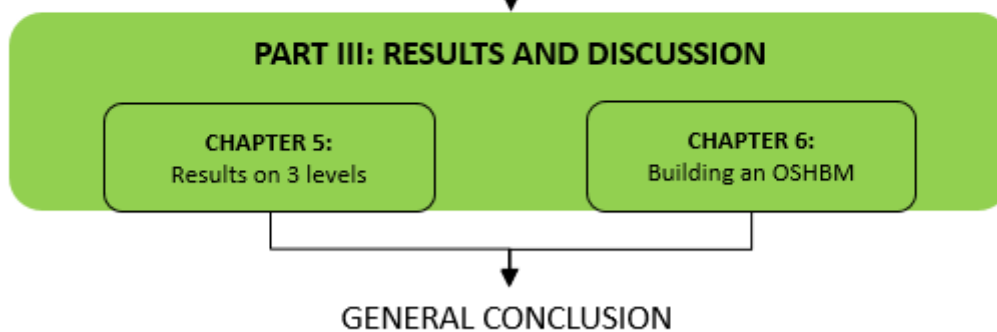
PART I: LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK



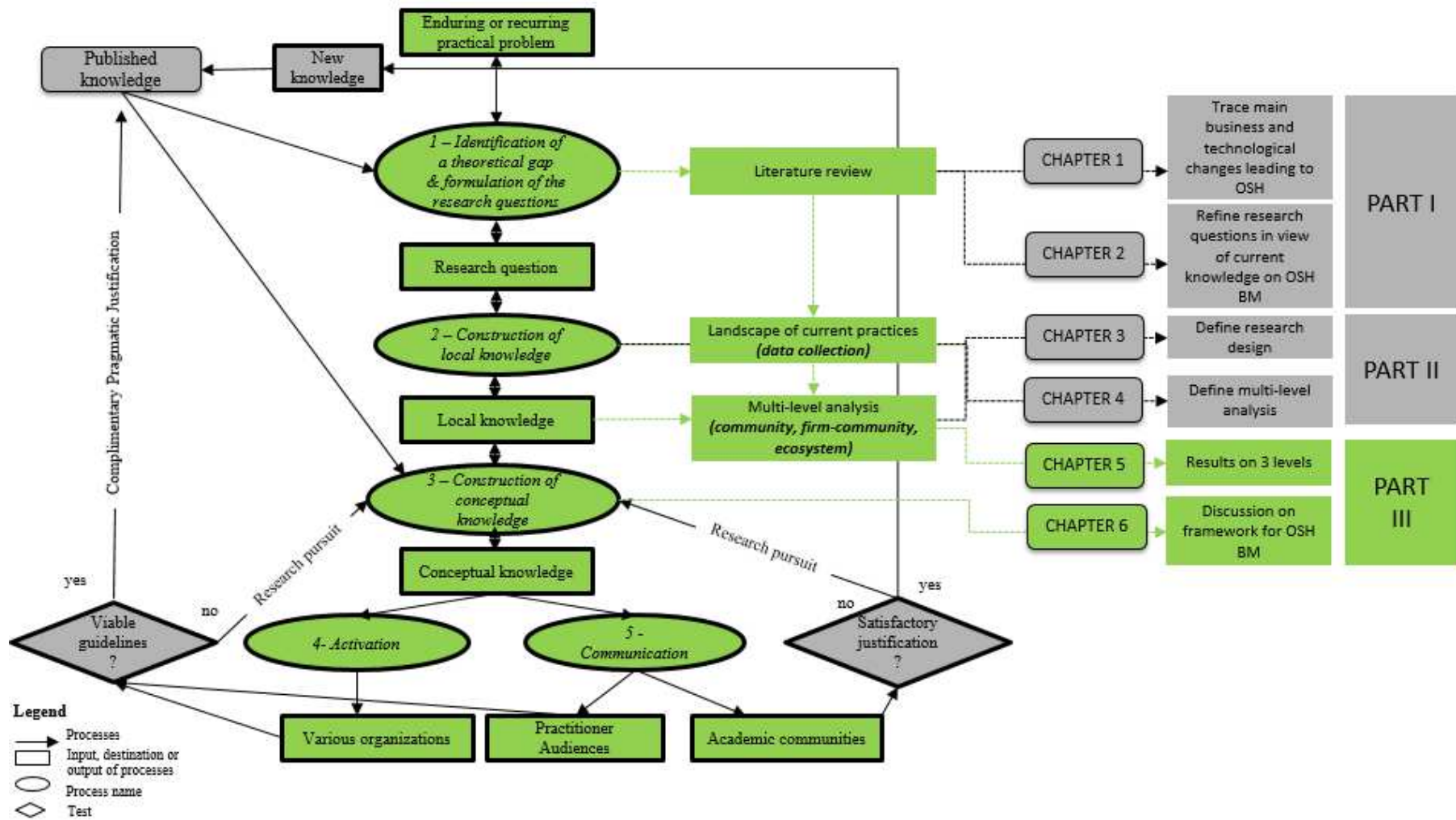
PART II: METHODOLOGY, RESEARCH DESIGN AND JUSTIFICATION FOR A MULTI-LEVEL ANALYSIS



PART III: RESULTS AND DISCUSSION



Part III



CHAPTER 5: RESULTS ON THREE LEVELS

CHAPTER 5: RESULTS ON THREE LEVELS

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CHAPTER 5 SUMMARY

Objective – Findings of our three-level analysis and a transversal analysis of all the data collected, are presented.

Methodology/approach - Semi-constructive interviews were analyzed horizontally to identify common patterns. Case analyses were used to contextualize findings in view of elaborating on the Commons theory.

Results - Community level findings revealed a staged process of value capture. A large spectrum of offers is activated to generate revenue that in turn feeds the community joining process. The firm-community interaction level indicates the importance of instilling an organizational culture of openness to empower employees to think outside the box. The ecosystem analysis uncovered a process by which OSH initiatives can leverage their ecosystem in order to grow.

Limits - Mixed-methodology attempts were unsuccessful. Inter-coder reliability could not be calculated for all interviews. For the Raidlight survey, correlation of the focus-group findings with the online community provided too few responses to be of use.

Managerial implications - This section is rich in practical implications as we address the different revenue streams types OSH projects can leverage; how firms interested in OSH can interact with innovation communities, and finally what cements their participation in OSH and can make them grow within their ecosystems.

Originality/value – Contrasting views are provided of the OSH phenomenon that enable comparing community-based business models, with community-oriented business models.

5.1. INSIGHTS INTO COMMUNITY-BASED BUSINESS MODELS

In this section we present the key take-away from the community-level study of 23 OSH initiatives. The initial intention was to understand:

- How value creation is **monetized** in OSH.
- How the **business model framework** can be broadened to include *value creation and sharing* for all **stakeholders**.

5.1.1. FULL RANGE OFFER THAT FEEDS THE COMMUNITY JOINING PROCESS

From our research, it is evident that OSH offers a large spectrum of revenue streams. The notion of value creation was singular and strong in the OSH communities interviewed but the heart of the business model is the value derived from the satisfaction of contributing to a greater cause and the accessibility of participation. The value of OSH initiatives is distributed over a large number of parties, who, through the process of joining the community, will have different benefit levels including user satisfaction and participation satisfaction. Table 16 shows the main value proposition categories found.

	DIY	Kit	Final product
Part of value proposition	6	5	12

Table 16: Value Proposition of OSPD projects (N=23)

Figure 30 below illustrates the large panel of revenue stream options serving as building blocks from a DIY product and service offer, to kits, then a full spectrum offer.

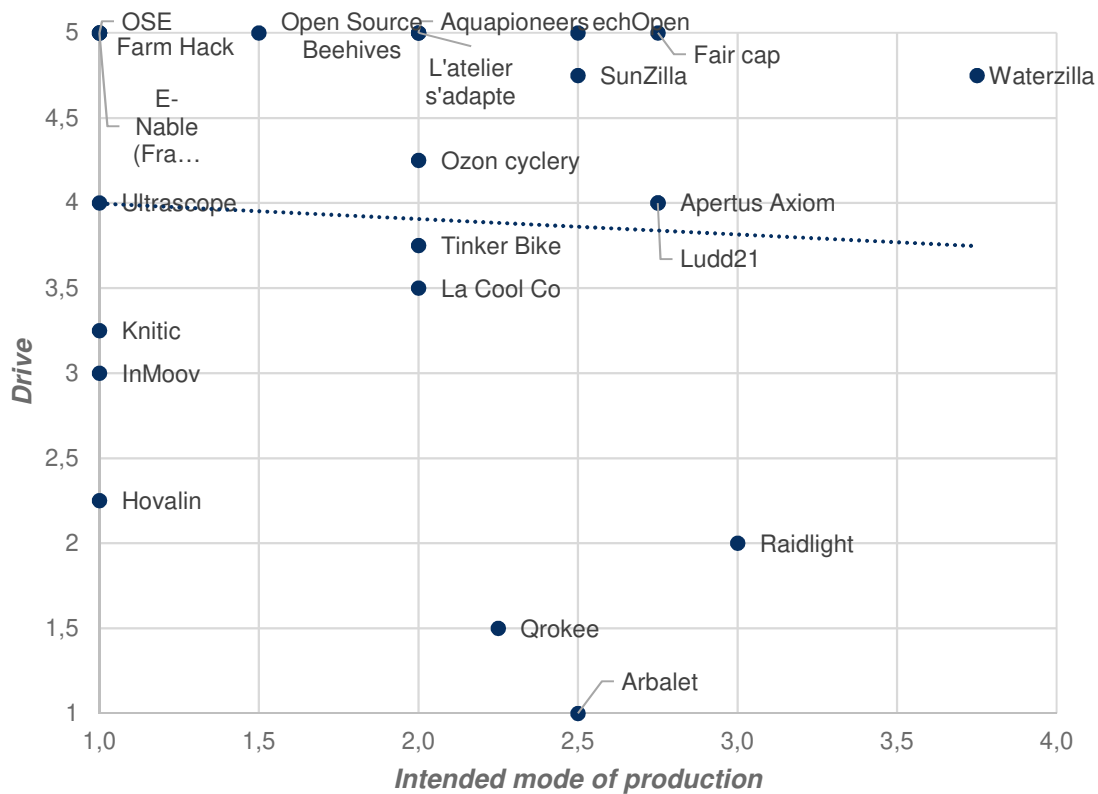


Figure 30: Drive and intended production mode for OSH projects

Production mode intended

1 – DIY pure peer-production, (at least 50 % added value)

1.5 - KIT (i.e. use standardized components and DIY components, commercial workshop production)

3 – FINAL PRODUCT (all of the above options) clear aim for industrial manufacturing

4 - Undefined

Projects under the 1 x-axis only offer DIY options: blueprints and bills of material are available for people who want to build the product from scratch. Projects under the 1.5 x-axis offer a hybrid option with DIY possibilities, a kit and a workshop to learn how to build the product. Projects in the 2.5-3.5 range, offer a full spectrum option. Projects rated 4 are undefined, either because they are hobbies or not far enough along in the process to have a carefully thought out value proposition.

Revenues will come from the kits, from workshops, or from the sale of final products, as a well as perhaps installation costs, personalized options and services or subscriptions. This indicates a particularity of OSH communities as concerns the relation between the offer and the value proposition in a Pareto-like proportion. The largest revenue potential comes from the sales of finished products depending on how many people can be reached, and on the margins between

kits and final products. These revenues will serve as a lifeline to support the project development. In the words of one respondent:

“I think by far, if you multiply how much a kit would cost, or a final product would cost, with how many people you can reach, by far, that’s the largest potential in terms of financial income.”

People, who perhaps don’t feel they possess the necessary skills to build a product in a DIY option, will be happy to buy a finished product or a kit and workshop support. In this manner, they will gain the satisfaction of using the product, of participating in the cause and eventually, the more they become engaged with the community, of being empowered by new skills learned. The cherry on the top, is the gain in pro-activity. Former customers become technologically capable of fighting programmed obsolescence as they’ve learned how to make their products evolve through time. The purchase of a finished product thus serves as a lead, enticing the buyer to engage with the community. The extended community then fuels the lifeline to the project, where -- shifting from a product or service perspective, to a platform perspective -- revenues come from a large spectrum offer, including kits, final products, workshops, trainings, subscriptions and customizable products.

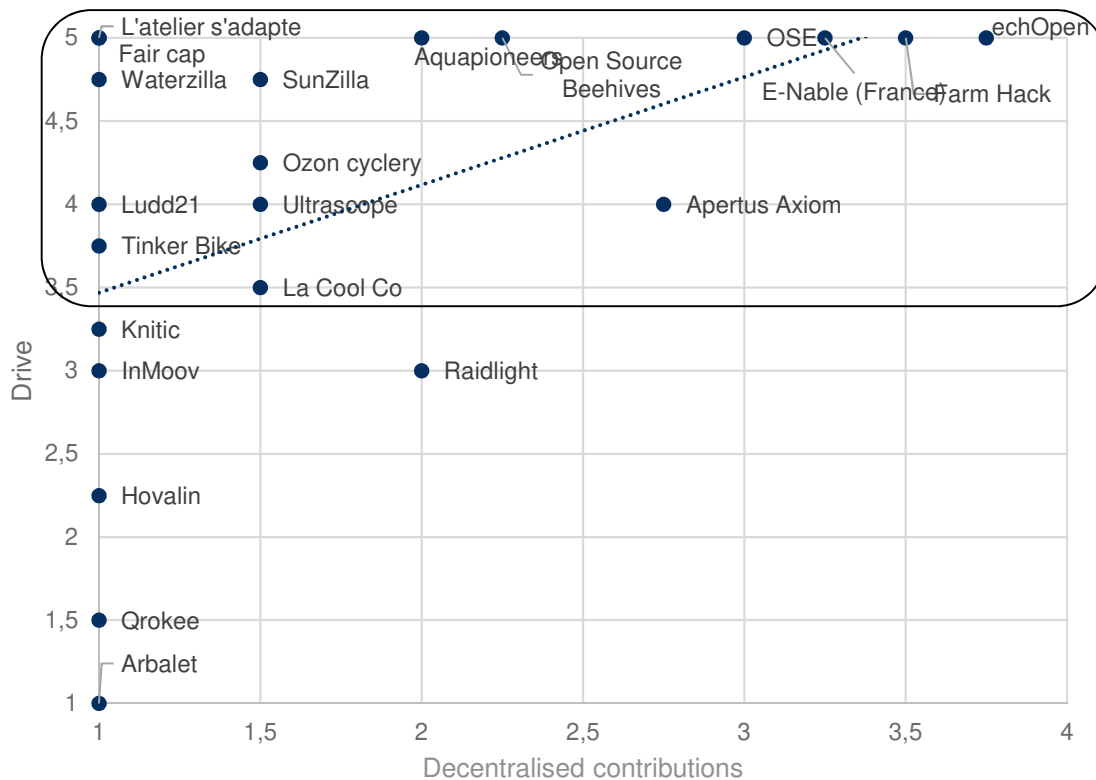
Only a small percentage of the overall community (10%) already has the skills to build something from scratch. Yet open community development is at the heart of the value proposition, and without it the project would lose momentum. The real value of OSPD projects is the satisfaction of participating in a project “making a real difference in the lives of people today”. The iterative process of learning, improving, participating and sharing, is what sustains the community. And for this, community members are willing to give their time, their money and their knowledge.

In sum, the fat end of value capture lies in the long tail of products and services around the hardware products. The heart of value creation, however, lies in the ability to access, replicate, modify and use design files. These openness factors, with the potential impact of innovation achieved through network effects, are what fuel the momentum for design collaboration, making the product live and become better, faster, cheaper and more efficient.

5.1.2. PROJECT MOMENTUM IS TIED TO CRITICAL PROBLEM SOLVING

Our findings also indicate that project momentum is tied to critical problem solving and its impact relies on network effects. Open sourcing the solutions becomes a mechanism to scale the impact of the innovation.

Figure 31 gives the average rankings for the “drive” of the OSH initiative (y-axis) and its decentralized contributions (x-axis).



Decentralised contribution x-axis

- 1 - everything done by core-team
- 2 - some tasks are done by chosen outsiders
- 3 - design is done by the community (volunteers) but mgt. is by core team
- 4 - design and management activities are done by the community

Figure 31: Drive and decentralisation of OSPD project contributors

The clustering across the top of Figure 31 suggests that projects with a high drive or “a real-life-problem-solving” mission, succeed in motivating people to remain committed over time and ensure the continuity of the project. Participants often had a collective mind-set for designing pragmatic solutions that could be up-scaled to become more impactful. Projects with decentralized, collaborative development, were found to have significant growth potential, calling for wide diffusion and for process documentation to render them accessible to dynamic

and fluctuating contributions. Projects where the founders' aim was just to have "geeky or artsy" fun were less successful in attracting development communities. This may reflect on the founders' ability to successfully market their blueprint, but also since they considered their project a hobby, that they were less interested in upscaling.

5.1.3. IMPACT RELIES ON NETWORK EFFECT

What can be appreciated from the findings on the link connecting the drive, decentralized contribution, intended mode of product and the legal statuses of these open source product development communities, is that OSH projects are community-centric. Incentive #1 is, to treat the problem that initially federated the community. In the case of the Protei project, that is using marine drones to clean the oceans of oil spills; in the case of the E-nable project, (subject of an interview), that means changing the lives of handicapped children today, by connecting them to a home-engineer with a 3D printer who will be happy to co-build them a prosthetic hand – for free. Incentive #2 is that the community will make the project live by attracting talent while creating better and faster, #3 technological solutions. Incentive #4, financial profit, comes last. Revenue is needed to sustain the projects, but their heart is in the satisfaction people derive from participating in something meaningful.

Growth of the community is necessary because first, its impact relies on network effects: the more community members join and participate in the project, the better the results for addressing oil spills or beehive colony collapse disorder. Second, the growth and activity of the community guarantee amplified innovation, in the sense that innovation becomes "more transparent, more efficient, involving more people trying to find solutions, learning from each other and improving the project" through faster rounds of iteration, at a lower cost. Through these two approaches, successful projects have the potential to set future industry standards by prescribing entirely integrated solutions using a unified (and hackable by definition) grid.

5.2. INSIGHTS INTO COMMUNITY-ORIENTED BUSINESS MODELS

The point of this analysis level was to understand how brands, in traditional and highly competitive areas, design business models around open source hardware. The following sections will present the findings of the studies we conducted in the textile sector with the case of Raidlight, and in the automobile sector with the cases of Renault POM Twizy, Volkswagen, Kreatize and Local Motors. In all cases, the research question was:

- How do firms design their business models around open source hardware?

Our findings are structured along the dimensions of value generated through 1) co-creation, 2) knowledge flow, and 3) collaborative capability. The success of an open initiative depends directly upon these elements which are respectively tied to those of content, structure and governance.

5.3.1. STUDY IN THE TEXTILE SECTOR

5.3.1.1. Value generated by co-creation

Raidlight's level of co-creation is user-centric. The company has established a community management process, employed at least for the past four years, to prioritize community user issues and integrate the most relevant of these into its value proposal. This inductive approach was used to elaborate a field-test protocol for carrying and for hydration systems in trail running.

The OSH aim was to go a step farther. The scientific and managerial challenge was to see whether or not an active community of trail runners could go beyond crowdsourcing to an open source hardware approach. The timeline was set to launch the Open Hardware initiative in August 2017, and in May 2018, to invite the best contributors for an immersion-day event to prototype their innovations with the help of Raidlight's athletic trainers, designers and factory technicians.

On paper, the client profile and value proposition, established during a May 2017 workshop, were coordinated and appeared coherent. The workshop findings, shared with Raidlight's community for validation, received 34 responses (see annexes). Launched in August 2017, the plans of the Responsiv Backpack were rendered public on the Github platform with 9 other issues on which the firm wanted feedback to improve the backpack.

After 4 weeks, 50 answers had been received from 13 different contributors. From these, 25 technical solutions were assembled into 14 different ideas and concepts. Through community management handled by Raidlight's Community Manager and a member of the OPEN! Team, 3 main ideas were identified. Most suggestions had involved adding a function, rather than simplifying or modifying the existing plans. Figure 32 is the decision tree of all the propositions brought forth by community members, then funneled down.

able to reclaim this information. Participants did not reuse it. Participation here is more like crowdsourcing than open source”.

Possible reasons for this include the gap between trail-running communities of practice using the Raidlight equipment, and textile experts who are aware of the technical imperatives for competitive manufacturing in France. Indeed, the number-one rule of Raidlight’s production is “streamlining assembly time by using cutting edge technology and materials in order to keep producing in France”. Suggestions, such as adding a waterproof pocket, if it means more weight or manufacturing steps, are not retained; in terms of knowledge flow, we may conclude that ideas for generating solutions were too narrow to elicit responses from a community. If the OSH initiative had been extended and broadcast to textile confection schools and other sporting equipment manufacturers or suppliers, the level of contributions would have been completely different. As a result, this initiative was more of an “open-washing” market strategy. True co-design, in the sense that the community would bring technical collaboration, was limited because the users are not textile experts. Moreover, the knowledge generated was only appropriated within the firm.

5.3.1.3. Value generated by collaborative capability

Raidlight has put in place effective crowdsourcing techniques for gathering information from its community of trail runners. Yet the brand still has a lot of room to grow in terms of overcoming the “not invented here” syndrome. It is also a far cry from developing the collaborative capabilities geared “toward mutual knowledge exchange, development and management of long term partnerships” (Saebi & Foss 2015).

5.3.2. STUDY IN THE AUTOMOBILE INDUSTRY

5.3.2.1. Value generated by co-creation

The Kreatize company is characterized by a lower level of value co-creation since the startup acts mostly as a facilitator, matching Original Equipment Manufacturers (mainly automobile OEMs) with suppliers. Using its closed platform model, Kreatize creates supply and demand. Interestingly, it was the platform closing, which made its business model possible: “*based on our customer feedback, we closed the platform. Total openness just did not work for our clients*”. The initial, open platform approach was an impediment since the OEMs and large corporations continually required long sign-up processes for every supplier engaged, hindering both fast exchange of CAD designs and subsequent production of hardware parts.

VW reveals a slightly higher level of value co-creation than Kreatize. This is primarily due to opening-up activities, which include market scouting for OSHW approaches, using OSS for internal use, and conducting user studies. While technology scouts scan markets for trends and solutions, the first internal projects with OSS and open innovation platforms, like Jovoto and Hyve, show the huge internal interest in better understanding working prospects with OSHW. VW further supports R&D units that focus on gathering the needs of prospective users, customers, and clients when it comes to cars, mobility, and autonomous driving. In this sense, it could be user-centric on the Saebi and Foss model, however most of these R&D units are internal, independently run, and rarely engage with one another.

Renault's level of co-creation is higher than VW's. The *POM Twizy* project, qualified as the "first open source, mass market, vehicle platform", telescopes novel processes internally with new players and serves as a technical demonstrator for car-body-makers, start-ups, and academics, who need to be able to transform and customize their vehicles. "*Our biggest contributors are clearly our suppliers with whom we co-create enormously... It's just not stamped Open Hardware, but it's definitely co-creation in the broad sense*". The engineers working on the *POM Twizy* seek a "*co-creation of values, meaning win-win partnerships*" with the originators of *POM Twizy* developments. "*If there are interesting things that emerge, we need able to interact and support the community of persons which developed them*" ...through intra- or inter- entrepreneurship. Although Renault's *POM Twizy* engineers intend to adhere to the OSHW definition of transparency, replicability and accessibility, the initial collaboration with OSVehicles, now called Open Motors has been put on hold until Renault irons out and is comfortable with regulatory standards around the development of the base object, essentially a shell and chassis, which is to be offered for external community developments. The base object will remain Renault's property; adaptations to the needs of others will be OSHW. Although the initiative is part of a strategy directed toward an open, organizational culture and is supported by top management, tension arises because OSHW projects are a radical disruption to classical project management.

Local Motors shows the highest level of value co-creation. Its activities to innovate OSHW jointly with its crowds of collaborators range from engaging co-creators on the platform through challenges on various topics ensuring high quality co-creation through constant feedback, to partnering with large corporations. As of today, Local Motors is not only partnering with manufacturing companies like GE, Airbus and Siemens, but also with

consumer brands like Hewlett Packard, Shell and Makerbot. Essentially, Local Motors offers its co-creation platform on a *software-as-a-service* (SaaS) basis. Most importantly, Local Motors is ambitiously enforcing openness, both within its own organization of around 130 employees at this time, and externally with co-creators and partners, even though, according to one person interviewed, “*it is hard to make every single email public.*” Nevertheless, to ensure flexible and fast communication plus high responsiveness, Local Motors locates its international employees in areas most suitable for communicating across different time zones (e.g., Marseille).

5.3.2.2. *Value generated by knowledge flow*

VW R&D appears to be aware of the possibilities for accelerating hardware innovation through OSHW. However, the low level of knowledge flow found is expressed as follows: Engineers and technology scouts deliberately state their ambitions to co-create with external partners. Employees are legally not permitted to engage on OSHW platforms, even if they scout them for innovation and knowledge. Merely informal knowledge spill-in to VW can be observed (outside-in), while inside-out knowledge sharing is strictly prohibited by employment contracts. Internal knowledge mixing may occur when engineers, externally engaged in platforms for leisure, share their knowledge informally. Few internal R&D units have started experimenting with open source software, thereby creating the potential for first-use cases and new levels of confidence, possibly even opening external barriers in the long run.

In sum, barriers to accelerated value co-creation arise from non-disclosure agreements (NDAs), which effectively express mistrust among partners. An NDA sign-up process for new partners (suppliers, collaborators, maintenance, ...) may take up to six months and require new partners to respect certain levels of confidence (i.e., in-house, partnerships, publications, ...). Naturally, sharing internal knowledge with outsiders, breaches legal restrictions enforced by the employment contracts.

Kreatize also reports a rather low level of knowledge flow. The start-up defines clear roles and responsibilities. Its engineers are especially important for validating CAD designs from OEMs to suppliers (outside-in knowledge sharing), and the feedback on design returns (inside-out knowledge sharing). This feedback would naturally help the OEMs to improve their quality, sustainability, and prices, however inside-out knowledge sharing is moderated by Kreatize’s closed platform approach as their engineers and account managers unilaterally filter and process design information and feedback: that is, information flowing from suppliers to OEMs.

“Originally we had an entirely open platform, but we gradually closed it. Now the connections between customers and suppliers are kept completely separate.” In sum, most knowledge flows, in both directions, are managed unilaterally without directly engaging collaborative input from either OEMs or suppliers. Therefore, no real enrichment of knowledge is being observed. In the meantime, the closed platform model enables Kreatize’s dynamic pricing, as mentioned in the case overviews.

In 2012, Renault set-up an innovation ecosystem: a purposive structure of internal, external and mixed labs serving as platforms for value creation complementing the existing co-creation with outfitters, suppliers, and car body makers. The goal was to boost non-hierarchical, *“fuzzy spaces challenging traditional processes”*. Open labs, in the heart of innovation hubs such as Silicon Valley, Paris and Tel Aviv, are in direct contact with start-ups, entrepreneurs, and universities. They serve to scout topics, which are folded back into the organization. Creative labs serving to break internal silos and put the *“thinkers with the makers”* are spaces mostly dedicated to digital production. Finally, Trade labs serve to deepen knowledge sharing in the spirit of Lave and Wenger’s situated learning concept (1991). Additionally, Twizy Contests have started to be held in French schools and universities.

Internally, new operational ideas are cultivated and nourished through presentations, seminars and workshops. Finalists of internal contests, such as POM Twizy, receive long term support from the innovation and creativity divisions.

The labs’ principal function is to foster an internal, organizational openness. The knowledge flow remains unilateral; as is the case of efficiency and user-centric business models, the firm siphons external knowledge into the company’s R&D system. POM Twizy’s CAD files are currently shared but the original equipment manufacturer (OEM) know-how is not. *“In this type of information sharing, the goal is to enable people to make, not to diffuse the company’s knowhow.”*

In our study, an even higher support of knowledge flow is demonstrated by Local Motors. Knowledge flow here is multilateral. The former start-up has spent years learning how to orchestrate a globally dispersed crowd of innovators and how to support their work through a platform to co-create engineering products. To do so, it has set up units dedicated to co-creation, mobility innovation, and additive manufacturing. Accordingly, these units operate on four instances of Local Motors’ newly introduced collaboration platform.

Given that new knowledge usually evolves around so-called challenges that are released on the platform, Local Motors' hardware related knowledge increases with the knowledge co-created on that platform. Every time a challenge ends, all designs are shared openly and under a free commons license, as was the case for the Olli bus. In other words, we observe an enriching of knowledge nourished by voluntarily contributing co-creators and Local Motors employees, which leads to new hardware innovation.

Furthermore, Local Motors conscientiously communicates the results and the chances of OSHW innovation to prospective partners from large corporations. "*We would like to collaborate and co-create even more with large corporations. Often there is no C-level buy-in and those open innovation initiatives do not survive.*" Put differently, successful sharing of inside-out knowledge, results in more successful product innovations on Local Motors platforms, jointly with third parties and co-creators. Value is being created mutually with the crowd. Yet, sometimes sharing knowledge that has been created with large corporations, depends on formal agreements.

5.3.2.3. *Value generated by collaborative capability*

With Kreatize, the degree of openness being controlled from within implies a lower level of collaborative capability: as platform owner, Kreatize takes responsibility for platform content, communication, and exchange. In addition, all platform contributors (suppliers) are monitored for quality. Despite this, Kreatize reports a positive learning curve based on the unilateral knowledge sharing and on collaboration from both OEMs and suppliers in collaboration with the platform itself. It appears that only when the platform was closed, value-capture became possible.

VW displays a comparatively higher level of collaborative capability. First, open innovation initiatives - like *MOIA*, an electric shuttle-bus and VW spin-off, or *Gett*, a taxi service similar to *Uber* without the private drivers - indicate VW's awareness of the need to open up. The objective of these inside-out driven initiatives is indeed to develop new business models. Understandably, those interviewed did not mention outside-in approaches when it came to VW's core competency of manufacturing. In fact, they stressed their closed production lines, which did not yet permit access to open production possibilities from additive manufacturing. The absence of structures and processes with regard to OSHW also became evident from statements like: "We have neither a strategic agenda nor any particular goals when it comes to this subject." In sum, we did not find combined processes to leverage collaborative capabilities

with regard to OSHW and while new business models might evolve from spin-off initiatives, the Corporation itself follows a closed governance approach, enforcing knowledge retention within and leaving out any strategic goals in relation to OSHW.

Renault's aim is clearly to build collaborative capabilities. The firm's initiatives display incentives to overcome the "not invented here" syndrome and to further collaborative capabilities. The manager of internal Fab Labs explained that the three layered innovation ecosystem serves to foster organizational openness. *"We are trying to render double-loop learning an organizational competency to foster on-going learning capacities, to be able to change the way we organize ourselves in phase with what happens"*.

OSHW is one of the themes being supported by such labs. It is additionally driven by internal contests or public hackathons, culminating with the *"Pitch and Poc"* victory for the POM Twizy in 2016. The official company discourse on strategy, driven by Renault's CEO, is more centred on connectivity, automation, and electric mobility. Here, open innovation is understood to be a methodology that infuses the company's processes and enables platform value creation with external actors. The ultimate goal is to create platform spaces for value creation inside and outside of the company.

Three key indicators appeared particularly salient in the interviews with Renault as regards organizational processes. The first was the notion of measuring success by the internal awareness level of the POM Twizy; that is, by disseminating information on the project through presentations in order to reach a tipping point of adoption. However, those interviewed insisted that a lot of effort is still required before decision makers declare the project a full-scope activity. The second key indicator, is that employees within the company need to be acculturated to new business model types, including those specific to OSHW. Simultaneously, it becomes necessary for them to be enabled to question the existing business models. The third indicator, and a necessity, is to have promising projects illustrating innovation and its impact on the business model of the firm.

Benefits from open innovation for Renault are clear. The questioning of this methodology has brought forth the satisfaction that co-creation with suppliers is part of Renault's DNA. What is new, however, is involving customers and users in this process. Direct events such as hackathons provide mixed results. The resulting innovations of a two-day happening aren't

necessarily ground-breaking, but they provide a festive lever for further innovation and talent spotting.

Local Motors - attributed the highest level of collaborative capability - even captures value from its co-creation capability downstream by managing platform instances for large firms like GE and HP. Unlike most other SaaS system suppliers, they are giving all users access to all instances of the co-creation platform. Herein, Local Motors allows customer facing brands like HP to recruit talent on their far-reaching platform. In the meantime, users upstream are engaged in more challenging projects closer to the core of the Local Motors brand.

To manage these projects, Local Motors emphasizes a high level of open information sharing across all units and time zones. Additionally, they enforce constant quality control by asking co-creators to fill-in their information details and to rate their inputs. However, they regret that "there is not yet a consciousness about the importance of publicly sharing feedback to ensure joint learning."

Finally, they conscientiously administer knowledge gathered on platform engagements to trigger corporate awareness of the advantages of open source hardware. This includes promoting access to talent on platforms, the ability to develop new products quickly and at low costs with high, and possibly malleable, product results.

In sum, we find that our cases differ notably as regards their levels of co-creation, knowledge flows, and collaborative capabilities, which helps better understanding how they plan creating and capturing value from their open source hardware initiatives (see Figure 33). Meanwhile, we also detected many challenges that arise along the path of opening.

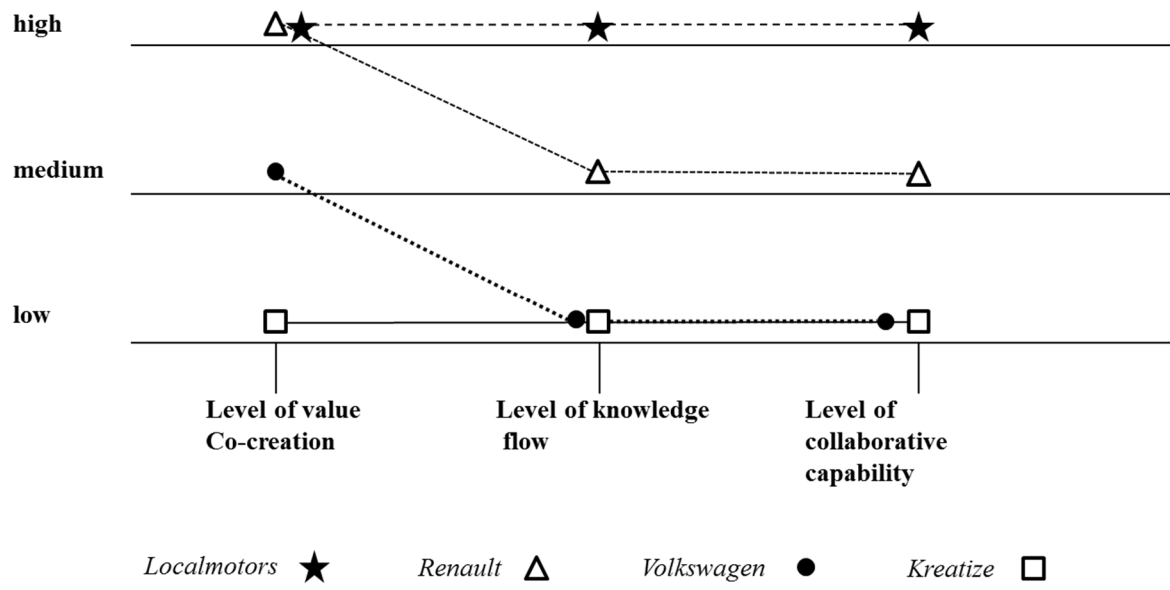


Figure 33: Open innovation strategy profiles in a cross-case analysis for the automobile industry

5.3. HOW OSH INITIATIVES LEVERAGE ECOSYSTEM INNOVATION GROWTH DYNAMICS

Our findings disclose values and processes required for the growth of OSH initiatives in the Barcelona context. To develop in scale and impact, OSH projects must be supported. Essentially, they need to retain their community-building process, while tapping into the soft links that will permit developing the network of stakeholders, access to funding, credibility, and projects that answer people's needs.

5.3.3. SHARED VALUES

Semantic analysis revealed an abundance of terms related to values, and to what stakeholders considered important around the themes of “making”, “freedom” and “collective innovation” (Table 17).

	Occurrences	Including related terms
Citizens	367	People-centered innovation
Empowerment	255	
Fab Lab	239	Participative democracy
Open Technologies	214	Importance of being able to access, use and modify technology to fit one own's purpose
Innovation	136	Collective innovation
Sovereignty	54	Technological, food and economic sovereignty as well as all the lemmatization from freedom

Table 17: Detail of terms related to values

Obviously, the point is not to single out core principles to which everyone must pledge allegiance. In 1990, Elinor Ostrom herself, explained that the commons must be upheld by a variety of different values. Nevertheless, taken together, these terms do somehow constitute a common front. Ron Eglash, at the Fab City Summit, explained that values are like “*Olympic rings that don't all intersect in the same spot*”. According to the Barcelona CIO, the common front of values held by Barcelona citizens serves to ensure that “*technical revolutions will serve the common good. This is a big challenge, which is all about confronting the present power games and the power concentration that we see in the digital space, and making sure to decentralize it and give the power back to the people, so as to democratize production*”.

As the CEO of the Fab Cafe explained, *“I think everyone has his own drive. There are different motivations behind it. There is always an overlap. So you can always find things in common, like “Oh we can do this together at the Fab Caf  ”*. Nevertheless, the most important part is the *“community and the sparks and new synergies that happen when people come together”*. The value that OSH innovation brings is the shift in mentality from the consumer mindset: going to buy a table at Ikea, to a creator mindset: *“whenever you buy a machine that is able to make a table, that machine -- or that way of thinking -- allows you to think that you can make a building, or a whole city!”*

5.3.3.1. *Creating tech for people*

What appeared interesting in the interviews is that Barcelona’s long legacy of people-centered innovation and technology is still present today. As the credo says, *“necessity is the mother of invention”*. In 2011, hit by the financial crisis, Spain almost left Europe. At that time, the founder of the IAAC (Institute of Architecture) and the Fab Lab Barcelona (the first in Europe) was appointed Chief Architect of Barcelona. Under his supervision, the city decided to make one Fab Lab (Ateneu de Fabricaci  ) per district under the mantra: *“Barcelona will be a self-sufficient city with productive neighborhoods at a human speed within a hyper-connected and zero-emission metropolis”* (Guallart, 2016).

A Program Manager from the office of Technology and Digital innovation, explains that the city has gone through waves of tech-for-tech. The initial smart-city paradigm was very technology and big-tech driven *“with connectivity and sensors everywhere”*. However, since the benefits for the citizens as well as their understanding of such initiatives were questioned, the paradigm of the last mayors in office, is completely different. Thus today, the avowed goal of the Barcelona City Council is tech-for-people, putting citizens first with technology to improve their lives. The CIO explains: *“We thought that we [should] start with real things that matter to people. In the case of Barcelona, this is about affordable housing, it is about health care and making health care universal, it is about sustainable mobility and making sure that we fight against climate change, creating air quality and more public space; and mobility across the city”*.

5.3.3.2. *Sovereignty*

For the Dimmons Director, it is indicative that the density of cooperative platforms in Catalonia is the highest in Europe, and that many of them are called “Som”: *“som energia”*, *“som connexio”*, *“som mobilitat”*- meaning *“we are energy”*, *“we are connectivity”*, *“we are*

mobility”. Not only do these initiatives fit with what matters to Barcelona citizens, but they also reflect a desire for sovereignty: technical sovereignty, “*which means empowering citizens, and building technology that serves citizens*”, political sovereignty and food sovereignty. In her words “*platform cooperativism gives credence to economic gain and technological sovereignty such as is used in the commons.*” In other words, successful OSH initiatives work on tech-for-people projects that tap into a common front of values resonating with technological, food and political sovereignty.

5.3.4. GROWTH PROCESS

Once, this tech-for-people core value established, our findings revealed a process through which OSH projects can pass and grow, while tapping into values shared. Like the ball in a pinball machine, OSH initiatives need to bounce and interact with the different stakeholders in the Barcelona OSH ecosystem: to get funding, to join the city’s *middlegrounds*, to integrate the community and its ecosystem, and to build a strong network and consortium. The steps of the process are: 1) have a tech for citizen projects; 2) answer government calls; 3) join the *middleground* and 4) build a consortium. These can happen simultaneously (Figure 34).

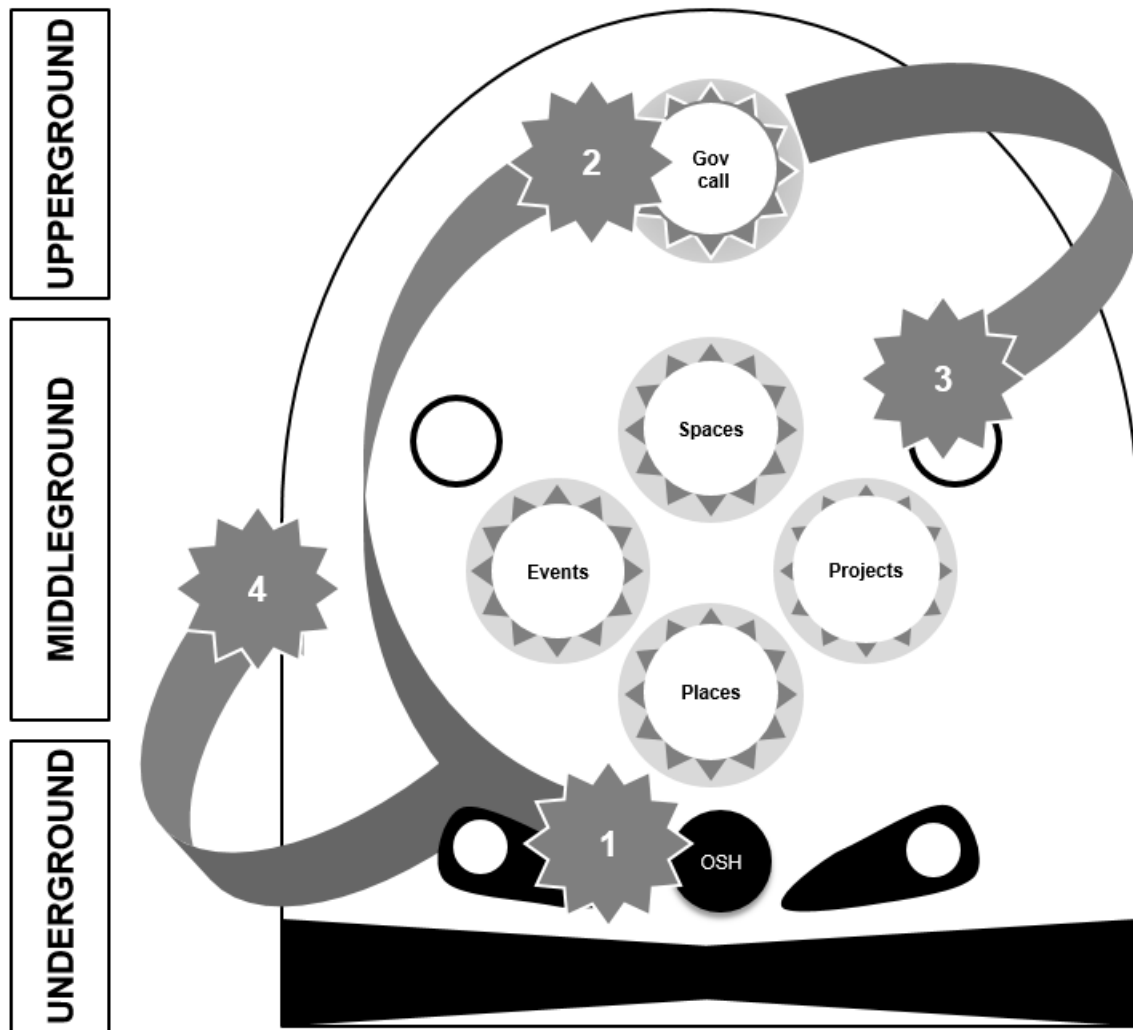


Figure 34: The pinball model. How to leverage an ecosystem for growth

As projects iterate through rounds of interaction with ecosystem stakeholders, they grow and become more valuable. The notion of scale for growth among those interviewed was not interpreted as how to turn OSH initiatives into Fortune 500 Companies, but rather as how to reach the tipping point, where a niche project becomes one which is useful in improving the lives of everyday citizens.

5.3.4.1. Answering government calls

For a community-based product-development project using OSH to grow, our interviews revealed that a good first step is to answer government calls. Examples, such as the Barcelona City Council's subsidiary lines, or the Comunicadora incubation program, are means by which underground projects can signal to the overall ecosystem a willingness to grow from their niche to being of service to others. When the *middleground* concept was explained to one

stakeholder, especially the notion of creative roots from the underground, he answered: “*I think that the argument of the roots is not correct. The flow is not always from the roots to the top. Sometimes the flow comes from top to down. To make a revolution, you must have good people pushing from the underground but you must also have good people in the government*”. Of course, the question is not to have a single individual reaching out for government help, but rather a community-based OSH project moving through technological readiness levels. The idea is to connect the people leading a novel project (*underground*), with those in government who can make regulations to ease the adoption of the innovation, and offer financial support and coaching (*upperground*). This step is also a check as to whether your “tech-for-people project” echoes what the government considers important.

5.3.4.2. *Taking part in the middleground*

The second step is to join the city’s *middleground*. The Makers Matins for instance, instigated by the Barcelona City Council is a *middleground* around digital production and open technology that serves to boost and consolidate existing projects. One program manager explains: “*We are not trying to just generate new things, but we are saying, ok you are doing that, so let’s scale your project. Let’s have you not work alone but work with people who are working on a similar matter, and try to collaborate with them, and when the next call for projects comes, let’s build a project together*”.

There appears to be a concerted effort to foster multilevel interaction by putting individuals with good ideas in contact with governmental entities creating regulations to “make it happen” and to shift the paradigm from top-heavy to bottom-up. For example, all the projects selected for the 2018 call for collaborative platform projects, will be uploaded on the Goteo platform. Pass a given threshold, the City Council will double the money to allow the projects to scale: “*We are multiplying the impact, by just mixing all the players, and putting money there.*” This measure ensures citizen engagement. Not only liking the projects but also investing in them is clearly a government initiative to ensure this.

Our research reveals the innovation dynamics that abound in Barcelona: from coworking places to makerspaces and Fab Labs and all the other places which cultivate community building, sustainability, and knowledge sharing. The concept of the *middleground* appears to be multiplied in this very dense city with a strong heritage of social capital, experimentation, and mobilization. *Middlegrounds* here seek to encourage collective innovation with the goal of improving the city’s energy, resources, and information management. Their multiplication

results from current events ranging from resilience mechanisms to the financial crisis, to the Internet revolution and to the associated system decentralization.

Many people interviewed mentioned that this phenomenon also has historical roots in Barcelona's anarchistic past. In the twelfth century, any slave who could escape to Barcelona, live peacefully for a year and a day, became free. The Ateneu Barcelones, founded by anarchists in 1906, is a third-place with an incredible library to encourage idea sharing. In itself, the word Ateneu is indicative, since Ateneu de Fabricació was chosen as the name for the district Fab Labs. Jordi Reynès, responsible for them, translated the meaning to "Athens" in homage to the cradle of democracy -- in essence setting the basis for democracy by putting production back into the hands of the people. The Barcelona CIO explains:

« This is why Barcelona is experimenting with a large-scale, participative democracy program. What this means is that we believe we need to integrate collective intelligence in the way we make decisions in government, in the way we make policies. Barcelona is running 11 participatory processes at the moment. The entire government action plan was made with the input of citizens. 70% of the actions we run today in the government of Barcelona, on the policy agenda, came from citizens themselves. »

5.3.4.3. Building a consortium

The third step needed to leverage growth in OSH ecosystems is to build a strong consortium. This is a key to credibility and to making more solid projects, thereby engaging more support from *upperground* stakeholders. This notion was repeated as an indicator of success from crowdfunding platforms, to the Barcelona city council, and the accelerators. "The first thing that you have to do is to apply to the [City Council's] subsidiary lines in order to finance the project; but in parallel, go to the Matins Makers and the regular meet-ups to know what the ecosystem is, because one thing that we take into account when we evaluate a project is if there's a consortium there". A consortium ensures the project be perceived as more valuable with the engagement and collaboration of different people, with complementary expertise, business partners with stakes in the technology and a good number of contributors who participate in its development.

The novelty of OSH and the Fab City approach is the local-global pipeline. OSH communities, by definition, are nourished through both online and physical platforms, creating both local and global reach. Aquapioneers, for example, was one of the first projects in Spain to originate in

a Fab Lab and become a business. Aquaponics³⁴ were unknown in Spain at that time, and the founders of the start-up were foreigners to Barcelona, thus the project did not have lots of local traction. However, the Ulule Crowdfunding Platform decided to take it on because it had a strong network of support “from MIT, and from the international Fab Labs”. Github³⁵ downloads are therefore now used by the Barcelona OSH ecosystem stakeholders to measure overall global impact.

The Ship2B social innovation accelerator further reinforces projects selected from their open calls by pairing them with local, established firms. These are interested in the open innovation that could result from the encounters in terms of discovering new technology, but also in boosting traditional processes with “dynamic young entrepreneurs”. They mentioned that initially, start-ups entered the program because they sought support from established corporate partners “...and now it happens the other way around. We have founders and new companies who want to join the lab because of the startups. So now it's becoming a virtuous circle”.

5.3.5. RISKS

5.3.5.1. *Links between tech and governance*

A main risk identified is that open technologies do not necessarily translate into open governance. This was echoed by Guido Smorto, a member of the Dimmons research team, and by Primavera de Filippi (2018) on the topic of blockchain technology: “the decentralized potential of blockchain technology does not necessarily mean that it will be used in a decentralized manner”. The so-called sharing economy has seen the rise of extractivist monsters very different from the generative justice Ron Eglash speaks of. What is the risk that the same happen to open technologies and to OSH in particular?

The point of OSH is that a “community can come together as a collective to produce things that couldn't be produced in isolation”. Technology cannot be civically led if no citizens are involved, and if in reality it is led “by just a few males who sit [...] with their MacBook Pros, assuming that the rest of society will behave according to their vision of it, we inflate this technological field, and in many cases, we are not really considering the impact it may have on society. Where is the data going, and is the data even meaningful? How confident are we

³⁴ Aquaponics is a system that combines conventional aquaculture with hydroponics (cultivating plants in water) in a symbiotic environment.

³⁵ Github is a hosting service offering distributed version control and source code management. It provides collaboration features such as bug tracking, feature requests, tasks management and wikis for each project.

that this data is robust and reliable? These questions have not been asked, and therefore not answered”.

Our findings reflected the concern for the thin line between narratives on open technology as “smokescreens”, creating hype out of something that is not ready yet, while at the same time needing to rely on stories and media coverage to get citizens interested and involved in OSH technologies. The importance of narratives was stressed in helping a society become ready and able to imagine, and therefore, to create something new. At times, the media will exaggerate the tangibility of a given innovation. For example in the case of the Citizen Kit, “*(in essence), the sensors [at the time] didn’t work and it was impossible to set up*”. Yet, narratives contribute to making a society ready for a new idea. “*Right now Barcelona is pioneering new narratives ... [that come] equipped with prototypes. Now this changes everything. Citizens realize they have the right to produce their own food, the right to produce their own energy*”.

5.3.5.2. *Quality of the middleground*

In answer to the risk of misusing of open technologies, the Office for Technology and Digital Innovation, with the DIMMONS Institute, are making a concerted effort to create and put in place ethical, digital standards³⁶. Just like the insalubrious cities of the past were improved via human-centered urbanism, ethical standards need to be applied to distributed digital platforms and commons-oriented initiatives in order to ensure that they are indeed, benefiting the common good. The CIO explains:

“We really think that the lack of trust, the crisis of our contemporary, liberal democracies, can only be fought with participatory democracy [...] To do that, of course, the main challenge is changing governments, it's changing institutions, it's changing our policymakers. It's making public institutions a place where citizens feel they are empowered, and they can track what's being implemented and how their money is being spent. And they can really make sure that we are building more smart, equitable, democratic cities. So not top-down, not from the big tech kind of interest, but bottom-up starting from citizens' real needs [...] what we are doing in Barcelona, is that we are creating ethical, digital standards to transform governments. This means that we have some principles in mind. We are creating new clauses for public procurement contracts. It's not very sexy but it's super important and this is what we do in government. We spend citizens' money in order to deliver

³⁶ As part of the DECODE European project.

better services [...] And let me end with the fact that we need more women in tech, and as our mayor says, we need to feminize politics meaning we need women at the core of politics and technology”.

Therefore, the goal is set to multiply *middlegrounds* and to foster their pro-democratic qualities by making sure they represent the diversity of Barcelona citizens and integrate collective intelligence.

5.4. CROSS-LEVEL ASSESSMENT

Our multi-level analysis on each separate tier of OSH ecosystems revealed interesting and specific information. However, we also wanted to gain a holistic understanding of all the twenty seven OSH endeavors studied. We therefore decided to use the Open-O-Meter devised by the OPEN! Team, complemented by the Sharing Star Framework devised by Fuster & Espelt (2018). Additionally for more specific focus on business models we sought to use the dimensions through which Troxler (2010) analyzed the Fab Labs business models.

The following cross-level analysis seeks to identify patterns in OSH hardware business models by combining data collected during the first two phases of our research: the community-level phase and the community-firm interaction phase. These initiatives are assessed in light of their governance and economic models, their knowledge policies, and their aim for impact.

- Interviews on 23 OSH initiatives were carried out from May through December 2016
- Interviews with employees and stakeholders of four 4 automobile actors were carried out from March to November 2017.

Although we did keep in touch with many initiatives and sought feedback on their Open-O-Meter and Star-Framework assessments, some of them have since closed-down. Therefore, the present analysis may not reflect current project reality.

What is interesting in this cross-level analysis is that, by delving deeply into OSH business models, we have been able to observe how they have mutated from the business canvas representations of Osterwalder and Pigneur, (2010) or Jouison & Verstraete (2008).

5.3.6. GOVERNANCE MODEL AND REVENUE STREAMS OF OSH INITIATIVES

In this study, the 27 initiatives and firms that we followed, and were able to interview (23 OSH projects and 4 firms), were based in France, Germany, England, the United States, Finland, Spain, and Estonia.

	Americas	Europe
Location	2	25

Table 18: Geographical Sample Description (N=27)

Analyzing the projects according to their legal status reveals an extraordinary variety from registered businesses to non-profits and hobbies. In terms of governance (Figure 35), the type of legal entity covers the range of enterprises (8), social businesses (4), non-profits (9) and includes a hybrid form (3), where the initiative, as a mid-goal entity, can be registered as a business and as an association or non-profit.

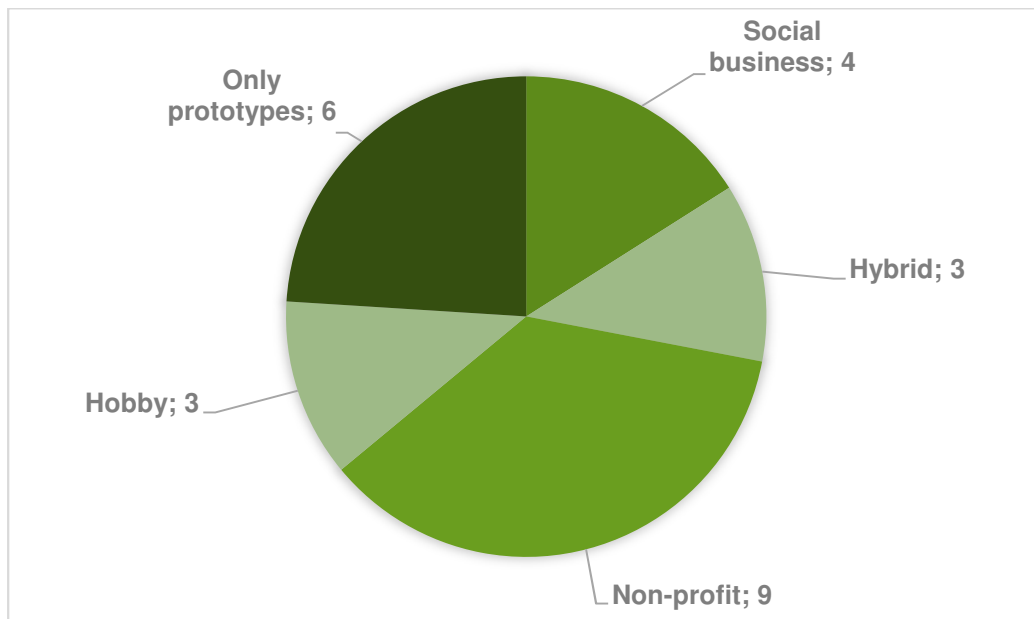


Figure 35: Governance: Type of legal entity of OSH initiatives (N=27)

Three projects were hobbies and had not pursued ambition to scale. Six projects were at a very early prototype phase. From the interviews, we were able to appreciate how the project members juggle between the for-profit and not-for-profit forms available in their different countries.

Over time, certain projects had shifted from one status to another. The blurring of boundaries between a customer and a key partner, discussed as a formal characteristic of open source

business models, had extended to the distinctions between profit and non-profit, between the community and all its stakeholders.

Essentially, as seen in most projects (17 out of the 27) have not-for-profit objectives (see Figure 36), yet they also need to cover costs inherent to hardware (material, equipment, wages....). Other projects consider a commercial strategy (e.g. based on product selling) as a way of strengthening their activity as well as the open source movement as a whole. The UK Community Interest Company legal document was one of the favored types as it provides a mix of company and non-profit legal forms. The notion of open source is still fairly new; project initiators have to justify why their projects are commons-based and why they are non-profit.

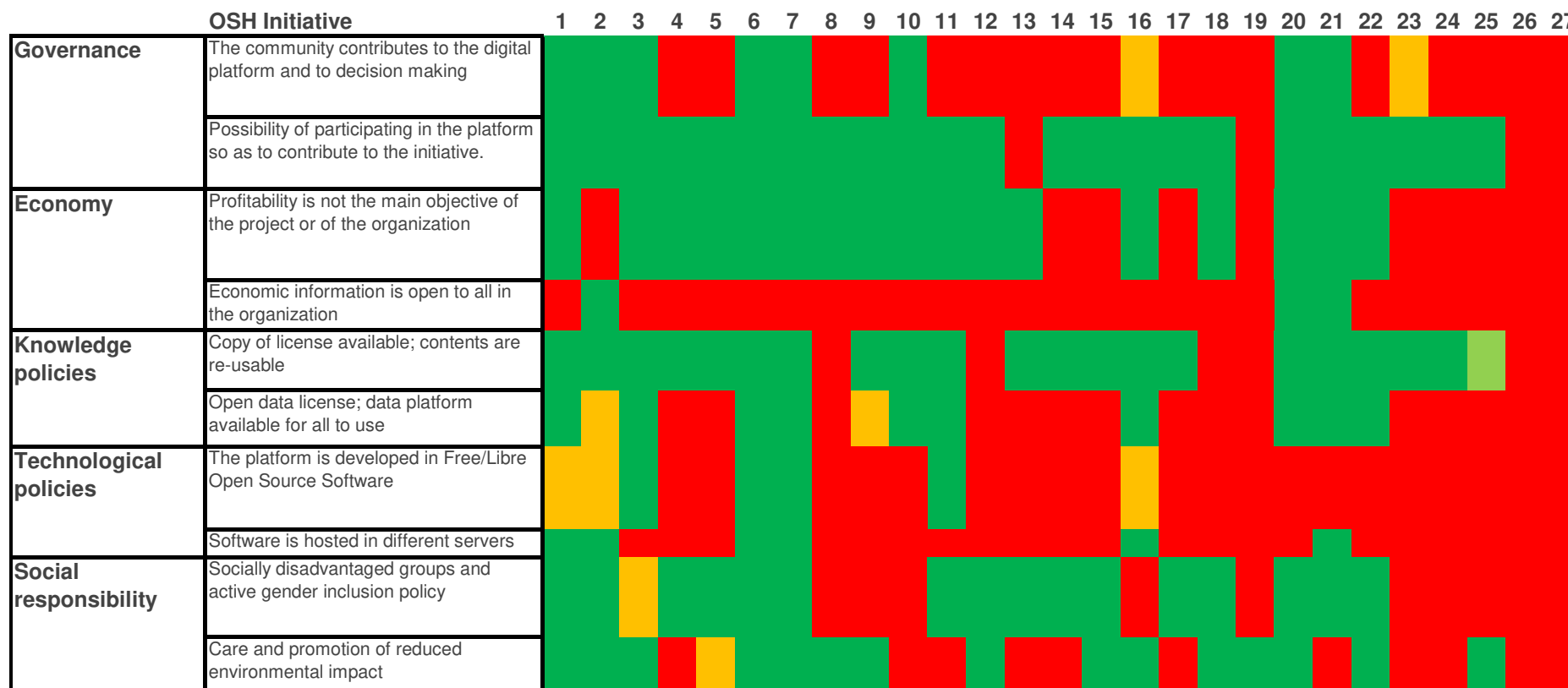


Figure 36: Commons Star Framework assessment of OSH initiatives (Green = yes; Red = no; Orange = getting there)

Figure 37 shows the types of revenue streams activated by the different projects. Most of them relied on 3rd party funding which included direct donations, governmental or corporate sponsorship and crowdfunding. The latter, described by one person interviewed as “one of the greatest innovations in finance in the last century or more”, is considered a means of decentralizing innovation so anyone may develop his ideas. Sales were cited as the second source of revenue streams, taking the form of kits and workshops. Many projects, still in their early stages, were self-funded. When looking for financing, those interviewed had found a cultural gap separating open-source, the banking sector and venture capitalists.

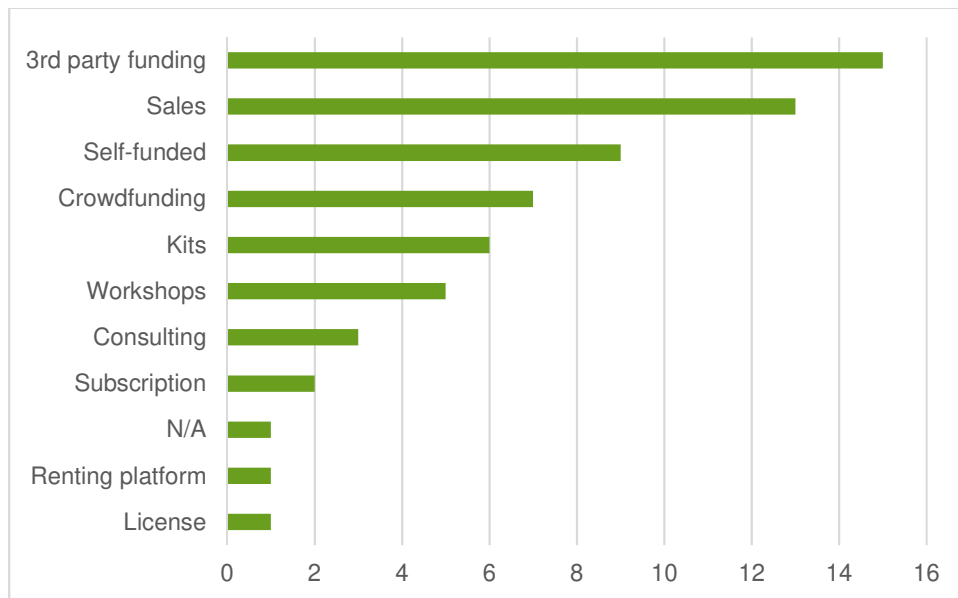


Figure 37: Economic model: revenue stream types

“Classical venture capitalists, have a problem with open source. And even if institutional funders do exist [...] they want people to make intellectual property, to save it, to have patents and whatever. They don’t like [...] open source.” The OSH approach is at odds with the conventional mindset seeking to secure income through protection of intellectual property. Exceptions are accelerator programs run by BNP Paribas or network ecosystems searching for startups in specific fields. Such is the case for the multinational company, Aguas de Barcelona, and its partnership with the Ship2B accelerator program.

Revenue streams are linked to the innovation ecosystems of which OSH initiatives are a part of (see Figure 38).

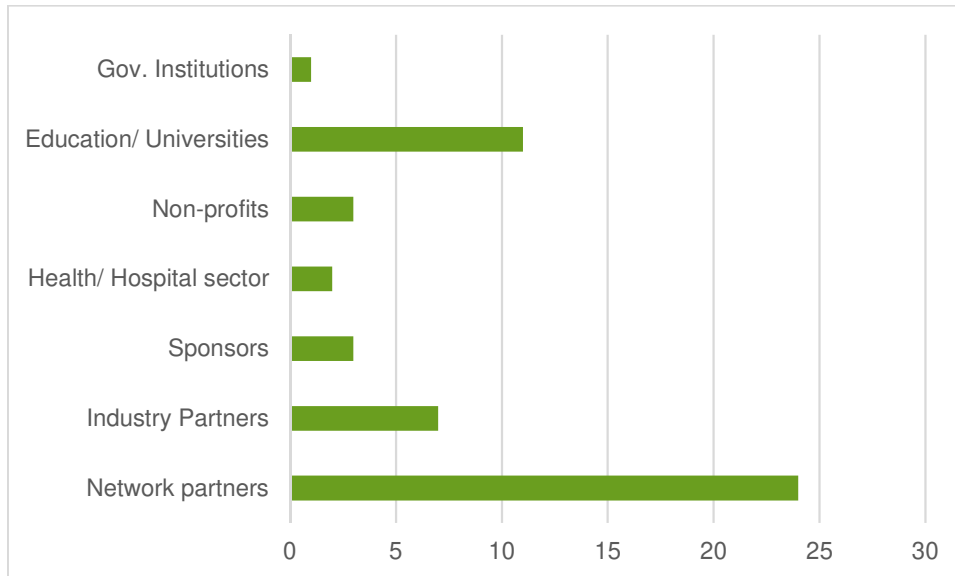


Figure 38: Innovation ecosystem of OSH initiatives

It is no surprise that nearly all projects depended on their network partners (25 out of 27), which consist of local and global communities using tools, such as Github, or thingiverse, to share building plans, assembly instructions or bills of materials. The 2 projects which didn't rely on community network partners, were the closed, firm-based automotive projects, where either the OSH initiative had been closed down, or the company was still in the process of scouting to discover whether or not they wanted to build it. From the partners listed in Figure 38, we can definitely identify the main *middleground* players: education and universities (11) including STEM programs; industrial partners (7), sponsors including art residences (3); the health and hospital sectors (2); non-profits (3); and government institutions. Assistance provided by such a network ranged from financial support, to accelerator programs, and to endorsements helping to give projects more credibility.

5.3.7. KNOWLEDGE POLICY

Licenses enabled or disabled Open Source collaboration, yet many people interviewed were uncertain concerning the license to choose. Respondents felt there is no good hardware license currently available. An appropriate open source hardware license remains a riddle to many dealing with the distinction between patent law (hardware, industrial applications) and copyright (text, images, software, works of art and of the mind). The idea being that the mind-work is naturally closed and should be opened through a license for use by others. Conversely a patent “is born free” and is closed through a license. At this time there may be no good open

source hardware license. According to the community, the situation for software may be easier and better, but like for hardware, there is nothing good on the market right now.

In our study, the majority of OSH projects were covered by copyright licenses such as Creative Commons, CC-BY-SA (attribution share-alike license), GNU GPL, or the MIT license (see Figure 39),

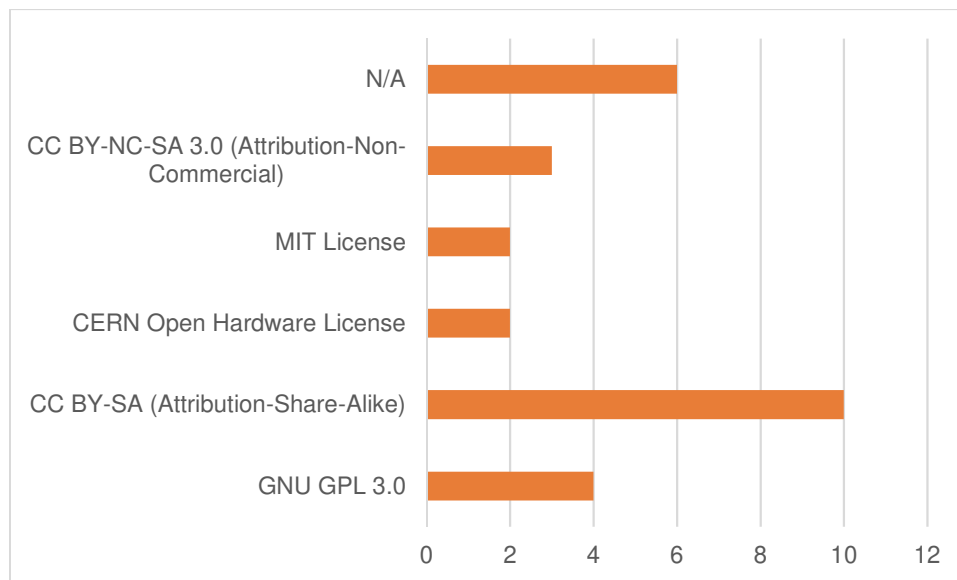


Figure 39: Knowledge policy: User-generated content license

meaning that, although the OSH product is hardware, a mind-work license was being used for it. Arguably this would be a first stage before progressing to a hardware license. For instance the Apertus Axiom project diffuses their conception plans through separate licenses. "All of our software is released under the [GNU General Public License V3](#), all our documentation under the [Creative Commons License](#), and all hardware under the [Cern Open Hardware License](#)."

The CC-BY-SA license means that anybody may copy and fork the project providing they acknowledge the paternity of the original inventors, and then share it using the same license. The second, most used license is the GNU public license, directly derived from software with Richard Stallman's initial, legal hack.

From the list, the only license that applies to patents, and is therefore applicable to technical hardware, is the CERN Open Hardware license used by two projects.

Discussion of the CC BY-NC-SA copyright license, where NC stands for “non-commercial” sparked a heated and somewhat divisive debate. Some respondents felt strongly that this “NC” clause signals “do not copy me” and therefore should not be associated with open source hardware. Especially since the OSHWA definition is: “Open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design“. Others felt that the “NC” clause protected against “industrial trespassing”, meaning the risk that an enterprise would come along and close an innovation that had been collectively developed for the common good. Such proponents, said they had no issue with someone replicating their design, or going to a Fab Lab, or a metalsmith shop to have the product made, and they even encouraged it. They just wanted to prevent an industrial player from drawing margins and profit from a collective innovation.

Figure 40 attempts to map a correlation between the legal status of the OSH initiatives studied and their Open-O-Meter score (see Table 19). Social businesses, hybrid mid-goal entities, non-profits and hobby projects tend to have higher Open-O-Meter scores (>2). Exceptions are the Raidlight Responsiv Backpack OSH initiative as it was coached by members of the OPEN! Project; and the Waterzilla and LUDD 21 projects, since, at the time of the interviews they were still in an early prototype phase.

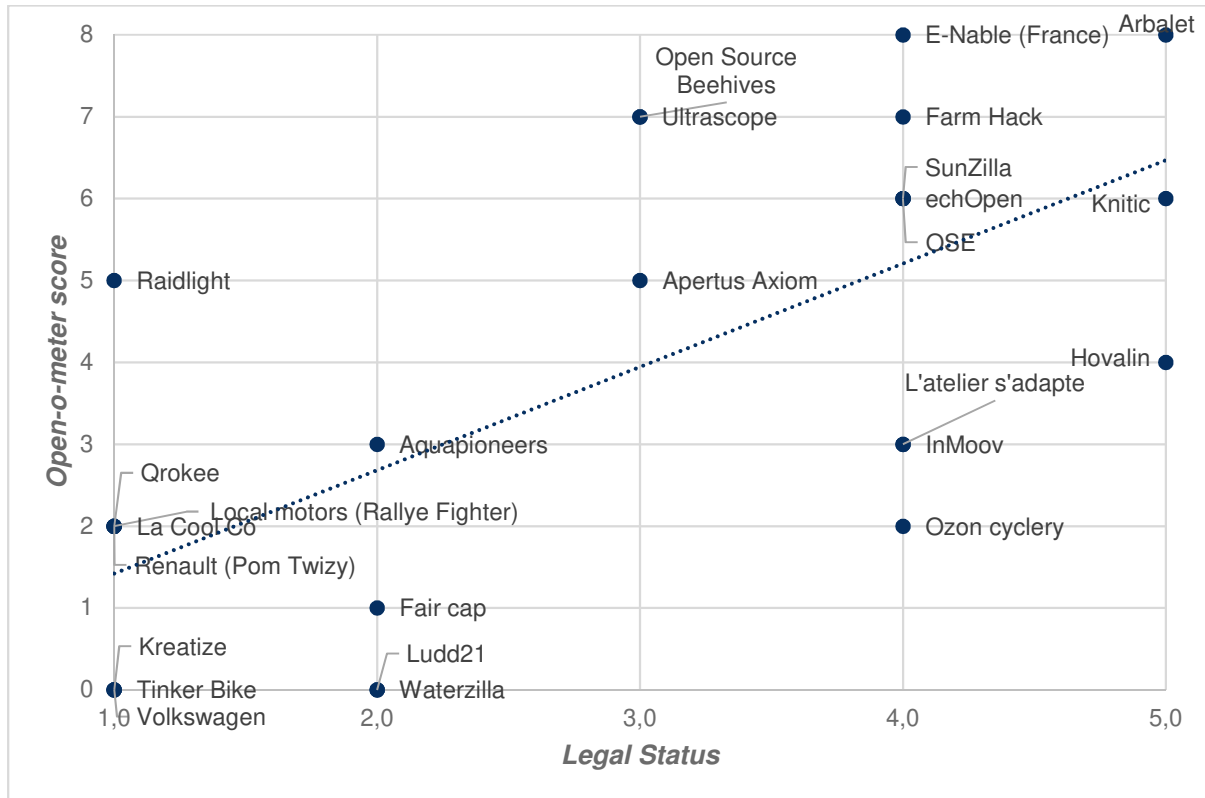


Figure 40: Correlation between legal status and openness

The Fair Cap water filter is an interesting case. The project started during the POC 21, 2015 innovation camp for open source hardware³⁷. The initiative is part of a growing “maker movement for humanitarian innovation” seeking to use the power of decentralized problem solving to address needs related to emergency relief, health, energy, food, housing or education. The founder explains that “having a lower development cost and being open, means that those economic savings can be transferred to the end user, hopefully by offering high quality products at a much lower cost³⁸.” The Fair Cap, Open-O-Meter assessment ranks the published assembly instructions for the 3D printed prototype³⁹, with a score of 1. The founder explains: “3D printing was a key tool for experimenting, prototyping, and generating ideas, while the open maker culture of innovation was key for the final product design.”

Yet water filters destined for disaster relief, cannot be printed in a local Fab Lab as they must conform to very strict quality and safety regulations, ensuring that they are indeed capable of

³⁷ <http://www.poc21.cc/>

³⁸ <http://faircap.org/faircap-open-design-and-innovation/>

³⁹ <https://www.instructables.com/id/Open-Source-3D-Printed-Water-Filter/>

filtering life endangering bacteria like E.coli. The requirements for open source hardware and digital manufacturing for humanitarian innovation are “quality, speed, reliance, food-contact regulations, effectiveness, high volume production, and costs”.

The imperative for industrial production in this case also meant coming face to face with incumbent companies who had no desire to let a cheaper alternative enter the market “because there was no economic incentive to do so, which is strange considering that people’s health could be improved even if it’s not a question of saving lives”.

OSH Initiative	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
Do they allow partial or full redistribution for non-commercial purposes? Do they use a legal license that allows users to redistribute without economic gain?	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red	Red	Red	Green	Red	Red	Red	Red	Red	Green	Red	Green	Green	Red	Red	Red	Red
Is the published bill of material editable? The bill of material is published in editable format	Red	Green	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Red	Red	Red	Green	Red	Red	Red	Red	Green	Red	Green	Green	Red	Red	Red	Red
Is the published assembly instructions editable? The assembly instruction is published in editable format	Red	Green	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Red	Red	Red	Green	Red	Red	Red	Red	Green	Red	Green	Green	Red	Red	Red	Red
Are the published design files in editable format? One or more of the file formats used is editable	Green	Red	Red	Green	Green	Red	Green	Red	Green	Red	Green	Red	Red	Green	Green	Green	Red	Red	Red	Red	Green	Green	Green	Red	Green	Red	Red	Red
Is the contributing guide published? A guide for how users can contribute is available	Green	Green	Green	Red	Green	Red	Green	Red	Green	Red	Green	Red	Red	Green	Red	Red	Red	Red	Red	Red	Green	Red	Green	Green	Red	Red	Red	Red
Is the bill of materials published? The product bill-of-material is publicly available	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red	Green	Red	Red	Green	Red	Red	Red	Red	Green	Red	Green	Green	Red	Red	Red	Red
Are assembly instructions published? Instructions for how to assemble are publicly available	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red	Green	Green	Red	Red	Red	Red
Are design files published? Technical components of the product is publicly available (CAD-files, computer code, schematics ect...)	Green	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Open o-meter score	5	6	7	4	6	6	7	2	6	7	8	1	3	3	2	7	2	0	0	0	8	3	5	2	2	0	0	

Table 19: Open-o-meter assessment of OSH initiatives (Green = yes; Red = no)

Figure 41 reflects the original open-o-meter assessment devised by the OPEN! Project team. It doesn't include the following two questions, added in the REMODEL version:

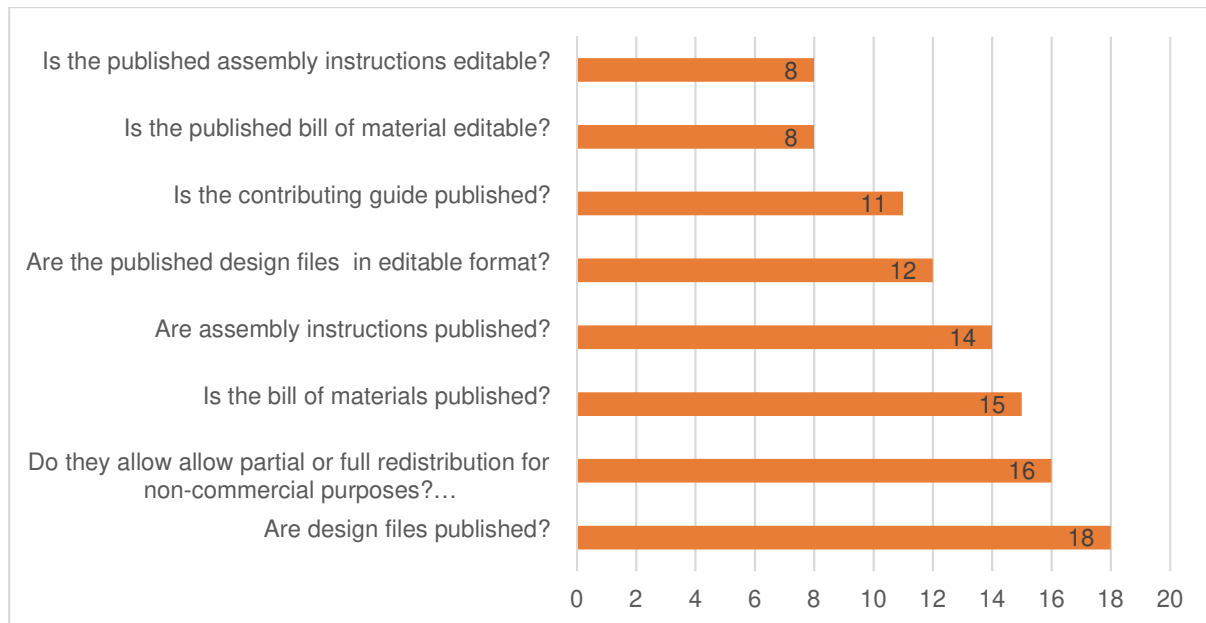


Figure 41: Types of elements most commonly opened in OSH initiatives

- Is free redistribution of the full product, also allowed for commercial purposes?
- Is free redistribution of some elements also allowed for commercial purposes?

We can see that OSH initiatives tend to prioritise published design files and a license for full or partial, non-commercial redistribution. As shown in Figure 42, three OSH initiatives explicitly chose the NC commercial clause, even though CC BY-NC-SA applies to “mind-works” and is not the license for open source hardware. After design files, the next most commonly shared documents are the bill of materials and the assembly instructions. The fact that files are less frequently in editable format, was revealed in our interviews: project initiators feel they lack time to properly document their efforts. Furthermore, due to the voluntary status of community members and to their high turnover rates, there tends to be a loss of valuable project information.

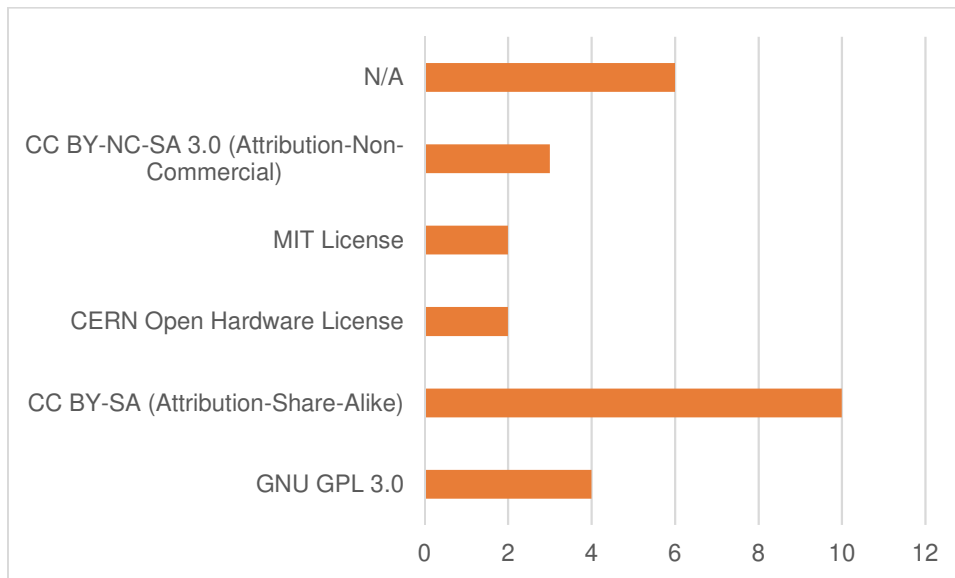


Figure 42: Type of knowledge license used

5.3.8. IMPACT ON VALUE CREATION

Since the *Drive of OSH initiatives* was identified as a key element, the projects were rated by 4 coders on a scale of 1, for “just for fun” projects to 5, for “critical problem solving” projects. Figure 43 indicates project distribution according drive. Only 2 out of 27 (with 2 N/A) projects were rated with a score below 1.5. 16 projects were rated as real-life problem-solving, with a strong drive to serve existing needs and to spread the project widely ensuring its use (see Figure 43).

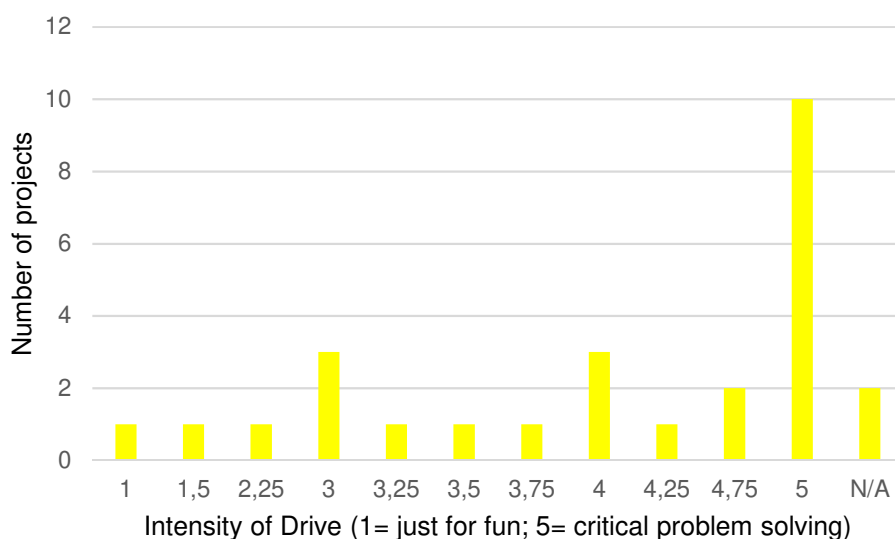


Figure 43: Distribution of OSH initiatives according to the intensity of their drive

Assessing the projects using the star-framework on dimensions such as the:

- Inclusion of socially disadvantaged groups and active gender inclusion policy (Figure 44).
- Initiatives care for and promote reduced environmental impact (Figure 45).

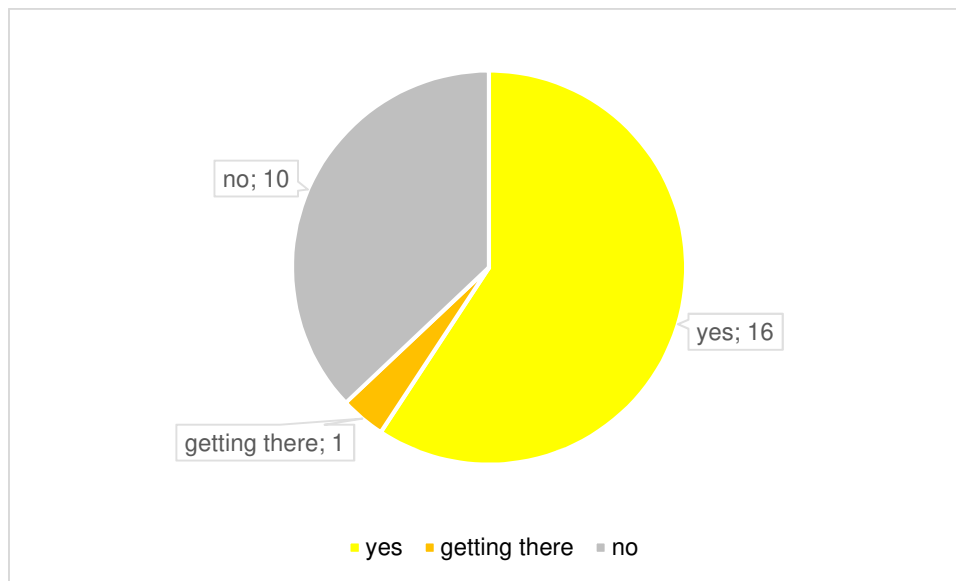


Figure 44: Inclusion of socially disadvantaged groups and active gender inclusion policy

evealed that 16 out of the 27 projects actively sought to include disadvantaged groups or have an active gender policy. Examples of such initiatives ranged from teaching at-risk-youth how to grow plants in a controlled, robotic environment, to changing the lives of children born with impaired hands and forearms. One project initiated by and for handicapped parents, aimed to show that devices conceived for differing abilities can ergonomically benefit everyone. Other projects focussed on developing the technological sovereignty of farmers, of filmmakers, of urban dwellers with bamboo cargo bikes. Various projects either had developed or were developing clear manifestos for gender inclusion in fields as varied as agriculture or digital art. One project, which started out as a hobby, became an educational tool to “fight against social and gender prejudices through digital art”⁴⁰.

⁴⁰ <http://www.arbalet-project.org/wp-content/uploads/2019/04/CodeCouleur.pdf>

Interestingly, many projects which had begun with an intent to sell DIY kits or just-as-hobbies, found real meaning and new scope in their work by integrating educational aspects or STEM programs⁴¹.

“After we launched, we realized that this project actually helps a lot of kids in STEM programs, because their music programs are being systematically defunded while the STEM grants in elementary schools are introducing 3D printers. So, instead of seeing this as a problem, it is actually the solution. Our new goal is to be able to reallocate those STEM grants to 3D printing new music programs, and potentially even 3D printing of things for the rest of the school.”

Figure 45 displays the number of projects which actively protect the environment and reduce negative impacts upon it. Many initiatives targeted planned product obsolescence and carbon footprint reduction by manufacturing items locally. The argument for this, echoed throughout the interviews was:

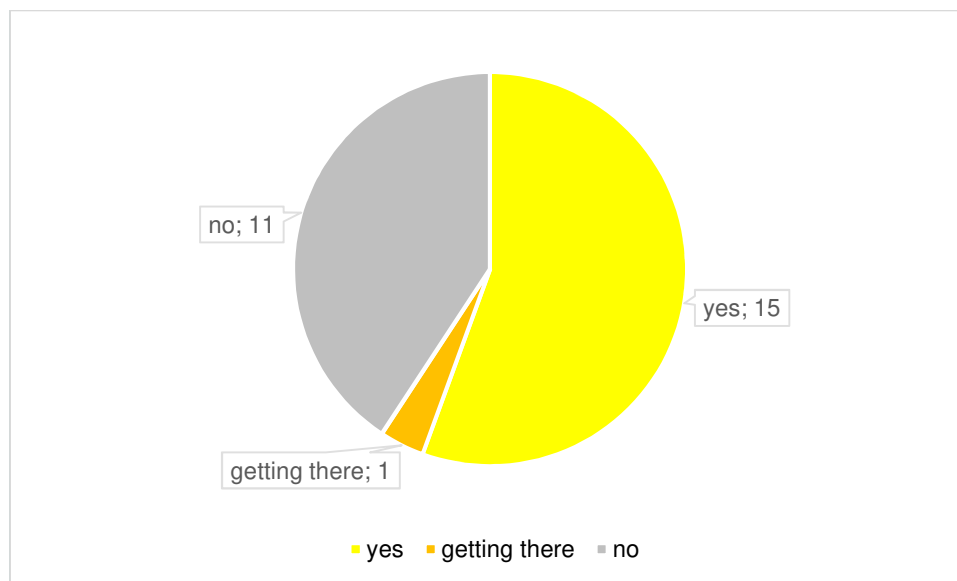


Figure 45: Initiatives care for and promote reduced environmental impact

“So not mass manufacturing what is average and works for most [...] but what is optimum and works best for each [...] is the aim”.

⁴¹ https://en.wikipedia.org/wiki/Science,_technology,_engineering,_and_mathematics

One initiative repurposed motor engines into new, locally constructed motor vehicle frames. Another proposed to empower people by teaching them to build their own solar power generators in order to decelerate climate change. Another project devised closed-looped shower systems to reduce water consumption. Community members sought to build competence in robotics, in sensors to monitor beehive health, and in building objects better fitted to their needs and that could be endlessly repurposed.

Figure 46 displays the value categories appearing most frequently in the interviews. The leading category (14 initiatives) regroups notions of “freedom” with technical, agricultural, and energy sovereignty. The idea reflected by respondents is that our current “take-make-and-waste society” has turned citizens into passive consumers of what are today major transitions related to energy, food and mobility. Open source offers the potential to learn, teach, share and empower each other to become co-creators in the product development process, building products better adapted to the end user and his needs. For instance, in the agricultural sector, farmers incur large debts by purchasing expensive, software-intensive equipment that they are not necessarily able to repair on their own. A growing number of initiatives such as Open Source Ecology (US), Farm Hack (US) or l’Atelier Paysan (FR), seek to pool existing farmer innovations, improve upon them, and offer specific workshops (welding), to help farmers create their own tools.

The second largest value category hinged on the importance of using open source as a means of diffusing a useful design to scale for scope. Tied to the notion of the business model for distributed enterprise, many projects are seeking to increase their user-creator base. Thus the notions of “empowerment through education” and “entrepreneurship” were other favoured values.

Respondents from the automobile sector mentioned the importance of “changing perceptions by demonstrating change”. The main goal for these actors was to provide a proof-of concept that showcases novel operation modes.

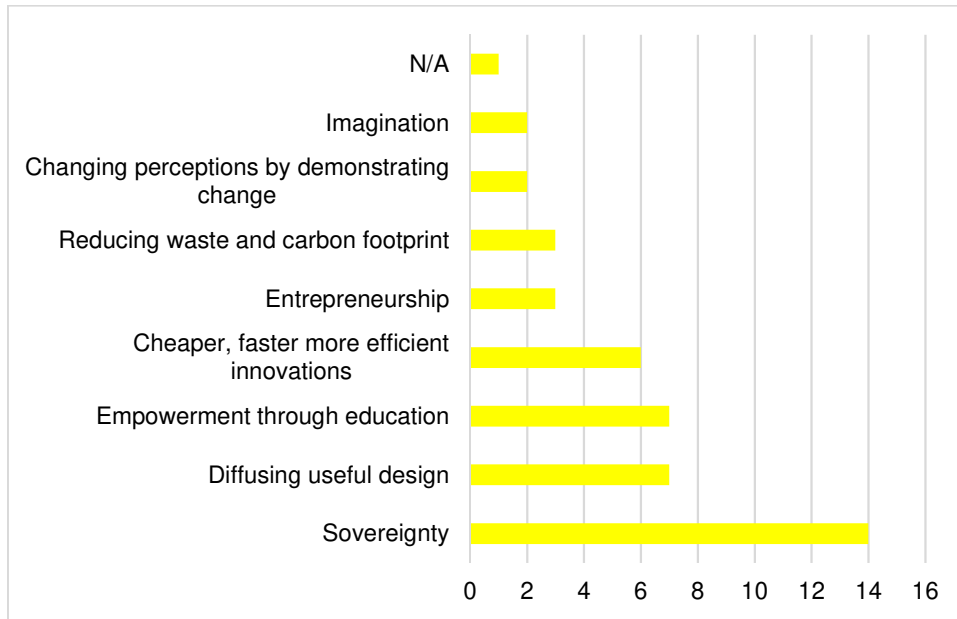


Figure 46: Values for OSH initiative

CHAPTER 5: KEY TAKEAWAY

For the community-level, we see the types of revenue streams OSH communities activate. Value propositions cover a full-spectrum offer, ranging from DIY Kit options, workshops, maintenance, subscriptions, customizable options to the purchase of final products. In terms of revenues, a pareto-like equation is observed where most come from final product sales and serve to support further project development. However, the heart of the value proposition is in open community development, without which projects will lose momentum. This full-spectrum offer appears to feed the community joining process, as consumers are progressively inspired to become more involved in the product development process.

Data from our second tier of analysis concerning how firms in established automobile and textile sectors respond to the innovation potential of OSH communities was analyzed using the Saebi & Foss (2015) contingency model for the success of open initiatives. Looking at the values generated by co-creation, knowledge flow and collaborative capability we observed that most companies interviewed were in stages of scouting to see how they could use OSH, what were the potential benefits and the risk associated. A best OSH was used as a demonstrator for change.

Data collected studying OSH ecosystems in Barcelona revealed a process through which the OSH practitioner can tap into stakeholder values in the wider ecosystem to find synergies, build consortiums, gain support and ultimately to achieve more value.

Additionally all 27 OSH initiatives were transversally analyzed using the Open-O-Meter, the Sharing Star Framework and the dimensions used by Troxler (2010) to analyze Fab Lab business models. The goal being to identify patterns in view of creating a typology of OSHBM that would help OSH practitioners to strategically assess potential moves discussed in the next chapter.

CHAPTER 6: BUILDING AN OPEN SOURCE HARDWARE BUSINESS MODEL

CHAPTER 6: BUILDING AN OSHBM**CONTENT**

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CHAPTER 6 SUMMARY

Objective – A typology of the most commonly used OSH BMs found in our research is organized into a framework displaying progressively more challenging ways of opening up a business model.

Methodology/approach – 27 OSH initiatives were transversally analyzed, assessing elements of governance, knowledge and technological openness (Bonvoisin *et al.*, 2017b; Fuster & Espelt 2018), as well as key elements for Open Design (Fjeldsted *et al.*, 2012; Troxler 2010b)

Results – OSHBMs are similar to building blocks. The projects we studied do not use one type, but a combination of many for different strategic uses. As a result, we are able to identify cognitive pre-requisites for building OSHBMs, how to use them, and the conditions necessary for their implementation.

Limits – The main limit or condition identified for the successful implementation of our framework, is the need for a corresponding change in mindset in order that OSHBMs to be reproductive and generative by design.

Managerial implications – Our Spiral framework provides the argumentation needed for practitioners to present and defend a concrete long-term strategy.

Theoretical implications – This framework is our contribution to the Commons theory as it explains how to make money while keeping core aspects of an innovation open. It also explains how value creation can be shared with others, with the goal of forging alliances challenging the current economic and industrial system.

Originality/value – Our analysis reveals the BM patterns from the easiest to the hardest to implement. The spiral progression serves as a creativity tool enabling OSH practitioners for viewing big picture and building long-term strategies.

6.1. TYPOLOGY OF OSHBM

7.1.1. OSHBM AS BUILDING BLOCKS

If we look at business model patterns (see Figure 47) in terms of the most common to the most daring or unusual, the most commonly activated pattern is 3rd party funding (16 projects).

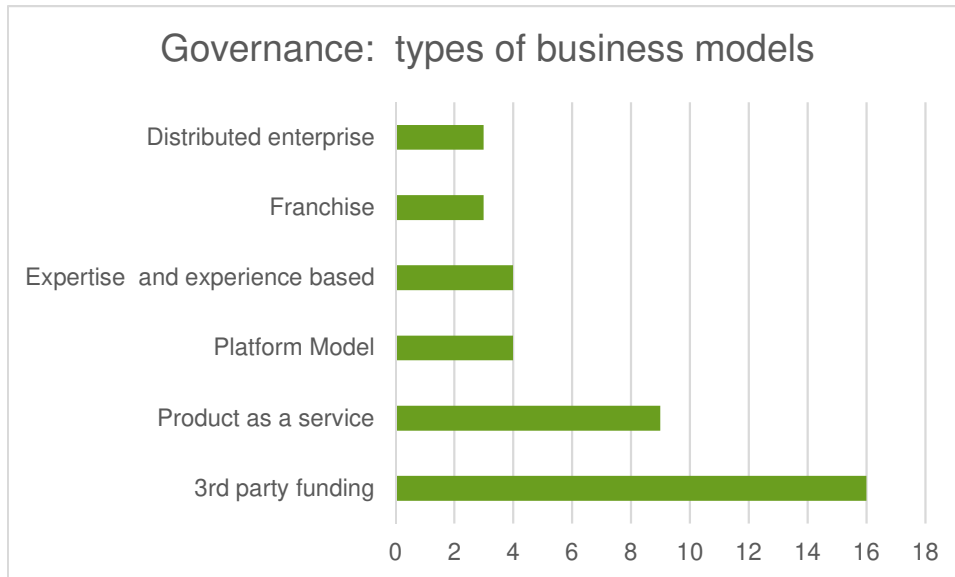


Figure 47: Business Model types (N=27)

Here, projects relied on forms of crowdsourcing, direct donations, or corporate sponsorships. More mature projects (7 years +) had evolved into a hybrid model where a corporate structure funded the operations of the non-profit. Next is the product as a service pattern (9 projects), which comes perhaps as a freemium offer that will be complimented by kit sales, training, workshops or maintenance packages. The following: expertise and experience based models (4 projects), includes “corporate competences” relating to design-centric or manufacturing-centric activities such as consulting, or customizing offers. The franchise pattern (3 projects), appears as a means of quality and safety standards. For instance, as with the open-source Arduino board, a special license or franchise will ensure that the product has been manufactured by the specific OSH brand or in conformity to its standards. The platform model (4 projects), as described by Zimmerman, included more elaborate interaction modes with co-creator communities through subscription, or matchmaking. The OSH initiative becomes a platform where customers can browse for designs, download them for a fee and produce them at their local Fab Lab, or be directed (through matchmaking) towards the manufacturer most apt to fabricate them.

In our findings, a pattern that appeared particularly novel, is the “distributed enterprise” model (3 projects). This one follows the spirit of Neil Gershenfeld’s and Sherry Lassiter’s vision of “Fab Labs making Fab Labs”, whereby the machinery in a lab can be used to create another lab, and “Fab Labs can self-reproduce for 1/10th of the original price”. From our interviews, we identified 3 initiatives where the point was to give other people the opportunity to reproduce the product itself, but also to train people to build a business around it in order for the initiative to scale. One respondent explained that this had been their ambition for the future, however, after considering and diffusing their concept, they’d found it easier to begin by building user-groups.

Another respondent explained: “We’re a distributed enterprise, we publish everything openly, so we can go on creating a few of these facilities worldwide, but we want to train others to do that beyond competition because we believe in open source. True innovation is [when] anybody can have access to the blueprints [...] more “students” simply [means] more energy for the project.” The idea being, “replacing the mindset of artificial scarcity on which global geopolitics are based with a mindset of abundance where people can enjoy a modern standard of living from widely available resources... So my motivation is to make that happen, which to me translates directly to freedom. Which means that we no longer have property or war to take resources from others. But we can produce them interestingly, with lots of meaning and without destroying the environment in our communities”.

What appears noteworthy in all projects is their use of business model pattern combinations. Table 20 shows the distribution of these patterns. Three different clusters can be identified:

Project	Sharing	3rd party funding	Product as a service	Expertise and experience based	Franchise	Platform Model	Distributed enterprise
1	S	1	1	1			
2	S	1			1		
3	S	1					
4	S	1					
5	S	1					
6	S		1				1
7	S	1	1				1
8	S	1	1		1		1
9	S	1	1		1		
10	S	1		1			
11	S						
12	S	1					
13	S						
14	S						
15	S	1	1	1			
16	S	1	1				
17	S	1					
18	S	1					
19	-					1	
20	-		1			1	
21	S	1					
22	S	1	1	1			
23	S						
24	-						
25	S					1	
26	-					1	
27	-						

Table 20: Distribution of business model patterns in OSH initiatives

-The third-party-funding cluster builds on the product service mix + expertise and experience models. Expertise is either design-centric or manufacturing-centric. The model is directly derived from FLOSS where the business model consists in shifting revenue-making strategies from product sales to expertise and services. Offers will take the form of DIY workshops, wherein people purchase “the experience of building it yourself”. Consulting services may be offered to customize or to build derivatives, such as an aquaponic greenhouse to grow fresh, aromatic plants for a restaurant; or learning to use your processes; or, for instance, the rental of the OSH initiatives collaborative platform for decentralized problem solving.

-The distributed enterprise cluster builds on the one above, with the difference that it adds “train the trainer” workshops in order to not only use OSH for the benefits of decentralized problem solving, but to further diffuse the concept by creating entrepreneurs who will replicate the model.

-The platform cluster includes the subscription and matchmaking models. These create their value through their capacity to orchestrate an ecosystem of industry players (designers, manufacturers, resellers, customers, prosumers) around one key technology or design platform.

The last two clusters stand out as the most elaborate in the sense that they articulate the most varied streams of revenues and value offerings.

7.1.2. OSHBM FRAMEWORK

This framework is the fruit of many rounds of looping reorganization and feedback. From January 2018 to May 2019 we tested out first results establishing the most common business model patterns associated with OSH among a public of entrepreneurs interested in opening up their business models, and among experts in OSH with academic and practitioner backgrounds. Through these loops of presentations and feedback from roundtable sessions, categories began to emerge based on what Gassman *et al.*, (2014) would call a similarity principle. The goal was to synthesize academic and practitioner perspectives (Fuster Morell *et al.*, 2017; Stacey & Hinchliff Pearson 2017; Wolf & Troxler 2016; Gassman *et al.*, 2014; Tinck & Benichou, 2014; Broca & Moreau, 2016) in creating an actionable tool kit, that didn't just address the different revenue streams OSH initiatives can activate, but which also included key findings from our research:

-open business models leverage collaborative value creation through open sourcing thus solutions developed do not belong to a single company but to the public as a whole.

-the notion of increased value acquired through interaction with an ecosystem of actors, enables the scaling for impact and problem solving that a single initiative or firm cannot do alone; and for which simultaneous collaboration on individual, collective and institutional levels is needed.

-the building blocks identified form categories and patterns; they can be grouped into processes with the goal, for example, of enabling cities to become at least 50% self-sufficient by 2054.

The modular nature of business model patterns means that, based on an organization's specific context and resources, the patterns can be combined to provide multiple revenue streams. They are "fluid" in that they can stand alone, be regrouped in different categories, and/or be used as building blocks.

Our categorizing process is structured as a spiral (see Figure 48). The process indicates how OSH initiatives progressively interact with their surrounding innovation ecosystems, enrich

their value propositions and grow in impact. This is not a linear process, nor is the last step (step 5, distributed enterprise) the goal for all projects. This framework should be understood as a creativity tool, to brainstorm “what is right for us” solutions. Specific combinations or steps will be relevant according to an OSH project’s specific competences and resources. Projects may keep coming back to the same step, but enriched from a slightly different perspective.

The order of the steps reflects the most to the least used clusters of business model “bricks” identified, through our analysis. These were later matched with Gassman *et al.*,’s (2014) 55 business model innovation patterns, to identify crossovers. In short, steps 1 through 3 are obvious. Step 4 is currently a struggle for organizations trying to open up their business models. Step 5 fulfills “the promise of OSH”. Together, they reveal the creative concessions OSH projects have to make for revenue while keeping the core aspects of their value proposition open.

The spiral form represents the iterative process that projects go through in designing an architecture of activities by which they create, capture and deliver value. Just as in the case of the Barcelona ecosystem, where projects need to leverage their ecosystem for growth, OSH project holders may constantly have to fine-tune the manner in which they create and share value with their key partners, suppliers and resources. The different stages that we were able to identify are explained hereafter.

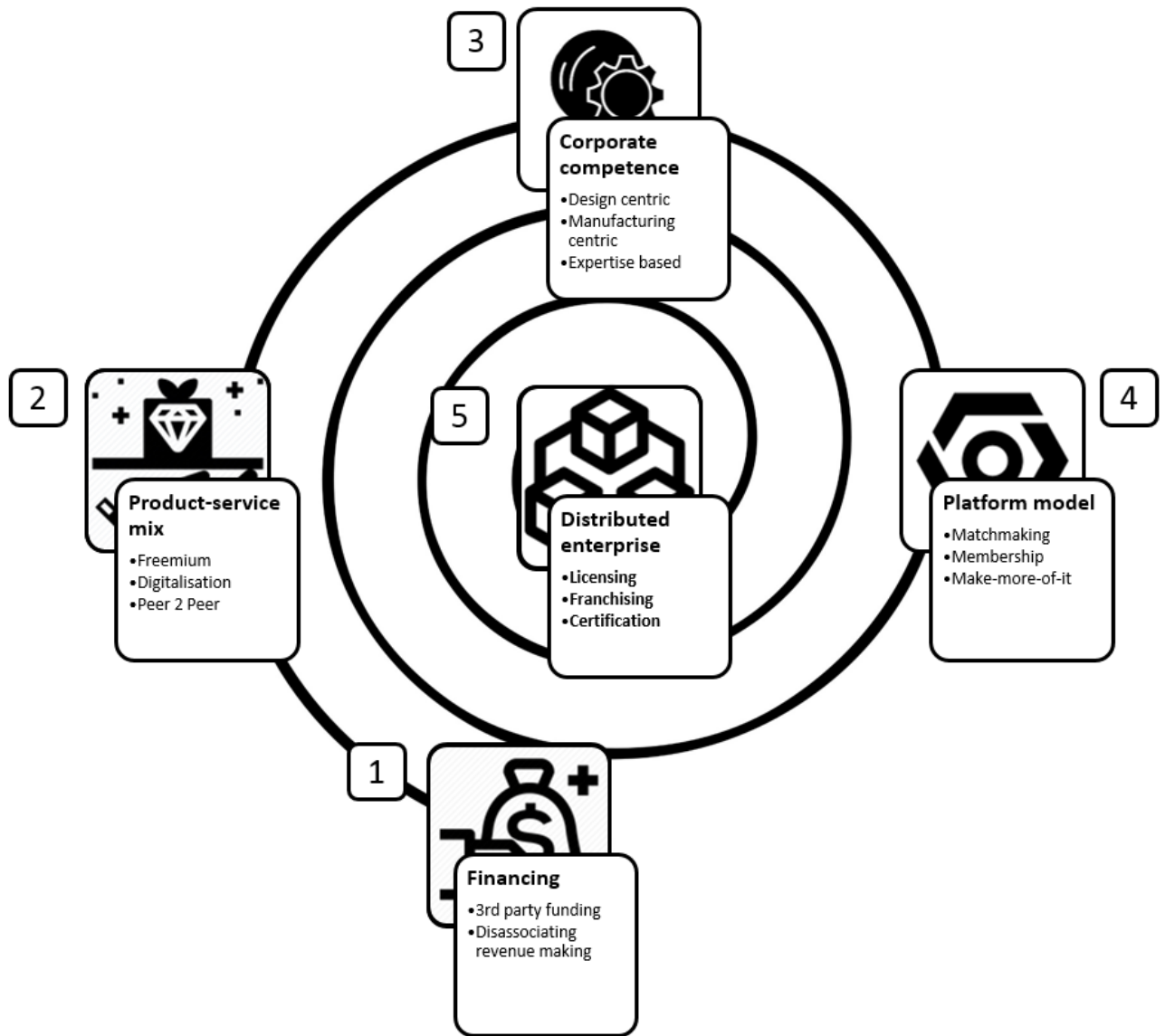


Figure 48: The spiral model. OSH Business model framework

1 – Financing

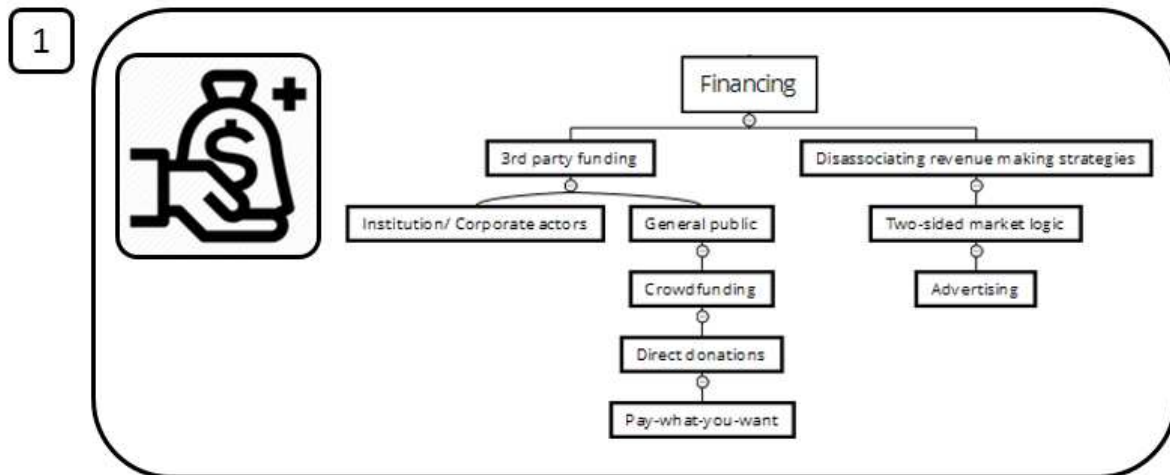


Figure 49: Financing options for OSH

As we observed, most OSH initiatives need capital to fund their activities. The cultural difference between an open source approach and the traditional closed model is that OSH initiatives need to be more creative. The first stage pertains to modes of external financing (see Figure 49). This stage also serves to build a community and consortium since the project will need outside funding. During this stage, it will be possible to get a sense of what public entities are striving for in terms of sustainable transitions. Two main options are available: 3rd party funding and disassociating revenue-making strategies.

3rd party funding refers either to sourcing money from institutions or corporate actors, who will fund the production/conservation/expansion of a common because they have an interest in it, or to support from the general public. Institutional support may include public funding, grants, or corporate sponsorship. The advantage is for an OSH initiative is to build its consortium and accrue its legitimacy. The drawback, of course, is risking a lack of independence as regards the governance or economic model. General public support can take the form of reciprocity-based revenue-making strategies, such as crowdfunding campaigns or direct individual donations. Voluntary financial contributions sustain the production of a common on the basis of reciprocity. The novelty here is the ability to limit influence or professional investors. This category includes memberships, donations, becoming a patron (through Patreon) or Pay-what-you-want, where customers are given a range of price options for a product or service.

Crowdfunding was dubbed a fabulous means of decentralizing the innovation process by supporting “people from anywhere in the world to come up with an idea and to develop it”.

The drawback is that “all the work needs to be done upstream” to create as much buzz as possible, as fast as possible to reach the target. Successful campaigns have been coached by professional platforms such as Ulule or Kickstarter to help OSH initiatives draw on their local and international communities, and receive sufficient media coverage.

The disassociating revenue making strategy is the second mode of tapping into external funding. Here, a positive externality created by the main output is produced to create revenue. The category includes revenue-making strategies such as advertising, sponsorship or the selling of personal data, which, in the case of OSH, is ambiguous and would be considered neither open nor as transparent.

2 – Product-service combination

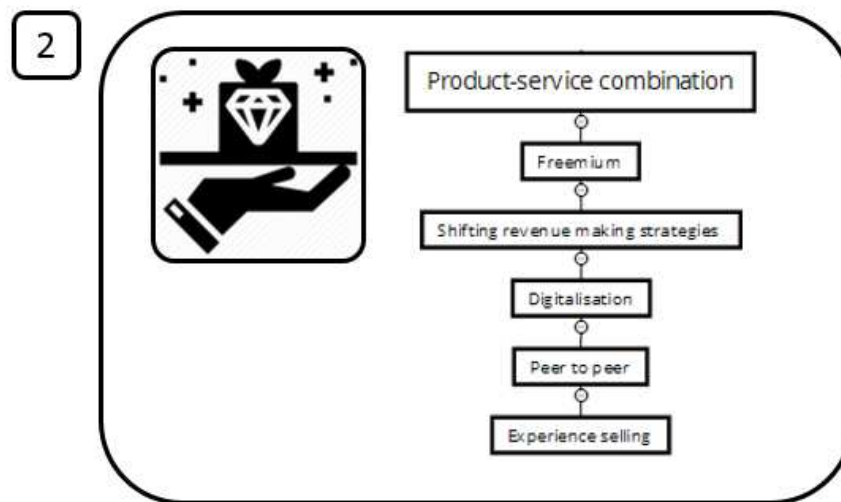


Figure 50: Product service combinations options for OSH

Through this stage, OSH initiatives can experiment with tailoring their value proposition design (see Figure 50). Indeed, in the initial stage of a project, proponents have a vague idea of who their target customers are, and what value proposition would adequately match their needs.

The idea here is to progressively go from a product mindset to a service mindset. As one of the respondents explained, “If we were just interested in selling a final product we might as well sell bidets”.

Propositions for this stage include freemium options, whereby what was collectively developed can be offered for free to establish a large initial customer base but custom add-ons and premium offers are developed for specific needs, or for a more performant version of the original digital common. The common produced is not charged but revenue making is ‘shifted’ to the selling of something else related to the common. In the case of OSH both ‘digital-to-

physical' and 'experience-selling' make perfect sense. In the case of the Danish furniture brand, Stykka, which intends to become the OSH equivalent to furniture design that Spotify is to music, Fab Market or Open Desk designers are compensated if customers select their designs, and if they choose to manufacture the designs in their local Fab Lab or woodshop. Experience selling, comes through selling DIY workshops where users learn how to build, weld and assemble their own machinery, brickpress, tractor, or solar power generator. Peer-to-peer refers to transactions between private individuals, such as the case for E-nable: matching 3D printing machine owners with parents of children born with agenasia. An organizing outfit functions as a sort of intermediary responsible for the safe and efficient handling of transactions, ideally becoming a nexus for community relationships (Gassman *et al.*, 2014, p.253).

3 – Corporate competence

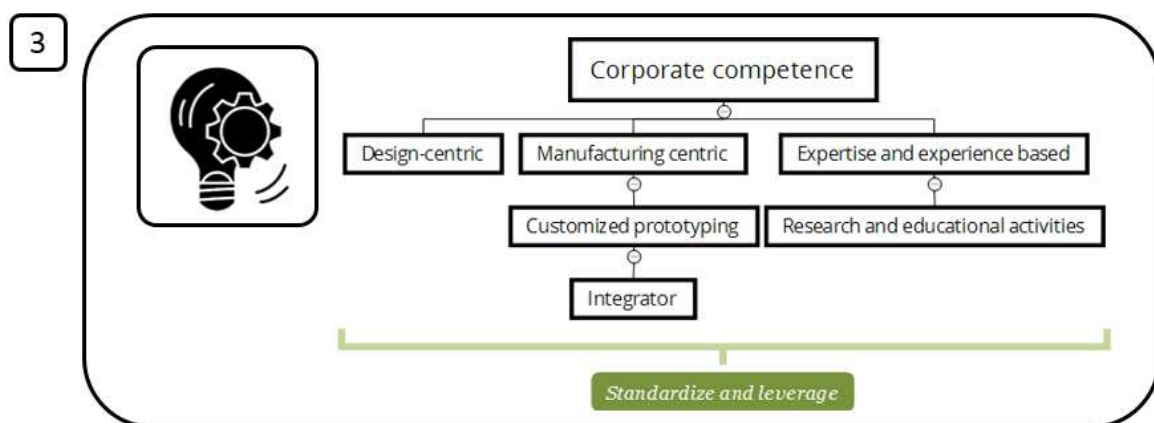


Figure 51: Corporate Competence based OSH revenue model

During stage 3, the OSH initiative needs to carefully assess its core strengths in order to build its competitive advantage (see Figure 51).

If the founders are design-centric, they are most often focused on product design and R&D, while they outsource the manufacturing. In this model, the brand and the community are key strategic assets. Tinck and Benichou (2014) identify three different cases:

Case 1: third party suppliers provide parts that the designer can sell assembled, or more often as a kit (ex: Open ROV, Open Energy Monitor)

Case 2: a partner manufactures finished products that will be distributed under the brand of the project (ex: Arduino)

Case 3: a prospective model inspired by free software, envisions an ecosystem of manufacturers selling their own products based on shared designs managed by an open hardware foundation (ex: Wikihouse, Dronecode, Fab Market)

If they are manufacturing-centric, the organization's core value proposition is to manufacture and distribute open hardware products for an affordable price. In addition to the brand and customer community, industrial efficiency is a key asset. Tinck and Benichou (2014) explain that "depending on the industry, the diversity and renewal of the product catalog can also be a key differentiator". One noteworthy example is Seeed Studios, the "IOT Hardware enabler" which manufactures electronic products for Makers and Engineers⁴². Indeed, many parts required for hardware are manufactured in Shenzhen, China, "the factory of factories" which, based on its manufacturing might, has developed a synergy with all manufacturers in the world and has become a "hardware accelerator". Another example, is #customized prototyping for industry or private clients. As the design skills for creating and developing a 3D printed prototype are scarce, therefore still novel, customers can be "locked-in" to a vendor's world, which will make switching to another provider more difficult (Gassman *et al.*, 2014, p.208; Wolf & Troxler 2016, p.84).

Through the #integrator model the organization will gain economies of range and efficiency by controlling most or all parts of the supply chain from sourcing to manufacture to distribution. In the case of Baidu and Telsa, this approach fosters innovation and improves efficiency. Tesla, for instance, is using this model to consolidate its position and modify market boundaries from the inside by creating both the demand and the supply of associated products and services, such as electrical batteries, charging stations and Powerwalls.

If the organization chooses to focus on expertise and experience, their revenue models will come from monetizing expertise and services. Consulting services may be offered to customize or build derivatives of a given product (ex: Arduino) or learn your processes. Local motors and Wikispeed offer the service of renting out their collaborative design platform. Similar to the #make more of it pattern, knowhow and resources are sold to third parties as a service. Accumulated specialist knowledge and spare capacities "can be monetized and new expertise built up, all of which can be used to further improve internal processes and revitalize the core business" (Gassman, 2014, p.188).

⁴² <https://www.seeedstudio.com/>

These design, manufacturing or expertise-based design types, offer the opportunity to “standardize and leverage”. The idea being to open-up one key product in order to make the associated technology a de facto standard in the industry.

4 - The platform model

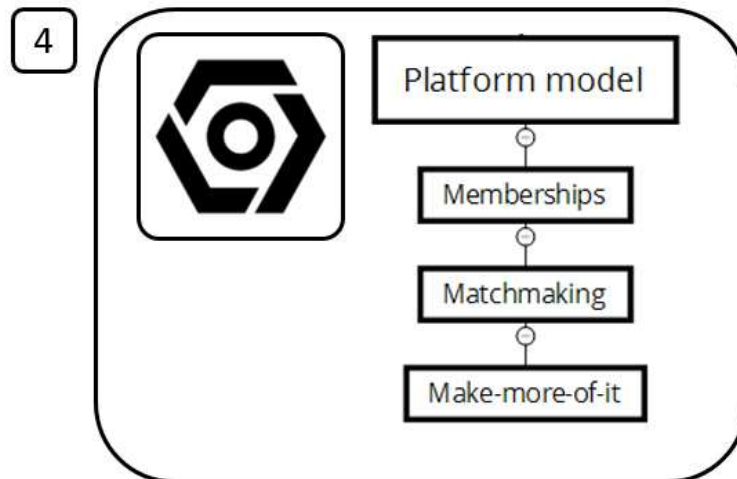


Figure 52: Stage 4 Platform Model

Inspired by the digital economy, the core of the value proposition in this model is an organized ecosystem of industry players around one key technology or design platform (see Figure 52). The point is to regroup a variety of different players: makers, designers, manufacturers, buyers, to form a multi-sided market. As discussed by Lars Zimmerman⁴³, this model opens-up core assets, in order to enable new roles in a firm’s organization. Revenue extraction, beyond just selling a product, can come from subscription fees, training sessions (#experience selling, #make more of it).

This category includes deriving revenues from brokering strategies. Here revenue is based on matchmaking two parties such as driver or a rider or a host and a guest. The method is widely used by platform cooperatives and can take the forms of a transaction fee or a subscription (Fuster Morell *et al.*, 2017, p.45). In the case of Kreatize, the value proposition is based on an algorithm that matches a manufacturer’s requirements with a supplier capable of producing and improving the design. Make Works is another example specific to manufacturing, enabling the sourcing of local manufacturing and materials⁴⁴. This type of competence will become increasingly important through distributed manufacturing, wherein

⁴³<https://community.oscedays.org/t/solution-videos-tool-on-open-source-business-models-for-circular-economy/4625/6>

⁴⁴ <https://make.works/>

key assets are the ability to map manufacturers and their competencies so as to reconfigure supply chains. Speaking about the DDM (Distributed Design Market) and DDMP (Distributed Design Market Platform) initiatives⁴⁵, one respondent explained: “what we are trying to do is to create supply chains on the fly, in the sense that depending on the products and the local actors, you organize the supply chain locally”.

5 - Distributed enterprise

The last of our business models is the distributed enterprise (see Figure 53). We chose to place this at the end of our process, because, although it may not be the goal at the start of many OSH initiatives, it is a logical progression. Neil Gershenfeld’s modest initial goal for Fab Labs, was to expand access to digital fabrication. He didn’t expect the movement to grow exponentially from Fab Labs to Fab Cities as it has, nor from 3D printers making 3D printers, to Fab Labs making Fab Labs.

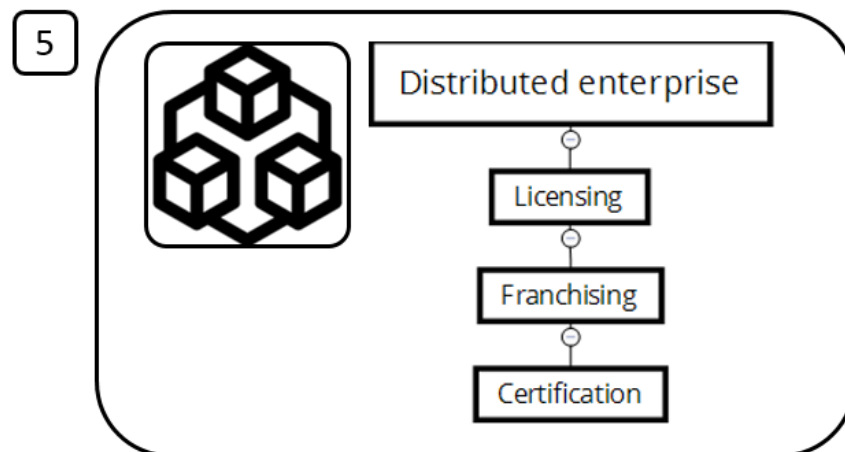


Figure 53: Distributed enterprise OSH model

A distributed enterprise seeks to empower entrepreneurship by training people to use open design, technology and principles available in order to replicate the model elsewhere, thereby scaling for impact: “open source hardware businesses making open source hardware businesses”. The challenge is not only to have immersion workshops for people to learn the technology but “to share the knowledge on how to make a business out of that”.

One respondent explained: “So we’re training them either to just produce the machines they can in a fabrication shop, or to actually produce them by taking the blueprints to a fabricator, having the product fabricated, and then selling it. We prefer the idea of the immersion-training

⁴⁵ <https://distributeddesign.eu/>

workshop in manufacturing, where you organize the workshop. We have twelve people or so, they pay you to build it, they get immersion training and you sell the product. It's a dual revenue model, where you're catching revenue for manufacturing as well as education".

In this form, revenues can also come from labels and certifications from the host organization, certifying that after having gone through a certain number of workshops, the resulting product is sufficiently safe. #Licensing or #Franchising or matchmaking, are other options if the initial project has developed a superior knowledge of supply chain logistics that makes buying in bulk easier. One respondent explained: "I'm saving them the trouble of having to find all the materials they need from 25 different places". Franchising is a perfect means of allowing for geographical expansion without having to muster up all the resources and carry all the risk, which is handled by franchised, independent entrepreneurs (Gassman *et al.*, 2014).

7.1.3. ILLUSTRATION THROUGH A CASE STUDY

To illustrate the framework, let us use the 1083 French ethical fashion brand that produces and manufactures jeans and shoes. According to our conceptual framework this would be an example of a community-oriented business model, wherein a formally closed firm gradually seeks to open-up key aspects of value creation, capture and distribution. We use this example on purpose because it does not necessarily fall into the "classical fold" of OSH.

Founded in 2013, the brand got its name when Thomas Huriez and his brother decided to leverage their family owned former textile factory in Romans and create a brand where the longest distance between two manufacturing points is 1083 km, the distance between the two most distant points in France. Initially founders of the Modetique label selling ethical fashion, the two brothers set out to reinvigorate French textile fashion production through their new brand 1083 in order to boost creativity and jobs locally. The denim used for the confection is mostly made by Tissage de France (formerly Valrupt Industries)⁴⁶, and is manufactured near Marseilles. The 1083 Flagship store in Romans hosts all design and marketing and operations departments⁴⁷.

Mindful of the severe environmental impact of cotton production, and of the increasing textile waste caused by the fast fashion industry (Fletcher & Grose, 2011). Thomas Huriez began looking into how to make his own textile recovery plant. After giving presentations of his

⁴⁶ Which they purchased in 2018 because they sourced 80% of their fabric there and the firm was undergoing legal redress. The challenge now is to cater to the Valrupt Industries former clients' production needs.

⁴⁷ They also recently purchased the Charles Jourdan factory, which had been an industrial wasteland for the last ten years. <https://www.1083.fr/blog/a-pieds-doeuvre/>

concept in Greece, he was approached by Greek and German entrepreneurs who wanted to create local franchises. Thomas's response was that there was no sense in setting up German or Greek stores selling jeans made in France, because these countries had their own textile waste, and unemployment issues. Here came the idea of open-sourcing his ideas.

Following our framework, the 1083 team would initially seek financing options to fund the R&D and construction of their jean-recycling factory. They would need to convince investors, apply for funding through governmental calls, grants and European projects, perhaps establish partnerships with the Altext label, or the Tissage de Charlieu to build the new plant. They could also set up a design sprint with architecture and engineering schools in order to build the most LEED certified building and process.

Next, they would think about product service combinations. For instance, in order that their factory be continually busy, they would need to figure out how ensure proper material flows; whether their own 1083 production would be sufficient or if they would need new clients and who would these clients be; how best to set-up lean manufacturing processes optimizing their supply-chain.

According to our next step, they would need to decide if of whether they remain design-centric, which is the base of their present value-proposition on, or how they could now vertically integrate manufacturing activities in the scope of their activities. Moreover, would they have an engineering faction helping to design and implement recycling factories elsewhere such as in Greece or in Germany.

Brainstorming the next stage of our framework, would permit them to see how they would capitalize on their factory, and store, and website by enabling roles in their network. How could shoe making, or jean making workshops be leveraged with design students? Or with existing designers and entrepreneurs interested in small scale production? How can this activity be harnessed in order to create more buzz for the brand? What sorts of revenues, in terms of subscriptions, trainings and matchmaking other brands with local manufacturers, can be created? How could they become the Kreatize of Techshop of their industry? The Localmotors of ethical jean manufacturing?

Finally, according to the final step of our framework, how could their concept be exported internationally in order to enable and empower others to tackle textile waste through a distributed manufacturing approach?

6.2. PRE-REQUISITES FOR CREATING AN OSHBM

In this section, needed insights we will provide for open-source practitioners to forge their personal conviction in order to understand the full scope of what open-source hardware can offer. During events such as the Fab City Summit in Paris last year, or the Collaborative Economy conference in Barcelona, it was remarkable to witness the impact theoreticians had on their audiences. In true epistemic fashion, their arguments helped lone inventors and OSH entrepreneurs see the big picture and bond with others engaged in similar pursuits. This bonding corresponds to the second algorithm of evolutionary intelligence described by Richard Barrett (2018).

Arguments listed below are helpful in structuring a discourse on the benefits of and prerequisites for a collaborative OSH approach.

6.2.1. A MINDSET CHANGE FROM “ME” TO “WE”

The first condition is a shift in mindset from a “me” perspective focused on personal interest and scarcity to the “we”/common good perspective of abundance found in Commons-based peer production.

Our findings suggest highlight the importance of value in federating a community of contributors. Values are essential to driving community dynamics, therefore this mindset change needs to pass by a change in values. Our findings on the importance of values as a cementing factor in OSHBM join those of a growing stream of research results on value drivers, both in organizations and in addressing the grand societal challenges we face today (Spieth *et al.*, 2018, Breuer & Lüdeke-Freund 2018; Breuer & Lüdeke-Freund 2017; Inigo *et al.*, 2017; Barrett, 2014).

The values we uncovered during our transversal analysis of all projects, and those specific to the Barcelona ecosystem, revealed the importance of freedom, independence and sovereignty. Sovereignty, in our findings, means building one’s capacity to create and empower others to do the same, fostering local solution-seeking for global problems. Completely in agreement, Stallman's (2009) statement that FLOSS stands for “free speech not free beer”, the notion of sovereignty that our respondents expressed is the individual freedom to choose the (monetary) relationships and technology they depend on. The ability to reuse the work done by others, without having to pay for licenses, encourages creativity and social and economic equality.

In line with findings on the motivations for open source by Unterfrauner *et al.*, (2017); Li *et al.*, (2017); Acquier *et al.*, (2016), we suggest that OSH projects have a strong potential for social innovation, and that values are key to understanding OSH business models. Zott *et al.*, (2011), cited in Massa *et al.*, (2017) and Breuer & Lüdeke-Freund, attest to the importance of values-based innovation for addressing complex societal problems (2017).

The plural form of values stands out as the cementing factor binding interaction between community members with larger sets of external stakeholders. On the community level, that OSH projects with strong social and/or environmental vision were likelier to receive contributions, upholds the ecosystem level, that OSH projects with a common-front of values and technology at the service of citizens, are likelier to obtain stakeholder support. Contributions may not necessarily be technical, as described by the community joining process, Herstatt & Ehls (2015), but can be extended to broader stakeholder support. Similarly, value generated goes beyond what can be quantified.

The conclusion, implied from the consortium building process of OSH initiatives becoming their own *middlegrounds*, is that values are key to reaching out to actors in a broader ecosystem to solve problems that a single entity or company cannot solve alone. This supports Gassman *et al.*, (2014, p. 231) who found that open business models leave profitable niches for others; it also fits with Porter and Kramer's (2011) position that the understanding of shared-value potential is just beginning. Our research therefore suggests the necessity of sharing core values relevant to the OSH endeavor being built.

OSH initiatives are thus highly value driven. As they embody an unusual set of values, conversely, when interacting with and within organizations which do not have an organizational culture endorsing these values, at best there is a stasis state, and at worst the values are undermined. Our results from the community-oriented perspective are indicative of this.

6.2.2. VALUE-DRIVEN GOVERNANCE THROUGH GLOBAL MIDDLEGROUNDS

The crux of the matter seems to be the ability to establish participatory governance to ensure the transparency and effectiveness of the initiatives on multiple levels. In line with our findings on the importance of values, we suggest that this governance needs to be value-driven order to promote generative, decentralized, bottom-up innovation processes. This point coincides with the principle of “nested enterprises” evoked by Ostrom, 1990. “Appropriation, provision, monitoring and sanctioning, conflict resolution, and other governance activities are organized

in a nested structure with multiple layers of activities” (Hess & Ostrom, 2011, p.7). To these authors, the essential values behind any commons “are inevitably about equity, efficiency, and sustainability”.

Richard Barrett explains that democracy is a journey from freedom to trust. “Democracy begins with freedom, and evolves through equality, accountability, fairness, openness and transparency to trust. Each step of this journey, in other words each value, is an essential foundation for the development of the next value [...] Without equality, accountability, fairness, openness and transparency there can be no trust, and without freedom (autonomy) people cannot individuate and self-actualize” (Barrett, 2017, p. 185)

Given the range digital production platforms have taken, OSH initiatives now have local and global impact. This is what Capdevila (2017) refers to as “the geographic multi-scalar character of innovation processes”. Elaborating on existing work done on *middlegrounds* (Capdevila, 2015; Cohendet *et al.*, 2010; 2014), we propose that the *middleground* concept, as applied to OSH is like fractal geometry (Eglash, 1999) where the part looks like the whole, self – organizing through recurring features. OSH initiatives not only need to participate in the city’s *middlegrounds* in order to build a consortium, but the initiatives must become both local and global *middlegrounds* in order to ensure dynamic interaction among community members. Effective governance of OSH initiatives need to reflect this fractal geometry, ensuring pro-democratic processes on all levels of OSH ecosystems.

The question of governance lies at the heart of *middleground* innovation dynamics and grows in importance as OSH projects grow in scale, progressively emerging from underground Fab Labs until they reach every day citizens. Some researchers, like Störmer and Herstatt (2015), on the differences between endogenous and exogenous (self-versus firm-initiated) governance on innovation communities, find that grass-root democratic processes can “be a double edged sword”. They suggest that the key to good governance lies “not between endogenous versus exogenous, but in the design of helpful, fair and purposeful governance rules”. As such, the physical-virtual and global-local dynamics observed in OSH projects can serve to mitigate conflict and boost the performance of communities. Indeed, just as the OSH innovation itself becomes “faster, cheaper and more efficient” through rounds of forking and modifications by distributed developers (Bonvoisin *et al.*, 2017) hopefully the standards guiding these communities will follow. Positioned on a global level, OSH initiatives will be refined and pushed forward (Gershenfeld, Lassiter, 2018). Successful projects are emulated by other cities

and enriched by collective intelligence, creating “new sparks” not only on the individual level but also throughout a global network of cities (iCapital, 2018). Initiatives instigated by the Barcelona City Council guiding cities on how to deal with open technologies are paving the way and are taken-up by the Fab City network to inspire and help identify best practices.

6.2.3. MANIFESTO ELABORATION

Another crucial pre-requisite for the diffusion of OSH initiatives and values is the creation of “manifestos” and “codebooks” to attract larger communities. Manifestos are the means through which actors can self-organize in order to create, build, share and preserve open resources (Cohendet *et al.*, 2014). To that end, Troxler (2019, p. 9), building on Ostrom’s (1990 see Figure 54) “Design principles for long-enduring Common Pool Resources Institutions”, has simplified them into five, rather than eight design principles (see Figure 55).

1. *Clearly defined boundaries should be put in place.*
2. *Rules in use are well matched to local needs and conditions.*
3. *Individuals affected by these rules can usually participate in modifying the rules.*
4. *The right of community members to devise their own rules is respected by external communities.*
5. *A system for self-monitoring members' behavior has been established.*
6. *A graduated system for sanctions is available.*
7. *Community members have access to low-cost conflict resolution mechanisms*
8. *Nested enterprises. Appropriation, provision, monitoring, and sanctioning, conflict resolution and governance activities are organized in a nested structure with multiple layers of activity.*

Figure 54: Ostrom's Design Principles of robust, long enduring, common pool resource institutions (Ostrom 1990, p. 90-120)

1. *Clearly defined boundaries.* Participants who have the rights to draw resources from the project must be clearly defined, as must the boundaries of the project.
2. *Congruence between appropriation and provision rules and local conditions.* Rules restricting time, place, technology, or quantity of resource appropriation are related to local conditions and to provision rules requiring labor, material, or money.
3. *Governance.* Most participants affected by governing rules can participate in defining and modifying these rules, through monitoring conditions and appropriate behavior, sanctioning participants who violate rules, and resolving conflicts.
4. *Relative independence* (minimal recognition of rights to organize). The rights of participants to devise their own institutions are not challenged by external authorities.
5. *Nested enterprises.* Appropriation, provision, monitoring, enforcement, conflict resolution and governance activities are organized in multiple layers of nested enterprises in the case of larger systems.

Figure 55: Troxler's revision of Ostrom's Principles adapted to Open Design (2019)

Ostrom, cautioned that those principles were “found to exist in most robust institutions – but they were absent in failed systems”. She indicated that whether these principles could be applied to complex systems such as Knowledge or Digital Commons necessitated further study.

OSH actors must undertake considerable efforts to convince others of the usefulness and potential of commons-based value. That is, of the necessity to create value and business models that are distributive, regenerative and generative by design. In the words of Thomas Huriez the founder of 1083. “The point is to be non-competitive with allies, and collaborate with them in order to join forces, because we are less strong on our own, and be very competitive with what we know as the norm today”. In his case, the norm, for instance in the case of Levi’s jeans, is “the American dream made in Bangladesh”. A system where cotton cloth using an inordinate amount of pesticides and water is produced using cheap labor. Huriez seeks to reverse this system by producing ethical jeans made from fibers of available local textile waste produced locally. Instead of exporting his model by creating stores internationally, Huriez seeks to export his concept, which falls under our distributed enterprise model: “the French dream made in your country, using your available waste”.

Central to research on epistemic communities, proper governance of OSH communities requires the co-creation of a “manifesto”, “which expresses the breaking of rules that will guide the cognitive work of the community” (Cohendet *et al.*, 2014, p. 235). In a second phase, OSH

agents must create codebooks to clarify the codes, norms and practices that the community will respect. The “Principles for Common Pool resources”, defined by Ostrom in 1990 are an example of commons-based codebooks. Her research found that the fact that they were co-elaborated by a heterogeneous set of stakeholders insured the fact that they would better respected. When values are codified and reinforced, “they turn into obligatory normative orientations [...] and can play a crucial role in the formation of networks” (Breuer & Lüdeke-Freund, 2017).

6.3. USING AN OSHBM

To date, OSH just has not had the same impact and spread as OSS. Perhaps the reasons reside in a lack of argumentation for support. Just as the previous section outlined a theoretical context useful for practitioners to see the bigger picture and bond with others, this section provides concrete advice for entrepreneurs to wish to put OSHBMs in practice. To date, the overlapping OSHBM have not given clear directions on suitable courses of action. The result is that OSH entrepreneurs lacked concrete reasons susceptible to convincing potential investors of their projects can evolve over the long-term. Indeed, in spite of the fact that some research has found that the mode of collaboration through openness is becoming more *short-term and problem-driven* (Tech *et al.*, 2017), our findings show a gradual process through which OSH initiatives can scale and grow with time.

The following section will discuss key insights from our findings of use to both community-oriented and community-based OSHBMs.

6.3.1. LEVERAGE YOUR ECOSYSTEM FOR GROWTH

Findings highlight the essential role of community building for OSH initiatives. In this perspective, the traditional role of project manager evolves from developing projects to animating communities, and serving as an intermediary between users and customers.

Our Pinball Model displays how OSH projects can go about interacting with members of their ecosystem to grow. As expressed by Barcelona’s former Chief Architect, Vicente Guallart, the collaborative premise of OSH will not necessarily be realized through incumbent firms, which need to get governmental support, so new regulations can become the standard. Our results are based on the case-study we conducted in Barcelona. They suggest that first, OSH community-based projects need to create a “tech-for-citizens project”. The high social or environmental impact will be more likely to motivate contributions. In this stage, real attention needs to be

given to thinking about how the technology can be made easiest, safest and most empowering for most citizens to use. Second, the OSH project needs to respond to governmental calls. This is an important step for being aligned with what your city/country considers important. The third step is to join the city's existing *middleground* (or to create your own). This enables OSH projects to become familiar with their community and ecosystem. Thus, new synergies can be created with people working on similar ideas. The fourth stage is to build a consortium of local and global partners. Finding partners willing to sponsor, to improve your technology, and to test it in the field, increases the project's credibility and the reputation. Which, in turn, will ensure more ecosystem support. The steps in this model are not necessarily sequential; they can happen in parallel. The goal is to better align an OSH value proposition with users. The project's overall value increases through rounds of interaction with its ecosystem.

6.3.2. STAGED AND EVOLUTIONARY PROCESS FOR OSHBM

Our findings offer a practical way of understanding what revenues OSH projects can activate in answer to the "What's right for us?" question. They suggest ways that OSH projects can raise money to get traction for their ideas, and even design the ideas themselves to produce their own revenue. Just as Gassman *et al.*, (2014) suggest with the Business model navigator, the idea is to assess the current means of revenue an OSH initiative is activating and to brainstorm other possibilities. Business model design is similar to the lean start up premise: Practice experimentation and fail early and often to have strategic knowledge on the potential of open source for your company, and then draft a strategy to see how it could apply to your own business. Because in the end, the strategic advantage of a company is its capacity to learn quickly.

Each stage of our Spiral Model framework suggests consecutive steps that may assist in more fully understanding how to create an OSH business model project for an innovation, how to market it and how to position oneself in the market.

Although most of the projects interviewed here were in the early stages of this process focusing on 3rd-party-funding and product-as-a-service options, the key to bear in mind is that business models for OSH are like building blocks (Wolf & Troxler 2016). As we were able to assess during the findings of our community-level analyses, there exists a large panel of options from DIY options, to kits, to full spectrum offers. The revenue options build upon one another, compiling "all of the above" solutions. The modular nature of these "bricks" creates both a level of complexity and a facility of use, as the projects can begin from wherever they are.

The Spiral Model displays progressively more challenging steps to implement. OSH initiatives and companies should not be deterred by these sequential steps. Together, they form a logical progression of OSH potential and can be taken separately or grouped, like building blocks. Most businesses operate on the 1 to 3 model basis. The model 4 is really the result of Lars Zimmerman's Open Platform design Flowchart⁴⁸ that was taken up again by the REMODEL toolkit of the Danish Design Center⁴⁹ and used to explore and develop new business models for physical products based on open source principles. It is already sufficiently difficult to implement in sectors and industries accustomed to revenue from closed intellectual property. The stage 5, the distributed enterprise model, is the most risk-embedded step for enterprises. It enables OSH initiatives to think about how to become the "Mc Donald's" of their own industries and to grow in geographical scale. The distributed enterprise is a means of riding "piggyback" on something that is already in place. In line with FLOSS's philosophy, it permits standing on the shoulders of the giants, and is where a real potential for OSH lies.

This phased approach to business model design allows the initiatives to progressively reach out for ecosystem support, gain a broader customer-user base, strengthen their core competences and scale for impact. It also allows these initiatives to fulfill their strong OSH potential for social innovation. In this manner, collaboration of the OSH initiative with its ecosystem "is a decisive element of value creation and capturing" which is a key attribute of open business models (Frankenberger *et al.*, 2014).

In line with Tech *et al.*'s (2017) findings on key attributes of open business models, our framework illustrates the blurring of boundaries between partners and customers. This happens at various entry points. One is the access to the innovation's blueprints. Another is through crowdfunding, as customers now become investors and partners. The platform stage gives additional ways of blurring lines. Matchmaking provides clear, open-innovation opportunities with key suppliers, who can become partners. Finally, in the last stage, the distributed enterprise further blurs lines, as not only the blue print for the innovation is shared, but the business as well.

From our results, it appears that the mode of collaboration in community-oriented business models may be more short-term and problem-driven. However, the process identified in

⁴⁸<https://community.oscedays.org/t/workshop-tutorial-business-models-for-open-source-circular-economy/4709>

⁴⁹ <https://remodel.dk/>

Barcelona, of consortium building to establish synergies among similar initiatives by rounds of interactions through the *middleground*, is definitely a long-term process.

6.3.3. OPENNESS STRATEGIES FOR COMMUNITY-ORIENTED BUSINESS MODELS

The findings on the cross-case analysis of the automotive sector again indicate a link between OSH implementation and a firm's organizational culture of openness. OSH initiatives serve to strengthen the firm's "collaborative capacity muscle", through successful *middleground* building. Via this process inter-lateral knowledge exchange flows are created, opening up value creation and capture for firms and the stakeholders involved in OSH initiatives.

Our results also indicate that the opening of innovation strategies is a non-linear process. The companies studied alternated opening phases of their business models with closing phases, once results could be transferred internally to capture value. This non-linear process can be analyzed using three dimensions: (1) community creation and stimulation; (2) knowledge sharing capacity and (3) value sharing. Each dimension activates the following, diffusing inter-lateral waves of knowledge exchange through the boundaries of the firm, stake- shareholders, users and crowds.

6.3.3.1. *Community creation and stimulation*

Creating open source hardware generally depends on open sharing within collaborative communities. Sharing, an essential process of open business model function, facilitates community creation and stimulation. As discussed by (Enkel *et al.*, 2009), and Sandulli and Chesbrough (2009), the coupled process facilitates the emerging of truly open business models. The process is described as co-creation with trusted partners, relying on external resources to develop innovation and create value while also creating new revenue streams by externalizing knowledge. Business model governance, as displayed by the cases studied, relates mostly to legal, strategy, and capability management.

This sharing means that firms must re-think their regulatory system (working contracts, information-sharing rules, NDAs, etc.) in order to better interact with innovation communities. Legal aspects, in the cases studied, have ranged from very closed, proprietary systems (Kreatize, VW) to gradually opening systems (Renault, Raidlight) to fully open systems (Local Motors).

They must also build either physical or virtual interfaces with communities and respect a number of community-based rules. The rules include respecting the communities' often-tacit codebook: building trust, animating the community and sharing without expecting anything in

return. In such situations, firms need to act as gardeners, carefully tending the *middleground* co-created between an organization and its surrounding communities. In the case of Raidlight, the community forum, GitHub platform and the 2018 Chartreuse Trail Festival, serve to foster interaction between the firm and the community. In the Renault case, open source hardware provides a cognitive space that, on one hand enables employees to break through organizational silos in a non-hierarchical manner and question the firms' existing business model. On the other hand, it allows interaction with innovation communities external to the firm. In this specific case, OSH appears not as a goal, but as a part of the open innovation process to foster an organizational culture of openness. As was identified in the Renault case and the Barcelona ecosystem, OSH is only one of many cognitive "*spaces*" or themes that employees or citizens are invited to work on to bring about change.

6.3.3.2. *Knowledge sharing capacity*

Within the scope of OSH, it appears that knowledge flows in business model structures occur unilaterally, multilaterally, and inter-laterally. Unilateral flows occur within the central firms (business units, departments, and specialized units, formal and informal meetings) and help either to condense existing knowledge or to enhance preeminent understandings through market insights, user research, or reporting. Multilateral flows arise among the central firm and the stake- and shareholders in the form of formalized meetings, Intranet, internal forums and annual reports. They can be considered a first step toward generating new, internal knowledge from the outside. However, most of the time a central firm will act rather as an informant, because of its legal restrictions regarding any public sharing of internal knowledge. Hence, hardware designs or software codes generally remain undisclosed. Inter-lateral flows support a give and take of information from the inside to the outside and vice versa. They include a willingness and ability to openly share knowledge, e.g. on virtual platforms, digital and real forums with people internal as well as external to the firm through feedback, public profiles, or motivation for interaction. Thus, existing knowledge of products and services (hardware and software) increases while options for collaborative models (e.g., shared services, additive manufacturing) develop (see Figure 56). Briefly stated, unilateral and multilateral flows facilitate knowledge absorption for the central firm, whereas inter-lateral flows support both absorption and dispersion beyond the firm's boundaries.

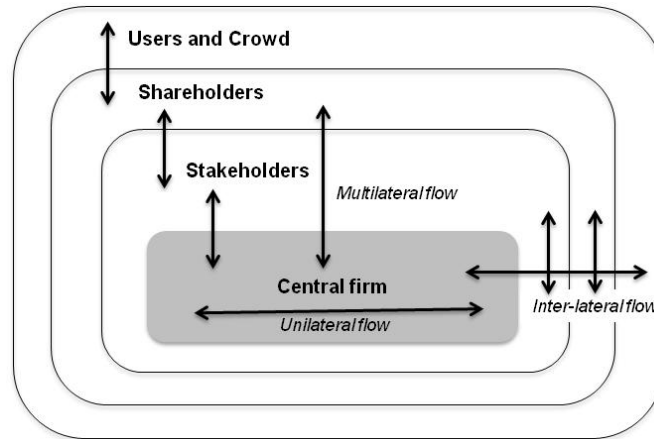


Figure 56: Knowledge flows for business model design

In especially two of our case studies, (Renault and Local Motors), we were able to observe how firms face uncertainty when devolving knowledge resources to external communities to attract further collaboration and to elicit feedback on their solutions. At the same time they risk dispersing their own knowledge, they capture value from the inter-lateral knowledge flows coming from these communities. In the case of Raidlight, knowledge creation could not be absorbed by the community, which lacked the technical knowhow.

6.3.3.3. Value sharing process

An incumbent industry dealing with the question of how to open the business model to capture more value, will take steps to transform formerly closed business models, giving them more openness, (Renault, VW). Large corporations like these, first display internally motivated efforts by initiating an overview of open source hardware and software services (e.g. VW technology scouts), which is mostly internal, but also includes collaborative projects (VW User Design Centre), and open projects (Renault POM Twizy).

In other words, the shapers of co-creation and knowledge flows can be described as initially learning and absorbing. They will later support interacting and dispensing (see Table 21). At the absorption stage, value generation occurs as learning for the central firm. While the platform provider at the end of a challenge openly shares designs, therefore shares value, the corporation's insights remain internal and proprietary.

The initially open firm may enforce closed activities in order to create value from them (Kreatize), which can be interpreted as sticking to the status quo of its closed-industry clients.

Consistently open firms maintain their openness through actively managing challenges, and sharing the knowledge created (Local Motors). At delivery stage (dispensing), the central firm, jointly with platform providers and the crowd, learn and share by providing knowledge. They open up their business model by providing services around new designs, subsequent designs or manufacturing processes and new partnerships.

Our research enables us to extend the three open innovation process archetypes described by Gassmann & Enkel (2004) in their widely cited research on firms' open innovation practices. Although they discuss open source practices as a background for their research, their perception of the open innovation phenomenon remains proprietary, meaning that even the inside-out process of "*transferring ideas to the outside environment*" is predominantly discussed as "*profits by licensing IP*". Our findings suggest that an equivalent of all three-process archetypes exists in the domain of value sharing (see Table 21).

Knowledge Value	Searching	Bilateral	Dispensing
Shared	Commensalistic approach	Shared value	Broadcasting approach
Proprietary	Outside-in process	Coupled process	Inside-out process

Table 21: Open innovation and mechanisms of open source hardware innovation (developed by the OPEN! Team)

The searching and dispensing dimensions refer to whether or not an organization relies on external stakeholders to create value, and is willing to leave profitable niches for others. But it also enables others to profit from the technology, and fits with the four freedoms associated with open source hardware⁵⁰. From left to right, the searching dimension for the shared value, is a commensality, available to all and managed for individual and collective benefit. Based on the idea that, as Benkler (2013), and Benner & Tushman (2015) suggest, the use of collaborative product development applies when costs of communication are low, when the core tasks can be modularized (as is the case in commons cooperative platforms such as OSPD and OSH), and when the knowledge for selecting and generating solutions is broadly dispersed; paraphrasing Benkler's terms, when the "what shall we do?" questions abound.

⁵⁰ Or rights that apply to free software: a) to use or perform the work for any purpose, b) to study and adapt it to ones' needs, c) to make copies and share them, and d) to distribute derivative works.

On the pendulum of what is proprietary to a firm and what is shared with stakeholders, users and crowds, the broadcasting approach strives to standardize and leverage associated technology making it a de facto standard in the industry. In their article on “What is the source of open source Hardware”, Bonvoisin *et al.*, (2017, pp. 5) describe this approach as being usually employed by firms or people who disclose their product design at the end of the development process, when the product versions are fully developed. The authors call them “isolated innovators”, who broadcast their innovations to enable other people to produce them. On a much larger scale, Google and Tesla’s strategies are examples of this approach (Tinck & Bénichou, 2014; Roberts, 2014). The processes characterizing the two other approaches require more study.

6.4. CONDITIONS FOR OSHBM IMPLEMENTATION

The main limit, of course, is that this model has not been applied in workshops. This is also a limit of the dialogical model upon which this thesis has been designed, suggesting constructive exchanges between theory and practice. To this end, we have included the illustration of how a company such as 1083 could use our model. Obviously, using this model in workshops such as La Comunicadora⁵¹ in Spain or the REMODEL program at the Danish Design Center would further enhance the processes we have identified.

The other more pernicious limit concerns the question of governance, which is much more important than legal ownership issues, as reflected in the Open-O-Meter. The Sharing Star Framework (Fuster & Espelt 2018) provides an assessment of commons based cooperative platforms, but does not set clear guidelines to steer the distributed enterprise model (Step 5) towards a positive societal outcome and away from, say, pyramid schemes and drug cartel operations. In such cases, the social contract established is based on the benefit of protection. What is the value of this new type of social contract in OSH ecosystems that would make the distributive enterprise model generative and not extractive?

In order to answer that question, the notions of sovereignty both individual and collective, as a basis for the social contract, needs to be revisited to reflect 21st century reality and commons-based digital platforms. The basis for the social contract, as developed by 18th century philosophers, stood on the grounds of individual and universalism values. These value groups in the Schwartz’s values circumplex (1992) are neighboring cognitive frames. Individualism

⁵¹ <http://freeknowledge.eu/lacomunicadora>

implies that participation in political power brings something to you, whether it is security or private property. Universalism is the notion that all individuals in a political body have the same rights and responsibilities. Which in today's language translates to "La mia libertà protegge la tua". My freedom safeguards yours.

Our findings on the importance of sovereignty are linked to the value of self-sufficiency, a basic human right (Bereni *et al.*, 2008). Individual sovereignty is the power of authority or decision that an individual wields. On a personal level, sovereignty is the will to live by certain principles, but mostly it is the freedom, as well as the legal and technical possibilities of doing so: the ultimate authority of determining one's life. Philosophers distinguish individual, collective and state sovereignty. An individual may abandon his freedom (sovereignty) to the state, in exchange for its protection of his physical person and or property.

Collective sovereignty is understood on a group level. Philosophically speaking, enterprises holding licenses (providing seeds to agriculture) are understood as collectively sovereign while exercising private interest. We propose that OSH offers a different way of understanding collective sovereignty. Through decentralized, peer-to-peer systems, new solutions are being created enabling citizens to rely on each other to develop a plethora of technical solutions to meet their individual needs with an interest in the common good. In line with Raworth (2017), Eglash (2016) and (Troxler 2010a) this is the novel configuration in value creation that the Commons theory offers: distributive and generative design. Eglash writes (2016, p. 393), "... these initiatives, as Alaimo (2010) puts it, they help us think about deviation as an ethical ideal of openness to unexpected change" (p. 139). And we need not stop at biology. This endless creativity is in some sense what brought us non-Euclidean geometry, atonal music, non-classical physics—the myriad alternative forms that mangles of human and non-human agency make available in every domain; in other words, the deeply generative nature of the universe itself".

When looking at Richard Barrett's 7 stages of psychological development it appears from our interviews that the average age of the people practicing OSH is 33: the individuating age during which one satisfies one's need for freedom and autonomy (Barrett, 2016). In this stage, evolutionary intelligence resorts to the second algorithm of evolutionary intelligence – bonding to form a group structure and focusing on the common good. This means there is a potential gap with the cooperating age necessary for deploying of the distributive enterprise model. The problem that appeared regarding values and governance in the Barcelona OSH ecosystem, was

that “technology cannot be civically led if no citizens are involved, and if, in reality, it is led by just a few males who sit [...] with their MacBook Pros, assuming that the rest of society will behave according to their visions”. This echoes a feminist critique of universalism (Bereni *et al.*, 2008) and Ron Eglash’s statements on the need to “decolonize technology” and the importance of generative justice (Eglash *et al.*, 2016; Eglash 2016) in order to fully democratize bottom-up innovation processes.

The distributed enterprise model works based on collaboration, corresponding to Richard Barrett’s integration phase (2016): his 3rd level algorithm for collaborating with others where connections are made to form higher order entities and to combat threats. We observe this happening on a territorial level: the Fab Lab movement has spawned “Fab Cities” and “Fab Countries”, such as Bhutan (Diez, 2018, p. 110). People do not share the same identity, but will bond together and collaborate when faced with a threat that no single person can face alone, pledging to produce locally at least 50% of resource needs in order to face global warming a threat that no human being has had to face before (Fab City Whitepaper, 2018; Barrett, 2018).

In conclusion, for this spiral model to be a contribution to Commons based peer production, in the sense that it may be a tool to help OSH practitioners monetize their innovations; while keeping their core innovation open, and broadening value capture to a wider set of stakeholders; collaborative product development needs to be associated with a corresponding shift in mindset. The words of Otto Scharmer, the author of Theory U come to mind. “The quality of results produced by any system depends on the quality of awareness from which people in the system operate” (Scharmer, *cited in* Elworthy, 2014, p. 264). In our findings, this appeared as the accompanying “organizational culture of openness” that needs to be instilled on a content, structure and governance level for open initiatives to be successful (Saebi & Foss 2015). In a later book, Scharmer explains, “the success of our actions as change-makers does not depend on what we do or how we do it, but on the inner place from which we operate”, (Scharmer, 2013) which in turn echoes Einstein’s statement that “you cannot solve a problem from the consciousness that created it”.

CHAPTER 6: KEY TAKEAWAYS

In this chapter, we present our final framework for OSHBM. This framework concludes work identifying different typologies of OSHBM and comparing them to the patterns for business model innovation identified by Gassman *et al.*, (2014). In line with Wolf & Troxler (2016), we were able to observe that there is not a single Business Model Pattern for OSH, rather there are a combination of patterns, used as building blocks.

Our framework is a creativity tool destined to help OSH practitioners understand the scope of OSH, and think about developing long-term strategies. It answers questions concerning the many revenue-making strategies that OSH initiatives may use. The last two steps of the framework: the “platform model” and the “distributed enterprise model”, answer the question of how to share value creation and capture with a larger set of stakeholders. They demonstrate the novel configurations for this offered through a Commons theory approach. The spiral model, in essence, expresses how OSHBM can be distributive by design, in the sense that others can take the innovations and replicate them, and how they are generative by design: provoking collaborative solution finding, tackling problems that a single firm or entity cannot solve alone. We have illustrated the framework using the French apparel brand 1083. The jist of the framework is not necessarily to build non-competitive business models that create revenue. Rather it is to be non-competitive with partnering organizations so as to render the existing economic and industrial models obsolete.

The prerequisites for building OSHBM are presented. These help OSH entrepreneurs in the personal conviction needed to collaborate with others. The pre-requisites are first, shifting one’s mindset from a “me” to “we” perspective so as to act for the common good. Second, the need for a values-driven governance that can be instilled at each level of OSH ecosystems. Third, for such a governance to be respected, in line with the epistemic nature of OSH communities and Ostrom’s Common Pool Resources Principles (1990, p.90), a co-created manifesto establishing rules and sanctions for violations of non-democratic practices.

Recommendations for how to use OSHBM follow. These include how to tap into the values of a larger ecosystem to help grow, how to progressively use the steps of the framework to reach out for support, to build consortium and to strengthen core-competencies. Our findings are discussed for openness strategies in community-oriented business models: the need to establish *middlegrounds* to build innovation communities and manage interactions, and

strengthen firms' collaborative muscles by allowing inter-lateral knowledge flows supporting absorption and dispersion beyond firm boundaries.

The conditions for OSHBM success are linked to “the inner place from which we operate” (Schwarmer, 2013). Politely stated, OSH initiatives cannot be implemented without an organizational culture of openness (Lang *et al.*, 2017) that is coherent with a firm's content, structure and governance (Saebi & Foss 2015). Einstein's words are worth repeating, “you cannot solve a problem from the consciousness that created it”, inferring that continual work be done to “decolonize technology” and revisit the social contract basic values of individual and collective sovereignty in light of 21st century digital commons.

CONCLUSION

1. MAIN CONTRIBUTION

Competition is at the core of what it means to be a business in a capitalist society. In the same way that land was once common for communal use, then became enclosed for private profit, organizations have used patents and licenses to protect their innovations and make money.

Drawing a parallel with agriculture and business, the notion of personal or private property is a critical issue. Framing this concept in a narrative would go something like this. For example, the seed needed for a dietary staple: for example the tomato, which naturally exists abundantly and in a variety of different species in a natural state. The seed can be reproduced by cultivating and harvesting. But cultivating one's own varieties and circulating the seeds DNA is forbidden by law. So two options exist.

1. Buy seeds sold by corporate monopolies which have modified them to produce sterile flowers and fruit making them impossible reproduce: something that was natural, has been privatized.
2. Don't enclose. Whoever wants to grow tomatoes, once they've bought them can do as they wish with them. The DNA remains in circulation.

Once the DNA is shut down so is generativity, the human capacity to creatively problem-solve in a myriad of different ways, adapted to a plethora of different contexts. We can see the same thing happening in business. Take a network of highly skilled machine SME manufacturers in Denmark working on HVAC systems, vegetable packing or oil filtering. Individually they have neither the money nor the team for the expertise required to face the digital revolution. Unable to build a new system from scratch, they run the risk of becoming extinct to winner-take-all solutions, because they depend on external technology. Their disappearance would, in turn, seriously undermine Denmark's economic vitality.

OSH projects are examples of a transformation underway. The transformation is made possible by rapid prototyping through democratized access to digital fabrication tools. Historically, unlike ever before, product development is leaving the confines of closed R&D labs, moving through networks of Fab Labs, Makerspaces and city-driven initiatives, through and into the hands of everyday people who use it to address different scales of local to global problems.

These people experiment, crossing ideas, using trial and error to make anything from agricultural machine tools to beehives, from furniture for the handicapped, to prosthetic limbs for children born with disabilities, or shape-shipping sailing robots to clean up oil spills or plastic waste in oceans. The novelty is that all the blueprints, bills of materials and assembly instructions of the products developed are publicly shared on repository hosting services such as Github, and Phabricator or sharing platforms such as Instructables, so that anybody can download them, replicate or modify them and even sell the resulting product (Bonvoisin *et al.*, 2018, p7).

How people can make money through OSH has baffled researchers, some even calling it the “puzzle of open source” (Chesbrough, 2003). Although a business model reflection was deemed crucial to help scale the innovations (Chesbrough & Bogers 2014), the notion of “value capture” as understood by business model academics is the sticky point for OSH. Indeed the mindset of OSH practitioners is different. They would argue that capture makes no sense: “There’s nothing to capture because you are aiming to share”.

The main tenant to bear in mind regarding OSH is Richard Stallman’s statement that free “stands for free speech not free beer”. The wager of technological openness in this sense is to remain free in a “mangle”; relying upon one another to solve problems collectively that no single organization could tackle alone (Breuer & Lüdeke-Freund 2017; Eglash 2016). The core values of OSH are openness and sharing. The result is the biodiversity equivalent to business: instead of having just a few GMO crops with sterile flowers and fruit, that people become indebted to purchase, human minds are decentralized, empowering people to use their imagination to find solutions⁵²⁵³.

However, because this is hard to do and we live in a culture where we are incentivized *not* to share, OSH endeavors must seek creative ways of finding sources of support that make them *not* competitive. The core of our research on business models for OSH seeks to address this tension. The question of business models for OSH translates to “What are you enclosing”? (because you have to). When deciding to develop and grow their OSH initiatives, OSH community members need to make concessions and impinge on their free ideal.

Moving from what was originally an intuition, and was gradually confirmed, we chose to study this phenomenon from a multilevel perspective. Because of the hybrid community nature of

⁵² https://www.youtube.com/watch?time_continue=1&v=jAemh_JxgOk

⁵³ <https://mail.google.com/mail/u/0/#trash/FMfcgxwChcgKDMwgbZMJVwfxSDBkQqrN?projector=1>

OSH (meaning combining aspects of both communities of practice and epistemic communities), where participants can work for organizations but may work on endeavors in *underground* settings, OSH addresses intra- and inter- organization levels, reaching beyond to interactions with broader sets of stakeholders. For these reasons we used Foss & Saebi's (2018) recommendation of building on business model research by using "OSH ecosystems" as our unit of analysis. We defined OSH ecosystems as circles of core community members, interacting in progressively larger circles with firms, and a territory-level ecosystem. We also chose to use the *middleground* concept developed more recently by Cohendet *et al.*, (2014) to dimension the interaction mechanisms at hand in OSH ecosystems. As suggestions on how to improve society in all evidence "circulate", it was enlightening to realize that the idea of fostering the roots of innovation in the underground goes as far back as the Marquis de Mirabeau (*cited in Higgs 1897, 21*).

OFFERING A FRAMEWORK FOR BUSINESS MODELS FOR OPEN SOURCE HARDWARE

Our contribution to the historical progression of the understanding of Commons and Commons peer-production in particular, is to provide a business model framework to help practitioners brainstorm creative ways for generating revenue, while working on their innovations. The aim of this OSHBM framework is to build on the key elements of distributive design and generative design as part of the Commons theory, which addresses novel configurations in value creation and capitalism.

In line with Foss & Saebi (2018) and Teece (2010), we used the understanding of BMs to orchestrate of activities surrounding value creation, delivery and capture. We agree with Chesbrough & Bogers (2014), that BM consideration can and must be added in order that OSH initiatives scale for impact. We were able to see the way revenue models evolve and how organizations get a finer understanding of building consortiums by tapping into the values of the actors in their ecosystems, making their initiatives grow in scale and scope.

Our framework reveals the tension inherent in OSHBMs. In their ideal form, they should be fungible. OSH is an abundance view in which you can just pick an apple off a tree; there is no need for enclosure to ensure private benefit. However, because we do not live in an ideal society, OSHBMs must creatively seek revenue streams "looking at what can be enclosed". In a society without the incentive to share, creative brainstorming is required to find the non-competitive form of support.

We found that values are key to cementing contributions and building a consortium of actors able to help OSH endeavors grow in scale, both on a local and a global scale. The set of values that stands out the most in our research are those linked to the notions of sovereignty and democracy. OSH practitioners defend their right to self-sufficiency; to build one's capacity, and empower other's to do the same while creating and adapting solutions

BUILDING ON THE COMMONS THEORY IN LIGHT OF OSH GENERATIVE POTENTIAL

As opposed to community-oriented business models essentially seeking to crowdsource ideas from the general public, the scope of OSH lies in reciprocity-based participation. Granted the level of expertise needed to participate in projects is most often high, in order to have citizen-led technology, citizens must be empowered through open access knowledge. Igniting human imagination is key to finding solutions.

We agree that circular economy innovations need to be open-source in order to spread. We suggest, however, that the current model focusing on the regeneration of biological and technical nutrients, is missing the generative human element. OSH and Commons based peer production fit the circular economy goal of regenerative design (Raworth, 2017, p. 220). Peer-to-peer networks of distributive design (Raworth, 2017, p.192, Troxler) and the capacity to “inform, learn and teach worldwide” enable copying and implementing innovations globally.

However, the value of sovereignty, as the “over-arching family of values” found in our interviews is directly linked the generative concept. Technology has provided many answers since the Marquis de Mirabeau (1768)'s metaphor of the tree, which seems to remain a favorite of Management Science and innovation dynamics (Cornella, 2010; Cohendet *et al.*, 2010; 2014). Although many proponents of OSH in agriculture would probably, and vehemently, argue Mirabeau's point that the metaphor belongs to agriculture; to OSH it offers the potential of building up human capacity.

Value created by OSH goes beyond the circular economy concept of recycling biological and technical nutrients. The concept of generative justice posits that, as technology becomes democratized, out of the confines of closed R&D labs, human skill and competence must be built up to co-create local solutions to global problems using a dash of “fab-lab magic” (Troxler 2010b). The value created by OSH initiatives closely matches Ron Eglash's vision of generative justice: Generative Justice seeks to replace the extraction of value alienated from its generators, with the circulation of value in its un-alienated form. It aptly describes, for example, the ways that composting circulates ecological value, worker-owned cooperatives

circulate labor value and online collectives like Wikipedia circulate expressive value (Callahan *et al.*, 2016)].

In line with Ostrom (1990, p.90), Cohendet *et al.*, (2014), and Barrett (2016) our findings underline the importance of co-creating a set of rules to manage a common effectively. The question remains however on how to implement Open design as a Commons since “we cannot be naïve about the lengths to which multinational corporate giants and militant nationalism will go to hold on to power” (Eglash, 2018, p.46). This is also the tension that our findings indicate concerning the gap between the average age of OSH participants and the psychological development stage needed to implement collaborative democratic open commons (Barrett, 2016).

BUILDING ON THE MIDDLEGROUND CONCEPT

We were able to validate the Cohendet *et al.*, (2014) notion of the *middleground* as means for OSH community-based and community-oriented projects to build community and to build a consortium of stakeholders, needed for support and to help the projects grow in scale. In line with Capdevila (2017) we were able to confirm that novel element enabled by digitalization, is that OSH projects have the potential of both local and global impact. OSH solutions are applied locally, and extracted virtually to be replicated and improved upon elsewhere (iCapital, 2018).

Furthermore we found the the middleground concept useful in dimensioning innovation interactions rendering theory on business models “fundamentally researchable and cumulative” (Foss & Saebi 2018; Cohendet *et al.*, 2010; 2014). The choice of an OSH ecosystem as the multilevel unit for analysis enabled us to appreciate the systemic interaction mechanisms involved between an OSH initiative and its ecosystem.

2. MANAGERIAL CONTRIBUTION

From a managerial perspective, we provide concrete tools to (1) build a community around OSH projects (2) to build a staged open business model.

The pinball model describes how OSH endeavors can leverage their ecosystem for growth. This model is useful to use in bottom-up innovation dynamics. It explains the proactive steps that OSH projects can do to gain *upperground* support, build their *middleground* and a global-local consortium.

The spiral model describes the reasoning needed to fine-tune an OSH value proposition in interaction with a larger set of stakeholders.

Both frameworks describe a learning process, through which, by interacting with ecosystem players, OSH initiatives grow in scope. The stages of our OSHBM framework display constellations of activities dedicated to value creation, delivery and appropriation (Foss & Saebi 2018, p. 10). OSH initiatives do indeed have revenue models, and monetize value created through collaborative product development. Moreover, that value is shared by a broader set of stakeholders.

The first 3 stages of our spiral framework are easy enough to implement. First, OSH actors need to get seed capital from 3rd party players. This can be done through academic support such as grants, corporate sponsorship or crowdfunding initiatives. This first stage serves to gain an understanding of what stakeholders will support, which is useful for the second stage, which requires fine-tuning the OSH value-proposition into a product-service combination. The third stage, requires a more strategic view on an organization's core competencies and competitive positioning. This stage is probably is where the most pressure can be felt on staying open or not or on gradual open and closing strategies. The fourth stage, the platform model is challenging for firms to implement. The Danish Design Center's REMODEL program, was specifically tailored to help firms experiment with opening up key assets to enable roles in their network. The last and fifth stage that we found from our research is the riskiest for firms to implement, but it is where the scaling potential lies.

Our findings on community-oriented business models indicated that openness can only be put in place if it is congruent with a firm's existing culture and existing business model. If firms are in a scouting phase, "collaborative capacity" can be developed by creating internal, external and mixed innovation labs to progressively interact with innovation communities.

3. METHODOLOGICAL CONTRIBUTION

In this research, we have striven to add to BM literature by explaining how OSHBMs work. To do so we have developed the concept of OSH ecosystems, as a distinct and three-tiered level unit of analysis. We have dimensioned it by using the *middleground* concept as a means of understanding the interaction mechanisms needed to animate community participation. The outcomes we are linking to the OSHBM are the spread of the innovations through distributive

design and generativeness. We have identified values around sovereignty as the necessary glue cementing community participation.

4. LIMITATIONS

From a methodological point of view, a mixed method approach combining qualitative and quantitative analyses would have strengthened our research. For instance, the project rating and correlations derived from it could be validated by further quantitative work. The Fleiss Kappa for the inter-coder reliability was weak, suggesting a lack of common understanding of the projects existed among the coders (for projects 1-21). This occurred even though transcriptions (in French and English) and summaries of the interviews (in English), had been done. As our research progressed we were able to interview two projects (of the 23 at community level), which the researchers considered pertinent, but which were not subjected to the same level of analysis via Nvivo coding. The findings were included in a general coding analysis spreadsheet with key citations selected directly from the transcriptions and progressively abstracted through a horizontal analysis (Gavard-Perret *et al.*, 2012, p.291).

Another finding needing to be quantitatively validated is the correlation derived from our initial study on 23 projects (from May through November of 2017) between “high critical solving projects” and decentralized contributions. This finding suggests that projects that are “just for fun” generated fewer contributions than those which are “high critical problem” solving. Indeed, Bonvoisin *et al.*, (2018) using a data mining on Github between March 2016 and March 2018 on projects identified as open source product development projects (OSPD),⁵⁴ where able to find that even the open source hardware projects with the most active communities showed substantially less complexity than typically closed source industrial projects. Their results reveal that at least 30% of the 105 projects selected displayed little evidence of process openness and collaboration. A quantitative analysis on at least 100 projects would be able to assess whether, even if collaboration is lesser in typically closed industrial projects, the OSH projects that have the most contributions are “high problem solving”.

Moreover, our research lacks a longitudinal perspective. This is true although a regular relationship through email correspondence, face to face and skype meetings was maintained over the course of the past three years with most of the 27 project leaders interviewed. A

⁵⁴ where the process is open and not just the final product

longitudinal analysis would have been a powerful means of studying a process, and even assessing causation.

This would have been particularly relevant in the automobile industry, for instance, by monitoring the reaction over a sustained period, of incumbent brands and how their approaches to OSH business models do or do not evolve. It would also have provided deeper observation on how, or whether or not, community-oriented business models also leverage the values of their surrounding ecosystems to collaborate in solving larger-than-self-problems that a single firm cannot address alone.

From a content perspective, this work was unable to pursue promising, empirical work conducted by the Free Knowledge Institute, concerning “virtuous combinations” of OSH BM. The Free Knowledge institute, along with the Dimmons Institute, are part of the Comunicadora program, helping cooperative-based digital platforms grow in scope. Our findings denote a process whereby OSH communities progressively fine-tune their business model, build a consortium and grow in scope. The Free Knowledge Institute’s work in Barcelona on the “Model de Sostenibilitat Procomú” differs from the Sharing Star Framework. This Framework, developed by the DIMMONS team, offers a real-time assessment of initiatives governance, technology and knowledge openness. The Free Knowledge’s work, on the other hand, offers a strategic model displaying the different configurations among knowledge sharing, revenue streams, production modes and governance. Researching and assessing which particular combinations are the most successful would have been very interesting.

Furthermore, in this work we only address the knowledge policies for user-generated content licenses. The legal framework needed to provide guidelines and sanctions for patent breaches is not covered, and is a crucial component of OSH. Conversations with practitioners revealed, “we are at the stone age of open cooperative regulations”. Legal regulations appear to lag behind what OSH commoners and civil society is doing. What precisely happens if “not in good faith” a behemoth seizes an OSH innovation and closes it down, is unclear. Practitioners rather optimistically argue in favor of a standardize and leverage approach, in the sense that if their innovation was taken over by Ikea, it would become a standard, and that would be positive. The lack of clearly understanding legal concerns regarding OSH appeared as a major blockage to adoption from our firm-community level analysis.

5. FUTURE WORK

Future work could first include research on the viral nature of OSH. We observed how firms sought to design their business models around open source hardware. Yet, in traditional industries such as the textile or automotive sector, operational inertia seemed so heavy, that leading examples used OSH as a demonstrator for change, as was the case with Local Motors and the POM Twizy. How the collaborative capacity muscle is strengthened or not by OSH initiatives, would be interesting to study and whether these initiatives do change the business model of these firms. Following Røvik's (2011) theory on virus spread and contamination, do OSH initiatives “infect” the host and change operational processes? For this research, we could keep the *middleground* concept as a means of dimensioning business model research, and assess where the entry points and barriers to contamination are found.

A second promising avenue for future research would be to study the role of OSH in fostering generativeness in specific industries, and putting them back in the safe zone of Raworth's “doughnut”. For instance, the textile industry is one of the most polluting in the world, and has one of the most complex supply chains ranging from agriculture to distribution and retail (Gardetti & Torres 2012). What role could OSH have in the “Model 3 - Corporate competence” business (design centric, manufacturing centric, expertise and experience-based, and integrator) models, in modernizing supply chains by boosting local production through digital fabrication? Following Fletcher and Grose (2011), how can OSH solutions be applied to create an embedded economy vision of the textile industry? A case study of the innovative 1083 brand would be a good opportunity to study this phenomenon.

Third, our research on OSH ecosystems revealed how useful it would be to conduct case analyses comparing different OSH ecosystems. This research could be extended upon through a multi-case analysis on different OSH ecosystems would serve to see if the findings on how to leverage an OSH ecosystem for growth are useful or not. The Fab City White paper goal of making cities at least 50% self-sufficient in terms of energy and resources produced, provides a good background for case selection based on ex-manufacturing centers who use digital fabrication to reintroduce manufacturing in cities (ie Paris, Copenhagen, London) and the realities of current manufacturing centers such as Shenzhen, “the factory of factories”.

Tied to legal considerations, another promising avenue is to build on Ostrom's design principles illustrated by long enduring common pool resources (CPR) institutions (1990, p.90) and to see how their pro-democratic qualities may be enforced. That is, to move from the co-

creation of a manifesto to guaranteeing the rights of individual and collective sovereignty. This work would serve to extend Rousseau's Social Contract in the age of Digital and Knowledge Commons, ensure that private interest does not supplant common interest and that such a system is generative and not alienating. Intermediate steps towards that goal, would include creating metrics for generative justice

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APPENDIX 1: SCOPE OF THE OPEN! PROJECT

	Descriptive	Prescriptive	Practical
WP4	<ul style="list-style-type: none"> • Open source business model typologies • Case studies on components of open business models • Motivation in communities 	<ul style="list-style-type: none"> • Framework concept (to render open source projects viable) 	<ul style="list-style-type: none"> • Guidelines for practitioners how to build a business based on open source
WP2	<ul style="list-style-type: none"> • OSPD process models derived from observation of existing projects • Gap analysis (comparison with industrial development) 	<ul style="list-style-type: none"> • OSPD requirements engineering concept (guidance for OSPD projects) • Adapted QM methods 	<ul style="list-style-type: none"> • Tool matching needs and processes
WP3	<ul style="list-style-type: none"> • Overview of existing tools for collaborative development in OSPD projects • Affordance/parameter (need/feature) matrix 	<ul style="list-style-type: none"> • Requirements for open design platforms 	<ul style="list-style-type: none"> • Prototypical implementation of IT-tools

1. Appendix 1 : targeted outcomes of the Open! Project work packages

WP1 seeks to collectively (with all team members) understand the current landscape of open source product development.

WP2 seeks to define an open source product development process, ensuring the convergence of open source product development projects and allowing for the design of high quality and complex products.

WP3 focuses on collaborative IT tools and supporting information systems adapted to providing design communities with the means of online collaboration, product data management and management of the developmental process.

WP4 defines guidelines for business models helping entrepreneurs to reduce risks associated with the development of business models based on open source.

APPENDIX 2: COMMUNITY-LEVEL ANALYSIS PROCEDURE

INTERVIEW GUIDE FOR COMMUNITY-ORIENTED BUSINESS-MODELS

Contents

Introduce ourselves and make a short presentation on the aim of the research

Validate the interview condition (length, recording, feedback...)

First question

List of topics that will be discussed

Closing the interview

Introduce ourselves

We are researchers from *your workplace* and are working on a project about open source development of physical products. The first aims of this project are to better understand open source product development communities:

the motivations of members to participate (e.g. fun, create value)

the way communities emerge, the way members work together

the supporting methods and IT-tools communities may need to enhance their existing collaborative design process

With this understanding, our aim is to develop supporting methods and IT-tools adapted to communities' needs facilitating both design activity and collaborative work.

This is an exciting area to study

The objective of the discussion today is to prepare a quantitative data acquisition (survey) we plan to make between August and September. We want to be sure the question we are asking are relevant and fit with the reality of open source product development communities.

We selected your project for this discussion because you are developing open source physical products and fit with the object of our research.

Validate conditions of the interview

Do you agree to discuss these topics with me?

I suggest a 45 minutes long discussion? (15 minute buffer) Is it ok for you?

Do you mind if I record our conversation? The recordings are only for internal communication within the project. Because we are an international team of researchers working at distance, we need these recordings for means of information sharing. The recordings won't be published and there will be no direct citation of your words without your explicit permission for which we would ask you first. If you want so, we can also anonymize the interview, so your name don't appear.

[start the audio recorder only after the person agreed with the conditions]

First question

The first question is focused on the object/project: "What are you working on? Can you explain your project to me?"

The first question is important and will depend on the context: the person works alone or in collaboration.

Strive to ask:

Unbiased questions

Focus on open-ended questions

Avoid "why", prefer "what"

Avoid ended questions on a high-pitch tone.

[how we lead the interview]

Main questions

Degree of openness

What information/files do you share (CAD files, schematics, project specifications, description of the concept, design brief)?

If not, is it something you plan to do?

Do you share the entirety of the product description, or are there some components you keep closed?

Is possible for anyone to reproduce your product?

Can people make changes to your documents? (CAD files, BoM, assembly instructions)

Community

What made you want to join this community?

Could you describe your community?

Who contributes to this project? Could you describe these (e.g. professionals in their private time, hobbyists, employees from firms with vested interests)?

How has the community developed (stable member base, growth, stagnation, etc.)?

How many members are in the community?

How big is the core team of the community?

What networks is the project engaged in (research institutions/networks, maker spaces, R&D alliances, other projects, etc.)?

Who are the project's main stakeholders in order of relevance (members, end user groups, suppliers, founders, society at large, etc.)?

Is there commercial interest in your project?

How much time do you spend on this project (offline / online)?

Do you meet with other community members (personally/physically/ online)?

The product

What is the product you are working on? Could you describe it?

What is your interest in this product? How did you choose to work on these product?

What is your vision? What are your values?

What does your project solve?

What's the potential impact of this product?

Project/process

Could you describe the design process (staged vs. highly iterative)?

Do you have clearly set milestones (i.e. rigid, frequent vs. flexible, less frequent design reviews)?

Is there a timeline for the entire project?

How are decisions made in your project (committees, regular meetings, type of meetings, approval guidelines, etc.)?

What particular knowledge management activities are done to facilitate sharing (Wikis, Lessons learnt, checklists, cross project communication, continuous improvement, etc.)?

What major issues have you come across during the development process?

Could you elaborate on any failures within the project? Which external & internal factors led to these?

What are the internal weaknesses you have come across?

What are the external threats facing your project?

Tools

Do you use an online design platform?

If not what do you use?

What enables your capacity to contribute to the design activity in the community?

What does the perfect platform look like to you?

Business model

In your understanding how does this project create value?

What is your target market/ segment? Who's your customer specifically?

What is your revenue model?

What are your customer acquisition channels?

What are your main cost drivers?

What makes your company and its offer unique?

What income sources do you activate?

Close the interview

If you don't mind, we would like to ask you these additional questions:

Age

Gender

Formal education

Occupation/ relevant experience (job or otherwise)

(What competencies do you bring to the community)

(What is your role in your project? Leader/organizer, contributor/participant)

COMMUNITY-LEVEL CODEBOOK PROCEDURE

This section provides the themes that were used as “knots” for the qualitative analysis we conducted on the 23 community-level interviews conducted.

MACRO THEMES

Interviewee: mainly deals with information gathered when interviewees were asked for more personal questions such as age, occupation, or formal education. We also include their role inside the OSPD project in this theme, and the time spent on the project when the information is available. This macro theme should allow us to conduct some descriptive statistics.

Openness: in this category, we find information regarding the criteria of openness defined by Kerstin Balka, Christina Raasch and Cornelius Herstatt (2013)⁵⁵. It includes three distinct aspects:

Transparency: the possibility for any interested person to see how the product is designed;

Replicability: the possibility for any interested person to make the product;

Accessibility (or Editability): the possibility for any interested person to take part in the (further) development of the product.

We can assume that these last 3 points will be further refined into new subcategories.

⁵⁵ Kerstin Balka, Christina Raasch and Cornelius Herstatt (2013). The Effect of Selective Openness on Value Creation in User Innovation Communities

Community: any information linked to the community, a social unit (a group of three or more people) who share something in common⁵⁶, fall under this category. In Business Dictionary⁵⁷, a community is defined as a self-organized network of people with common agenda, cause, or interest, who collaborate by sharing ideas, information, and other resources. We will consider all topics regarding:

The size (of the whole community and of the core team) and its composition

The motivation to join or create a community

The description of the community: members profile, structure of the community (hierarchical relations? Defined roles?), development of the community (growth, stagnation), and the strategy set up for the community development. The users of the product or services fall under this category too.

The interaction which can be internal (meaning between members, like physical or virtual) and external (i.e. networks and stakeholders)

Product / Project / Service: this refers to the description of the product (component, complexity, use, maturity level of this product) or the project and the service as well (some projects provide services). Emerging from data, we should consider the history of the project in this macro theme. Directly linked to the product, any information regarding standards and quality fall under this category.

Design Process: any information regarding the design process as a whole. This may concern whether the design process is staged or iterative, the timeline of the project, the knowledge management, the decision making process and collaboration⁵⁸ (i.e. the situation of two or more people working together to create or achieve the same thing).

Tools: refers to tools, platforms as well as their functionalities, the ones that already exist and the ones that people would like to see appear in an “ideal platform”. Based on the clover design model provided by Ellis⁵⁹, we can categorize tools this way:

⁵⁶ <https://en.wikipedia.org/wiki/Community>

⁵⁷ <http://www.businessdictionary.com/definition/community.html>

⁵⁸ <http://dictionary.cambridge.org/dictionary/english/collaboration>

⁵⁹ Ellis, C., Wainer, J., A Conceptual Model of Groupware, in Proceeding of CSCW'94, 1994, p.79-88, ACM Press.

Communication: refers to person-to-person communication such as e-mail, relay chat, mediaspace

Production: refers to the objects produced by a group activity or to the objects shared by multiple users.

Coordination: covers activities dependencies including temporal relationships between the multi-user activities. It also refers to the relationships between actors and activities⁶⁰.

Business models: the underlying structures of how companies create, deliver and capture value. They determine the speed at which economies grow, and the intensity at which our resources are consumed⁶¹.

Fall under this category any information regarding the identity (like the vision and the values shared, the problem addressed, the status of the project), the revenue model, legal aspects (Intellectual proprietary and licences), marketing, the cost structure, how the project creates or distributes value.

“Other”: During coding, we could encounter some paragraphs that are difficult to classify. They will be re-classify with the refinement of the coding.

Categories and a coding scheme can be derived from three sources: the data, previous related studies, and theories (Zhang & Wildemuth, 2009). Table 2 contains a summary of macro themes including their source: data, previous related studies, theories.

Table 2 : Macro themes synthesis

Code	Definition	Source
Interviewee	Information regarding the interviewee: age, formal education, occupation, role / position in the community	Data
Openness	Information regarding the 3 criteria defining an open source project: accessibility, transparency and replicability	Literature, wiki
Community	Any information linked to the community: motivation to join or create a community, interaction (internal like physical or virtual / external meaning networks and stakeholders), size (core team and whole community)	Lakhani, West 2008 Ehls & Herstatt,

⁶⁰ Yann Laurillau and Laurence Nigay, 2002. Clover Architecture for Groupware.

⁶¹ Clinton,L. Whisnant, R. (2014). Model Behavior : 20 Business Model Innovations for Sustainability

		2015 and data
Product / Project / Service	Information regarding description of the product (components, complexity, use, maturity level of this product), project history, standards and quality	Data
Design process	Any information regarding the design process, the knowledge management, the timeline, decision making, collaboration.	Data
Tools	Information regarding tools, platforms, functionalities	Data
Business models	Information regarding business model, marketing, competitors, revenue models, identity (vision and values, problem addressed), intellectual proprietary, licences.	Literature and data
Others	Philosophy, context, culture Lessons learned from other projects Unclassified data	Data
Problem	Risks, difficulties, lacks, failures	added 26.10.16

CODE REFINEMENT

After having classified the transcriptions among the 8 themes (level 1), the sub-categories (level 2) have been defined for each themes.

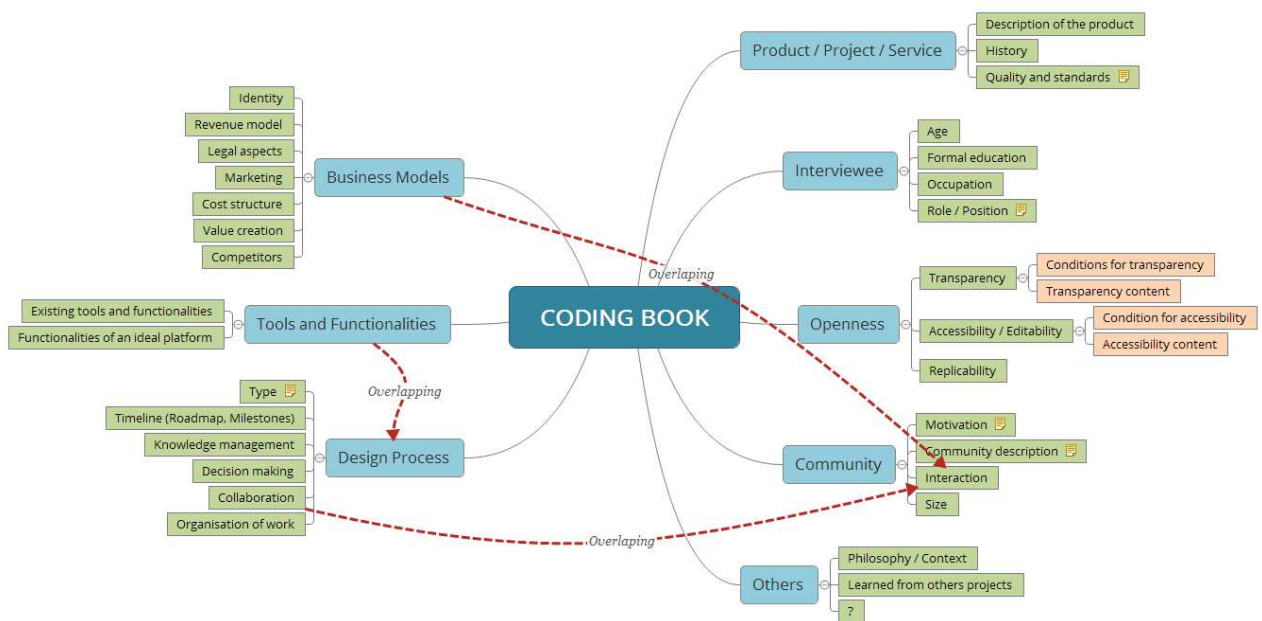


Diagram 2: Sub-categories

After a first coding, refinement has been done and overlapping identified (diagram 2) :

“Interaction” in “Community” and “Business models”

“Collaboration” in “Design process” - “Interaction” in “Community”

“Tools and functionalities” - “Design process”

The sub-categories (content, titles, description, creation/suppression) were modified iteratively through the coding process. At the end, we obtain 3 levels:

level 1 corresponding to the macro themes

level 2, sub-categories

level 3, only for one sub-category

COMMUNITY-LEVEL LEVEL 2 CODING

INTERVIEWEE		
Sub-category level 2	Definition	Comment
Age	How old they are	
Formal education	Educational background, degrees and / or diploma	
Occupation	Position held in their work (outside the	Caution: Possibly the same for the ones who work fulltime on the

	project), for living.	project (for instance La Cool Co). => Need to create another sub-category?
<i>Role / Position in the project</i>	Position held in the project - Time spent on the project	

OPENNESS		
Sub-category level 2	Definition	Comment
<i>Transparency</i>	<p>Possibility for any interested person to see how the product is designed, meaning published <u>design files or blueprints</u>.</p> <p>Includes <i>conditions for transparency</i> such as technical factors or personal reasons leading to access the files</p>	<p>URL where CAD files (computer aided design) or blueprints of non-electronic hardware components are made available. Depending on the maturity of the project, CAD files may not be available. If not, more qualitative information can be shared such as specifications or the schema of a solution concept.</p>
<i>Editability</i>	<p>Possibility for any interested person to take part in the (further) development of the product, meaning editable CAD files, editable assembly instructions, editable bill of materials, contribution guide available.</p> <p>Includes <i>conditions for accessibility</i> such as technical or personal reasons leading to the possibility of editing the files</p>	<p><u>CAD files</u> are editable, if they are released in the original format. They are not editable if they are only released in an export format (such as PDF or STL) which do not allow modifications to the 3D model.</p> <p><u>Assembly instructions</u> and <u>BOM</u> are editable, if they can be edited in a “Web 2.0” environment or downloaded as editable files. A file is editable if it is released in its original format. It is not editable if it is only available in an export format (such as PDF).</p> <p>URL where the <u>contribution guide</u> of the surrounding development community can be found.</p>
<i>Replicability</i>	<p>Possibility for any interested person to make the product: it includes published <u>assembly</u></p>	<p>URL where assembly instructions can be found.</p> <p>URL where the bill of materials (also named part list) can be found</p> <p>Production files</p>

	<u>instructions</u> , <u>bill of materials</u> (BOM) as well as replication examples.	
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COMMUNITY		
Sub-category level 2	Definition	Comment / Specification
<i>Motivation</i>	<p>Process that refers to releasing, controlling and maintaining physical and mental activities (Janzik, 2015)⁶².</p> <p>We can distinguish 2 types of motivation: intrinsic (such as fun, altruism) and extrinsic (such as personal need, reputation).</p> <p>Any information regarding motivation of the actor to participate.</p> <p>Under this theme, we will find the motivation to create a community and the motivation to join a community.</p>	<p>Biais: interviewees were exclusively the creators / designers of the project. The motivation to join is not relevant regarding the population interviewed. We can assume the data will essentially concern the motivation to create.</p>
<i>Community description</i>	<p>A community can be considered “a voluntary association of actors, typically lacking in apriori common organizational affiliation but united by a shared instrumental goal”.</p> <p>(source: Gäser 2001 quoted from: West, R. Lakhani 2008 - getting clear about communities in open innovation)</p> <p>According to von Hippel, the actors may be individuals and/or firms and other organizations. In open innovation, the goal is usually to create and adapt economically valuable innovations. Following a specific understanding of innovation that emphasizes both the process and the outcome of innovation, open innovation divides up in open content (like Wikipedia and OSS) and open design (the focus of Open!, that is on mechatronic and</p>	<p>Maybe need to refine this sub-category.</p> <p><u>Role</u>: followers (people looking at what is happening without contributing to the design), developers (people taking an active part of the design), managers (people animating the design activity), users (people using the product and giving feedback)</p> <p><u>Intensity of participation</u>: full time, part time, regular sporadic...</p> <p><u>Geographical dispersion</u>: whether the community is located in a well defined and small location (e.g. town) or not</p> <p><u>Hierarchical relations</u>: for example, the capacity to assign a task to somebody.</p> <p>Caution: possibly overlapping between hierarchical relations and decision making</p>

⁶² Lars Janzick (2015). Motivations to contribute for free in online communities. In...

	<p>mechanical products).</p> <p>(source: von Hippel 2005 quoted from: West, R.Lakhani 2008 - getting clear about communities in open innovation)</p> <p>Information about members, who they are (profile, geographical dispersion).</p> <p>How the community is structured (hierarchical relations between members? defined roles in the community?),</p> <p>How the community evolves (stable, growing, decreasing).</p> <p>Strategy set up for the community development /</p> <p>promotion strategies in order to foster community engagement and growth.</p>	
<i>Interaction</i>	<p>Description of the content of internal exchange and external interactions with outside networks. Information on what they get from the community for instance</p> <p>- Virtual versus physical interaction will be considered too.</p>	<p>The interaction deals with its content (qualitative) and its volume (quantitative). Considering the data gathered during interview, it mainly concerns content of the interactions.</p>
<i>Size</i>	<p>Two numbers have been collected: the whole community and the core team.</p>	<p>Caution: possibly the same for small community.</p>

PRODUCT / PROJECT / SERVICES		
Sub-category level 2	Definition	Comment / Specification
<i>Product description</i>	<p>What the product is about, the components (software, electronic hardware, non-electronic hardware), the complexity of the product, its use, the maturity of the product also. Potential</p>	

	evolution of the product.	
History	Information relevant to the history of how the product came into being	
Quality and standards	information regarding the rules, regulations and norms tied to the safety of the product usage or production.	

DESIGN PROCESS		
Sub-category level 2	Definition	Comment / Specification/ Sources
Type	Whether the design process is staged or iterative.	Unger, D., & Eppinger, S. (2011). Improving product development process design: a method for managing information flows, risks, and iterations. Journal of Engineering Design, 22(10), 689-699
Knowledge management	<p>Strategies and processes designed to identify, capture, structure, value, leverage, and share an organization's intellectual assets to enhance its performance and competitiveness. It is based on two critical activities: (1) capture and documentation of individual explicit and tacit knowledge, and (2) its dissemination within the organization.⁶³</p> <p>“Knowledge Management is therefore a conscious strategy of getting the right knowledge to the right people at the right time and helping people share and put information into action in ways that strive to improve organizational performance.”</p> <p>O'Dell, Grayson 1998 -</p> <p>If only we knew what we know: the transfer of internal</p>	

⁶³ <http://www.businessdictionary.com/definition/knowledge-management.html>

	<p>knowledge and best practice.</p> <p>Knowledge management within organizations relates furthermore to knowledge acquisition, information distribution, information interpretation and organizational memory.</p> <p>Huber 1991 - organizational learning: the contributing processes and the literatures</p>	
<i>Timeline</i>	Structure of the process in terms of planning, whether there are roadmap or milestones	
<i>Decision making</i>	<p>How and by whom the decisions are made ?</p> <p>Are there bureaucratic structures that emerge over time? Is the power of decision making based on meritocracy? Are there democratic mechanisms of decision-making?</p> <p>How can a contributor become a leader? Is it through its former technical contributions or do his organizational skills qualify him?</p> <p>(source: O'Mahony, Ferraro 2009 - The emergence of governance in an open source community)</p>	
<i>Collaboration</i>	<p>the situation of two or more people working together to create or achieve the same thing (source: cambridge.org) as well as the factors of momentum needed to carry it through. Unlike cooperation, collaboration emphasizes shared consensual and common goals, social learning and dynamic roles of the project actors. Thus it requires a better communication than mere cooperation.</p> <p>In addition, it is a process through which a group of entities enhance the capabilities of each other. It implies sharing risks, resources, responsibilities, losses and rewards.</p>	keep in mind that this category always entails cooperation. However, we need to identify specific indicators for the existence of collaboration (per definitionem).

	Collaboration involves mutual engagement of participants to solve a problem together, which implies mutual trust and thus takes time, effort, and dedication. (source: Camarinha-Matos <i>et al.</i> , 2009 - Collaborative networked organizations)	
Organisation of work	<ul style="list-style-type: none"> -How is decided who does what, task selection and assignment. -How the work is actually done, by task, sequentially.... -Design Brief -Hierarchical structure or not -the manner in which community suggestions are integrated in the development 	This and actually all the other categories of Design Process will interact with the collaboration category (since opting for real and strong collaboration affects the organisation, the decision making, the design process, etc..).

TOOLS		
Sub-category level 2	Definition	Comment / Specification
Existing tools and functionalities	Tools and platforms already used or known by the interviewee, description of their functionalities	
Functionalities of an ideal platform	Either lacking or wished for functionalities identified by interviewee	

BUSINESS MODELS		
Sub-category level 2	Definition	Comment / Specification
Identity	<p>This refers to the vision, values, problem addressed and</p> <ul style="list-style-type: none"> - status of the project whether it is a hobby, a 	<p>Moogk (2012): https://timreview.ca/sites/default/files/article_PDF/RancicMoogk_TIMReview_March2012.pdf</p>

	business, a non-profit venture)	
Revenue model	The description of revenue streams that support the project. Comprises all the ways in which the project is funded: self, sales, donation/grants/foundation/public funding or crowdfunding.	<p>Osterwalder & Pigneur (2010): http://consulteam.theblackbox.org/media/5985/businessmodelgenerationpreview.pdf</p> <p>— Weil & Vitale (2001): https://www.researchgate.net/profile/Peter_Weill/publication/5176478_FROM_PLACE_TO_SPACE_Migrating_to_Profitable_Electronic_Commerce_Business_Models/links/00b49518ae03facf1b000000.pdf</p>
Legal aspects	Information pertaining to intellectual proprietary, commercial or non-commercial licenses	<p>Alt & Zimmermann (2001): https://www.researchgate.net/profile/Hans-Dieter_Zimmermann/publication/255996598_Preface_Introduction_to_Special_Section_-_Business_Models/links/0912f50878bc947a96000000.pdf</p> <p>MacInnes (2006): http://link.springer.com/article/10.1007/s10660-006-5987-8</p>
Marketing. Client acquisition	<p>Any strategy for customer acquisition including the 5 P's⁶⁴ (People / Position / Price / Product / Promotion), including of course who the target customers are.</p> <p>Branding: the process involved in creating a unique name and image for a product in the consumers' mind as well as its perceived reputation. Branding aims to establish a significant and differentiated presence in the market that attracts and retains loyal customers.</p> <p>-evolution of offer</p> <p>-aspect regarding the launch of a crowdfunding campaign.</p>	<p>We will generally encompass the strategies from the promotion and the customers acquisition of the project.</p> <p>Magretta (2002): https://hbr.org/2002/05/why-business-models-matter</p> <p>— Kenny & Marshall (2000): http://jepelet.free.fr/studies/MBA/strategie/doc/chap4/kenny.pdf</p>

⁶⁴ Kotler, Philip (2012). *Marketing Management*. Pearson Education. p. 25.

	- Crowdsourcing	
Cost structure	-includes the COGS (Cost Of Goods Sold): materials, manufacturing, shipping, rent, etc... - information regarding the amplification of innovation where costs in innovation and product development are lowered. -information concerning economies of scale and logistics.	— Afuah & Tucci (2001): http://files.isec.pt/DOCUMENTOS/SERVICOS/BIBLIO/Documentos%20de%20acesso%20remoto/Internet-business-models-Cap5_Afuah.pdf
Value creation	The performance of actions that concretely increase the worth of goods, services or ⁶⁵ between different spheres (public, private, non-profit), the flows of information and the network configuration of actors outside of the company.	Johnson <i>et al.</i> , (2012): http://s3.amazonaws.com/academia.edu.documents/38668596/HBR_on_Strategy.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1479312441&Signature=beke81fx77%2FxxWOccXjjiy1N%2Fxo%3D&response-content-disposition=inline%3B%20filename%3DForces_That_Shape_Competition.pdf#page=57 — Gordjin <i>et al.</i> , (2001): http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.202.8264&rep=rep1&type=pdf
Network Partners	Relation to a community. How do they position themselves in network	Allee (2000): http://www.emeraldinsight.com/doi/pdfplus/10.1108/eb040103 Dubosson-Torbay <i>et al.</i> ,

⁶⁵ <http://www.businessdictionary.com/definition/value-creation.html>

		(2001): http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.159.286&rep=rep1&type=pdf
Competitors	Any rival entity in the same or similar industry / area with a similar offering	Not as pivotal Kind <i>et al.</i> , (2009): https://brage.bibsys.no/xmlui/bitstream/handle/11250/163176/dp2009-8.pdf?sequence=1&isAllowed=y — Bengtsson & Kock (2000): https://www.researchgate.net/profile/Maria_Bengtsson/publication/222667582_Cooperation_in_Business_Networks-To_Cooperate_and_Compete_Simultaneously/links/0f317533d0b6fbef1f000000.pdf

OTHERS		
Sub-category level 2	Definition	Comment / Specification
Philosophy / Context	Personal opinion pertaining to the scope of the project	
Learned from others	where the project demonstrate that they are learning from projects outside their community.	
Unclassified	Unclassified for the moment	

COMMUNITY-LEVEL LEVEL 3 CODING

IDENTITY		
Subcategory level 3	Definition	Comment/Specification

<i>Vision/Values</i>	-A vision statement provides strategic direction and describes what the creator wants the project to achieve in the future. -The operating philosophies or principles that guide an organization's internal conduct as well as its relationship with its customers, partners, and shareholders. Core values are usually summarized in the mission statement or in the company's statement of core values.	from https://en.wikipedia.org/wiki/Vision_statement
<i>Problem addressed</i>	What root issue is the project attempting to resolve	
<i>Status</i>	- status of the project whether it is a hobby, a business, a non-profit venture)	

COMMUNITY-LEVEL ANALYSIS

		<i>La Cool Co</i>	<i>Apertus Axiom</i>
Typology = Business Model + Openness	Status	Company	Non-profit taking care of development of community and product. And corporate structure taking care of operations Crowdfunding + Corporate structure taking care of operations + Sales 3rd party funding + product as a service + expertise based Licensing: GNU GPL 3.0
	Value	Pedagogical approach to keep plants alive in a electronically controlled environment. We want to teach people how to produce and how to create a system that's adapted to their needs and to their reality and to the plants finally that they're gonna grow inside. Greatest value is that this project can be rebuilt and redone without going through us. Personal greenhouses for urban growers.	Make ourselves independent by creating technology we wanted to use. Product and service oriented offer, maintenance contracts.
	Revenue model	B2C market: selling kits to growers and makers, consulting style business providing custom tools petit cool kit 350 euros. Mini cool kit 50 euros B2B: schools and agrotech businesses Workshops as packs including or not the material Partnerships with B2B market	Reached 200% of crowdfunding goal for Axiom Beta (was reasonable to develop and produce in time) Sell camera and accessories, And so the business model is more service-oriented, we plan to do customizations, custom-module development, implementation into concrete systems and applications,
	Network partners: Relation to a community. How do they position themselves in network	Lots of fablabs and makerspaces are interested in their workshops. Would like to develop more networks with education institutions. Agro Paris Tech. Accelerator from BNP Paribas	EU grant application called Axiom EcoSystem: ecosystem of different people in different parts of the world, supplying services, products, support, training, whatever, to specific areas of the development or specific customers, to specific implications. Serve as a hub to communicate, to show the customers where they get what, so kind of connect things together in this sense.

	<i>Arbalet</i>	<i>EchOpen</i>	
Typology = Business Model + Openness	Status	<p>Hobby. Although interested in commercial aspect. Licensing: not defined</p> <p>I have no precise goal at the moment. I'm just happy to share my work, to see that people reuse my project and rebuild something that they can customize. My priority is to make something beautiful that people would like to have in their living room.</p> <p>If I was selling the project there would be people interested in buying it. So, obviously I'm interested in this direction</p>	<p>Status: Association 1901. Non-profit. but interested in hybrid version: the association can change its status and become a commercial, trade association so as to be able to sell our probe that manufacturers will make so we have many solutions</p> <p>Licensing: MIT license. and for the hardware it will be a different license, today we have no license. Have to face two different problems. The first problem is that there's not really a license for hardware in medical field like medical device so we had to adapt a few things to make it work according to the law to be sure it will be free and the second option is also to put a patent and then from that patent to open the patent</p>
	Value	<p>Need for originality, for novelty, for something they can make: "A need I'm not sure that there is a need but you can create it"</p> <p>Target segments: end-customers, pubs, bars, clubs (would have money to buy product)</p> <p>No specific strategy to reach customers apart from going to Maker fairs (lack of training in communication)</p>	<p>Our point is spreading the concept, spreading the probe to improve people's health and faster diagnosis. Device permitting cheaper, smaller and more efficient sonographic testing during clinical examination. (which doesn't exist)</p> <p>Open Source in software or even hardware will lead medicine to be transparent more efficient, involving more people working on it and trying to find solutions for it, I mean for all human beings.</p> <p>Make hardware as cheap as possible to reach physicians around the world.</p> <p>Target: For hospitals, also for undeserved medical area or emerging countries, emergency medicine, it should be universal</p> <p>Brand management: echopen will be a kind of quality insurance, credibility insurance and we also have the concept</p>
	Revenue model	<p>Self funded. Thinking of selling a kit through a kick starter campaign to make money to improve project. My main goal would be to sell a final product that would be still open source. I still to find a way to combine both: open source and sellable with all that it implies, I mean I must provide support then</p> <p>Cost structure. Only has the capacity to make up to 3 a week. No idea how much the cost would be for</p>	<p>Funding: Pierre Fabre Foundation giving us a budget we use to buy equipment, components, food when we do workshops members subscribe for 1 euro per year</p> <p>Cost structure: Now with the decrease of the size and price of components we can put this in smaller volumes and make it cheaper but we are using a mono-element piezo-electric electric and a mechanical probe. Today one transducer costs 600€ with some specifications we need and after this research program we made one, the cost was less than 50€</p>

			<p>The brand echOpen is now a brand registered to the European union so we have to pay for that sometimes we have some expenses and also for the guy who's paid for being here full-time</p>
	<p>Network partners: Relation to a community. How do they position themselves in network</p>	<p>He works for a university research center, teaching programming to young students, but product is too expensive compared to the pedagogical value. Developing contacts with carpenters to do something together (UK)</p>	<p>Legal help: a group of lawyers specialised in Open Source patents to make it the best possible way Physical space and equipment support APHP from the Hôpital Hôtel-Dieu We're going to find partnerships with companies, manufactures that will be able to make it, to produce it, to manufacture it so the idea is then how to spread the concept within the medical field in Paris and abroad and in the middle of hospitals so people hear about the concept, they learn about the concept and there are more and more hospitals, physicians, medical staffs are interested in having this probe so we already have a group of future customers so the idea then with the brand is to have a license for any manufacturer any business who wants to manufacture us and sell us, they can have a brand license, they will give money to the association to make the association work like paying the internet access, the components, research and development, open source R&D , and then you will make money from that, you have to manufacture it, to sell it, to trade it. We're also working on the training for the physicians.</p>

	<i>E-nable</i>	<i>FairCap</i>	
Typology = Business Model + Openness	Status	Non-profit. The only thing that may vary is the commercial license associated with a model. Some makers prefer to state explicitly that their invention cannot be sold.	Community Interest Company in the UK
	Value	<p>We have a very strong social impact. This is our main value I believe. We demonstrate that 3D printing can do something today for society by using 3D printing to change the lives of children today in a positive way. Since the device is giving for free, they don't have enough (human) resources to meet the demand</p> <p>Target market: children specifically born with a malformation, missing some fingers or the entire hand. a few adults, but 98% of our devices are built for children. We have a few amount of people who were amputated after an accident.</p> <p>Our devices are not very expensive, our core value is to ask the makers to build them and give them away for free. Our next move will be to be able to give them 3D printers instead of giving them devices, and teach them how to build their own devices. In order to do that, that will cost a lot of money, we need to find financial partners.</p>	<p>problem addressed: water is basic need, and is being contaminated by human activity in pristine places and everywhere. small, portable and super low cost device giving access to drinking water to people so that people can have access to clean water and have a better health</p> <p>value proposition: The overall vision is to research, design and develop new open technologies for water. There is so much research on innovation being done on very useless products for example, then why not get really smart people, get really generous people who like open source and who like to share and who like to develop new things. You can combine both and try to solve real problems with technology</p> <p>value delivery: The smallest FAIRCAP filter is going to be probably manufactured centrally because you need to scale the project in case there is an emergency and you need like 50 000 units, it's impossible that you can 3D print that. 3D printing is good for prototyping, but not for actually making the filters</p> <p>Target market: humanitarian, perhaps other models for backpacking-travelers, sports or city people.</p> <p>values:</p>
	Revenue model	<p>Self funded, or through donations: We have a number of good people who have donated to us, through our website, and it's actually our only source of revenue. Since the beginning we have been financing the movement with our own money</p> <p>We do not sell anything. We do not generate any money. But we consume money obviously, so we need money to carry on what we do. In return, what we offer to potential investors is good communication.</p> <p>Ressources: lack of back office development, ressources in terms of software development since we don't have money to put on that, it's very difficult to find people willing to help us.</p> <p>Cost structure: Our devices are not very expensive, our core</p>	<p>concerned about the impact. To grow not only financially, but how many people are using the products at the end. I think that's really important to show that these open source movement is real, and is not just theoretical 16/01/2017</p> <p>open source should have a manufacturing part, in terms of business models maybe 10 or 20% of people want do it themselves but a lot of people just want to buy something. Also they just want to support you. So you should think about it. Scale the project and have something built.</p> <p>revenue stream: full spectrum offer from kits, to instructions. the most sustainable, financially, seems to be either workshops or the final product. Because a lot of people want to</p>

		<p>value is to ask the makers to build them and give them away for free. So the makers take the cost of the device which is around 50 euros, plus their time. Theoretically we have no costs. But it happens that when you are an association, when you want to communicate you need to buy things, you need to buy business cards, kakemonos (didn't understand), communication kits, you need to print that stuff, you need to travel to shows and so on and so on. The functioning of the association is the main cost today.</p>	<p>have the product but they are not so knowledgeable about how to make it on your own</p>
	<p>Network partners: Relation to a community. How do they position themselves in network</p>	<p>work with hospitals, with occupational therapist with another association in France called ACDA, who is gathering all the families of children born with agénésie. They provide us with our clients if I can call them like that. The prosthetic industry is looking at us with a lot of sympathy an interest. Because they know that what we do is what they will be doing in five years.</p>	<p>Oxfam, UN work with large organisation to get the reputation. Lots of funding around innovation. Going to a project with the people from Open State who organized POC21 who want to develop these camping systems for festivals and that's going to be the prototype for refugee camps, so that's going to happen in August</p>

APPENDIX 3: FIRM-COMMUNITY INTERACTION ANALYSIS PROCEDURE

INTERVIEW GUIDE FOR COMMUNITY-ORIENTED BUSINESS-MODELS

Contents

Introduce ourselves and make a short presentation on the aim of the research

Validate the interview condition (length, recording, feedback...)

First question

List of topics that will be discussed

Closing the interview

Introduce ourselves

We are researchers from [your workplace] and are working on a project about business models for open source hardware. In our current research we seek to understand how incumbents in the automotive industry (or new players) are reacting to OSH and the potential of innovation communities:

The objective of the discussion today is to prepare a qualitative data acquisition

We selected your project for this discussion because you are developing open source physical products and fit with the object of our research.

Validate conditions of the interview

Do you agree to discuss these topics with me?

I suggest a 45 minutes long discussion? (15 minute buffer) Is it ok for you?

Do you mind if I record our conversation? The recordings are only for internal communication within the project. Because we are an international team of researchers working at distance, we need these recordings for means of information sharing. The recordings won't be published and there will be no direct citation of your words without your explicit permission for which we would ask you first. If you want so, we can also anonymize the interview, so your name doesn't appear.

[start the audio recorder only after the person agreed with the conditions]

Questionnaire Open!

Background info

What were the main reasons for [company name] to implement the [project name]?

What were the goals of the implementation of [project name]? Which measures are employed to evaluate the success of the [project name]?

When did your company come up with the idea of implementing something like the [project name] for the first time?

How long has [project name] been running by now?

What have been the key dates?

Who were the key people involved?

General information (“Please kindly elaborate on the following”)

Person, role, background, age, gender

You have been named to us as company-internal expert with regard to the POM TWIZY project. Could you please indicate to us how you were involved in planning and setting up this project? What were your responsibilities and tasks?

Firm, firm size, industry, value proposition

Open source hardware innovation (OSH) - (We define OSH as ...)

To what degree are you aware of OSHI-approaches in your industry and in your firm?

How ready is your industry/firm ready for such approaches?

Which part(s) of your supply chain already benefit/could benefit from OSHI? How?

(If applicable:)

What is your firm's aim around OSHI?

How is OSHI relevant to your business unit?

What kind of innovations are you expecting from opening the system?

In which areas and to what degree have you considered open source hardware and software innovation?

Are there particular capabilities/competencies necessary to support OSHI? Which challenges and risks do you see for your firm in OSHI?

Value Sharing - Openness within the co-creation process

Who are the key contributors to OSHI? (characteristics: age, geography, background, motivation)

How do orchestrate, moderate, and motivate openness?

How do you communicate with co-creators?

How do you engage the co-creators?

How do you communicate how value is dispersed among co-creators?

How do you ensure that all complementors contribute to the same objective? How do you manage proprietary rights? What is shared, what remains proprietary?

Which platform are you using for OSHI?

What are the core elements of your platform?

tools

rules

collection of technical standards

Customer focus and user innovation

Is OSHI about addressing or creating user needs?

Is the user as a co-creator essentially a marketing channel?

Do you work with specific users/suppliers/partners during your OSHI-processes?

How do you identify them? What characteristics do they have?

How often do you interact with them?

How has this interaction changed your innovation process?

Do you use any scaled customer data in your innovation processes (e.g. surveys, feedback forms etc)?

Business model

Describe the product and/or service in 2 sentences!

Which needs does your product/ service cover?

Who is the core customer of your OSHI project(s)?

How would you describe the role of OSHI in your business model?

Has your business model changed through open OSHI?

Which forms of value creation and capture arise from OSHI?

How do you monetize your product? How do you monetize your OSHI activities?

How are you measuring the value of OSHI?

If applicable:

Which open business models could work for you/become relevant?

COMMUNITY-ORIENTED CODEBOOK PROCEDURE

This section presents the themes that were used to analyze the interviews in the firm-community level of analysis

Table 22: Kreatize analysis

	Activities	Actors	Openness quotes
Content - Level of value co-creation	<ul style="list-style-type: none"> - Two sided market - Customers: Suppliers use Kreatize software to calculate offers, users (OEMs) use platform to publicize inquiries - Customers: Joint digital value creation through outsourcing of manufacturing and distributing it to suppliers / partners - automatization of additive manufacturing through the platform 	Manufacturers (OEMs), tool suppliers to these OEM	"The problem is that softwares are not integrated, there are no open APIs. Kreatize is increasing efficiency by integrating software layers (and hooking up to existing softwares"
Content - Level of value co-creation	- matching of customers and suppliers	kreatize	"automatized matching must be our core capability"
Content - Level of value co-creation	- open platform at the beginning, they closed it because of legal necessity of OEMs to sign up every single supplier	kreatize	
Content - Level of value co-creation	- innovation: machine learning shall help to gather which manufacturing approach works best for which part	kreatize	

Structure: Type of knowledge flow	- OEMs feed CAD designs into the platform; Kreatize matches designs with suppliers	Kreatize IT, engineers	- "openness functions intuitively"
Structure: Type of knowledge flow	- gain of new knowledge through outside-in input from R&D labs from OEMs & feedback from suppliers	Kreatize	originally we had an entirely open platform, but we gradually closed it. Now the connections between customers and suppliers are completely kept separate
Structure: Type of knowledge flow	- coupled process: kreatize matches the needs and suggest CAD design improvements (other material, using 3 D printing, etc) - thus, support of OEM R&D - unilinear	Kreatize, OEMs	
Structure: Type of knowledge flow	- distribution of knowledge , e.g. improvement of designs, via Kreatize platform, again moderated by Kreatize	kreatize, customers	based on our customer feedback, we closed the platform. Total openness just did not work for our clients
Governance: Level of collaborative capability	- moderate the CAD designs on a unilinear basis; that is; single point of contact with suppliers and OEMS; no contact between suppliers and OEMS	kreatize	this helps us to follow a dynamic pricing structure

Governance: Level of collaborative capability	- quality control through checklists	kreatize	"after every interaction we control the suppliers based on checklists. low performers will be removed from the platform."
Governance: Level of collaborative capability	- matching improvement is being able to present customers with alternatives in suppliers (different materials, quality, faster production)	kreatize	

Table 23: Volkswagen analysis

	Activities	Actors	Openness quotes
Content - Level of value co-creation	scout the market for oshw approaches, good overview of market activities, no real action themselves	technology scouts	We know, we don't do enough with regards to OSHI
Content - Level of value co-creation	value is being created through manufacturing performing cars		

Content - Level of value co-creation	- engineering is the central part of r&d - engineers are VW employees, no externals or third parties	engineers	
Content - Level of value co-creation	- open source software	VW	"we currently use OS software for internal use"
Content - Level of value co-creation	- first pilots with jovoto and hyve, partners from R&D internally are very interested	engineers	"we pay for first pilots. our intention is to create best practices and to understand, what works and how it could function legally."
Content - Level of value co-creation	- colleagues who engage in open source on a private level communicate about the insights gained informally	engineers	
Content - Level of value co-creation	- user studies: collaboration with potential users, joint reflection on possible, future services, no HW focus!- Co-creation center: co-development of services with customers	Smart Mobility Team	
Content - Level of value co-creation	- research on autonomous driving with selected customer groups (e.g., blind people) - Test drives, language device testing, autonomous routes testing	Future Centre	" User-centricity is still not really on the agenda of OEMs. R&D is made by engineers for engineers."
Content - Level of value co-creation	- every new partner, supplier has to sign an NDA		" openness is really difficult for us"
Content - Level of value co-creation	- shared economy, shared mobility		"this makes totally new ways of revenue generation possible"

Structure: Type of knowledge flow	we are learning a lot from central actors like local motors and os vehicle	R&D, innovation management	
Structure: Type of knowledge flow	none of the OEMs have yet started developing an autonomous car without steering wheel	technology scouts	
Structure: Type of knowledge flow	radical innovations like cars w/o steering wheel are not in the minds of the engineers	VW	"we build cars"
Structure: Type of knowledge flow	VW employees gather privately to exchange insights gathered from platforms - informal inflow of platform insights into the corporation	VW engineers	
Structure: Type of knowledge flow	VW employees are not allowed to engage in platforms , no sharing of source code = violation of IP rights, which can cost them their jobs	VW engineers	

Structure: Type of knowledge flow	we do not have processes for giving and taking when it comes to open communities		" we have not developed a process for giving in form of patents or IT"
Structure: Type of knowledge flow	communication: who is actually allowed to communicate in the name of the firm - internal control processes for all information given to the outside	VW	
Structure: Type of knowledge flow	- opening up through partnering with startups		"we dont really know where to create the open interfaces for exchange on R&D and learning from each other!"
Structure: Type of knowledge flow	- " openness is not part of our culture"		- "openness is not part of our culture"

Governance - Level of collaborative capability	<ul style="list-style-type: none"> - R&D cycles in OEMs are very slow and long lasting. we have a hard time operationalizing HR, processes, and R&D cycles - biggest hurdle: R&D cycles 	R&D unit	we plan 15 year ahead and often do not see how to integrate third parties
Governance - Level of collaborative capability	<ul style="list-style-type: none"> - legal regulations: forbid sharing of internal knowledge and information - no transparency of data or permeability of information - no creation of trust with open communities 		"maybe the industry should consider establishing more loose relationships with suppliers or independent engineering offices in order to learn about the latest innovations like autonomous driving, etc"
Governance - Level of collaborative capability	<ul style="list-style-type: none"> - we do neither have a strategic agenda or any particular goals when it comes to open source hardware -colleagues scouting on open platforms are not formally managed or motivated to share their insights 		
Governance - Level of collaborative capability	<ul style="list-style-type: none"> - Moia - an electric shuttle bus: spin off of VW to co-develop mobility concepts with cities, first cit: Hamburg 		"jointly with cities we want to offer individual mobility solutions" "this is a great chance to foster trust and to start more comparable partnerships"

Governance - Level of collaborative capability	- Gett : taxi service uber style, but no private drivers, have their own maps and navigation system, but they use waze which has more recent information about traffic jams		
Governance - Level of collaborative capability	- Additive manufacturing		"we have closed production lines , and cannot simply print one part in 3 D"
Governance - Level of collaborative capability	- Open innovation and exchange of knowledge		"We lack the right employees and attitudes!"

Tableau 24: Local Motors Analysis

	Activities	Actors	Openness quotes
Content - Level of value co-creation	High level of value co-creation	LM, co-creators	
Content - Level of value co-creation	High engagement with the crowd, which usually creates very novel knowledge about products, HW	LM	but not all documentation is open - some internal communications are not open"
Content - Level of value co-creation	Background of co-creators: - industrial design - few with open source background - openness and motivation depends on industry background	LM	"the higher the linux relation, the higher the openness to share"
Content - Level of value co-creation	Efficiency of contributors - depends on current job situation (current employment = less contribution; IT freelance = more activity)	co-creators	"highly efficient contributors also have more financial security"

Content - Level of value co-creation	Value of co-creation hard to explain - C-Level does not have much time - it s hard to explain the value of open software, or how to capture value through OSHW		"C-Level does not have much time" - "it s hard to explain the value of open software, or how to capture value through OSHW"
Content - Level of value co-creation	Nutzungsrecht: - the more open, the more learning, e.g. regarding processes for innovation		
Content - Level of value co-creation	Competitors: - it s not so much that others can easily out compete us, but they should actually ask: Wouldn` t it be better to collaborate / partner? - Ecosystem = enabler		"Wouldn't it be better to partner up?"
Content - Level of value co-creation	User centricity: - depends on how clear partners are on user needs or about the expected outcome of the challenge		
Content - Level of value co-creation	Partners vs. co-creators: - Challenge to manage the crowd as LM engages with partners		"We have to ask ourselves with which partners we want to work, and how our crowd will react to them."
Content - Level of value co-creation	LM services for co-creation: - unit co-creation - unit mobility innovation - unit additive manufacturing		"Our business model is still plastic. The columns are still in a process of alignment with each other." "Basically, we aim at creating a best case scenario for openness."
Content - Level of value co-creation	Roboport - example for innovation initiative: - they wanted to build a project around co-creation processes - LM had the right digital tools, know how to engage communities of more than 50 K people - interface: Roboport and Launchforth (focus on open innovation)		

Structure: Type of knowledge flow	C-Level buy in necessary for successful open collaboration - legal departments often too close to fachabteilungen		"We would like to collaborate and co-create even more with large corporations. Often there is no C-level buy in and, hence, those open innovation initiatives do not survive"
Structure: Type of knowledge flow	collaboration with corporations difficult		"Large corporations have a problem making all communication public"
Structure: Type of knowledge flow	Onlinemarketing to engage co-creators		"We launch online campaigns, e.g. on Facebook, to target and attract students and retired co-creators"
Structure: Type of knowledge flow	Involvement - in partner projects: get everyone on board - make sure you have the right level of security (e.g. aviation projects)		"in partner projects: get everyone on board"
Structure: Type of knowledge flow	high level of sharing knowledge with the crowd (inside out, outside in, coupled)		we try to make as much communication open as possible
Structure: Type of knowledge flow	Example Olli Bus - all data went online and into the platform instantly		
Structure: Type of knowledge flow	Difficulty in sharing data - depends on the agreements with the corporate partners (e.g. Airbus)		"depends on agreements with partners"
Structure: Type of knowledge flow	Sharing of knowledge and feedback - esp. sharing of negative feedback to learn from each other quickly - sharing of feedback = learning on the job - 360 degree feedback - contributors, partners, and LM involved to ensure fairness and thorough feedback		
Structure: Type of knowledge flow	Innovation = chaos		"We have learned to deal with chaos in innovation procedures."

Structure: Type of knowledge flow	Internal communication: find a good balance of openness and closeness; external communication: keep the contributors on board		"Ensure long term commitment both internally and externally."
Structure: Type of knowledge flow	Olli bus: - initial code by a columbian student - challenge now: how to manage the crowd around olli - improvement of quality management in order to enhance Olli bus (design, usability, accessibility)	Berlin LM	
Governance - Level of collaborative capability	Profiles of co-creators - not all users fill in profiles - social media pages should give info about co-creators - yet, sometimes not all info is shared publicly - it s not always easy to understand where every co creator is coming from		"all co creators should fill in a profile, so that they can learn from each other which tools they use" "often, they do not fill in profiles which makes learning from each other more difficult"
Governance - Level of collaborative capability	Currently 3.5 K co-creators (Segments: entering the job market AND leaving it for pension) - measured by activity in the past 7 days - top 20 to 50: former "Abteilungsleiter", students, university students - very divers		"former managers of business units, aussteiger, freelancers" - "they do projects which they would always have liked to do" "students contribute as way of entering the job market"
Governance - Level of collaborative capability	Partners and innovation - Partners awareness of speed and degree of innovation increases through OSWH - partners often have very long lasting, complicated processes - hard to change these - we aim for C-level buy in and including the related management layers in finding solutions to problems		"Our partners realize that the degree of innovation increases in parts by 300%"

Governance - Level of collaborative capability	Our culture: - laissez faire management style; - due diligence - open and logic processes		"We want to create a culture of shared learning and of forgiving mistakes"
Governance - Level of collaborative capability	Transparency: - openness must be ensured to fullfill the promise of an open platform to the community - openness includes sharing of both positive and negative feedback		
Governance - Level of collaborative capability	Challenge to transparency: - to get everyone to participate - there s not yet a consciousness about the importance of publicly sharing feedback to ensure joint learning		"there s not yet a consciousness about the importance of publicly sharing feedback to ensure joint learning"
Governance - Level of collaborative capability	Open business model: - open soure model is not essential for survival, but our USP and competitive advantage - we build on open products and digital tools		"we do not neccessarily depend on the open business model"
Governance - Level of collaborative capability	Managing crowds in different time zones - to do so, LM has offices all over the world, allocate office in particularly well situated places so that LM employees can communicate well with the US and EU		

Governance - Level of collaborative capability	Roles and responsibilities: - at the beginning everyone in Berlin did everything - does not work, we also needed clearer attributions of responsibilities - we now have foci, e.g. product-, process, or logistics management	"we now have foci, e.g. product-, process, or logistics management"
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Table 25: Renault Analysis

	Activities	Actors	Openness
Content - Level of value co-creation	POM Twizy winner of the April 2017 Pitch and Poc internal challenge. Need to create technological demonstrators for on-going research themes	internal engineers, directions of communication, and production, vehicle programming	We would like to fit the OSHWA definition. We first want to have a basic object, and then make it evolve through interactions with the community. For the moment 20% interaction with outside community
	d'objet avec des standards autonomiques qui permette d'accueillir plus facilement les technologies qu'on voudrait y intégrer	Fabrique des Mobilités, Square Lab (part of the architecture of fablabs -- more later), Schools	
	Pom is a vector that allows interaction with external actors		
	Hackathon		
	Creative Labs		
	Square Labs		
	Lab Metiers		

Structure: Type of knowledge flow	indicators of communication. Promoting the project internally through events and presentations. Then possible indicators will be the # of people reached, # of sales of the platform, # of partnerships		
Governance - Level of collaborative capability		Avoir des gens aussi qui sont dans d'autres secteurs, sur lesquels on n'est pas forcément traditionnellement, c'est souvent une façon, au travers de l'Open Hardware tel qu'on l'imagine, de pouvoir interagir avec ces partenaires. C'est des compétences qu'on n'a pas forcément en interne, en tous cas pas encore, et justement de pouvoir accélérer un peu cette façon d'appréhender tous ces challenges.	

APPENDIX 4: ECOSYSTEM LEVEL ANALYSIS PROCEDURE

ECOSYSTEM LEVEL INTERVIEW GUIDE

Contents

Introduce myself and make a short presentation on the aim of the research
 Validate the interview condition (length, recording, feedback...)
 First question
 List of topics that will be discussed
 Closing the interview

Introduce myself

I'm a researcher from the *CERAG* research center for management sciences and I'm working on project called (OPEN!) Methods and Tools for community-based product development, which is a research and collaboration project funded by the French and German research agencies (ANR/DFG)

This study attempts to gain insight and explore the business models supporting open source hardware. Generally, how value is created and captured between OSH communities, companies and the larger sphere of stakeholders that comprise the OSH ecosystem. We seek to understand:

the specifics of the Barcelona innovation ecosystem that are conducive to the success of Open source hardware (OSH) initiatives.

the conditions that enable OSH reach/diffusion and potential market success.

The final goal of the study is to foster collaboration between different ecosystem actors. This is an exciting area to study. We chose to interview you, because you were identified as a major actor in the Barcelona ecosystem creating an economy around OSH.

Validate conditions of the interview

Do you agree to discuss these topics with me?

I suggest a 45 minutes long discussion? (15 minute buffer) Is it ok for you?

Do you mind if I record our conversation? The recordings are only for internal communication within the project. The recordings won't be published and there will be no direct citation of your words without your explicit permission for which we would ask you first. If you want so, we can also anonymize the interview, so your name don't appear.

[start the audio recorder only after the person agreed with the conditions]

First question

The first question is important and will depend on the context: the person works alone or in collaboration.

Can you describe how you are involved in supporting OSH? “What are you working on? Can you explain your project to me?”

Strive to ask:

Unbiased questions

Focus on open-ended questions

Avoid “why”, prefer “what”

Avoid ended questions on a high-pitch tone.

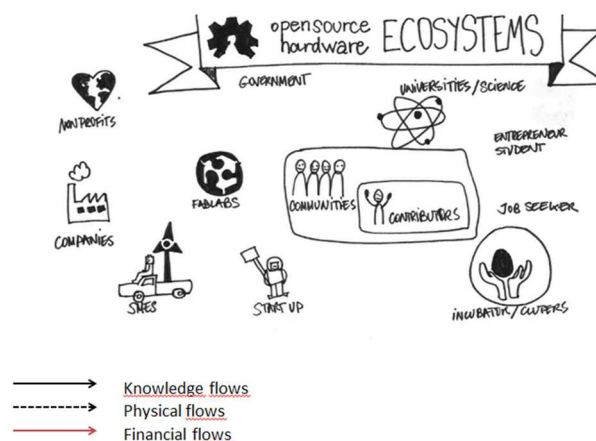
[how we lead the interview]

Main questions

How should the network of fablabs and OSH communities organize themselves to create value in the overall barcelona ecosystem?

Relationship type: Actors and flows

This is a proposition for an open source ecosystem. Here are the different actors (which ones would you add/take off)? Here are the different links, how would you map them? Which ones would you add?



Could you describe the ecosystem that supports OSH in Barcelona? Who are the main actors? How would you delimit them? How would you organize them (individual participants, communities, wider ecosystem of government, non profit, industry, universities)? Here is a proposition of different actors (which ones would you add/take off)? What is their common purpose? Do they have different purposes?

Could you describe the links between them? How would you map them? Here is a proposition to map the interaction between different actors, could you describe what types of relationships they have (financial, physical, knowledge, other)?

How would you describe the value generated, shared, distributed by these different stakeholder?

How is this new?

What do you feel is specific to Barcelona? Why did Barcelona position itself as a player in the global OSH ecosystem? This will lead to a discussion on the PESTLE that Barcelona offers:

Political climate, stability

Economic conditions (investment rate, unemployment, buying power)

Social factors (demography, education, culture)

Technological factors

Legal aspects

Value creation

What type of value is created by OSH? How has your organisation benefited from OSH and the work done by innovation communities?

Value Capture

Barcelona is the number 1 fab-city in the world. Can you explain to me why that investment was made?

What are the sources of funding for OSH projects?

Do you have institutional or corporate support? And what forms does it take?

What is put in place to foster collaboration between innovation communities and companies?

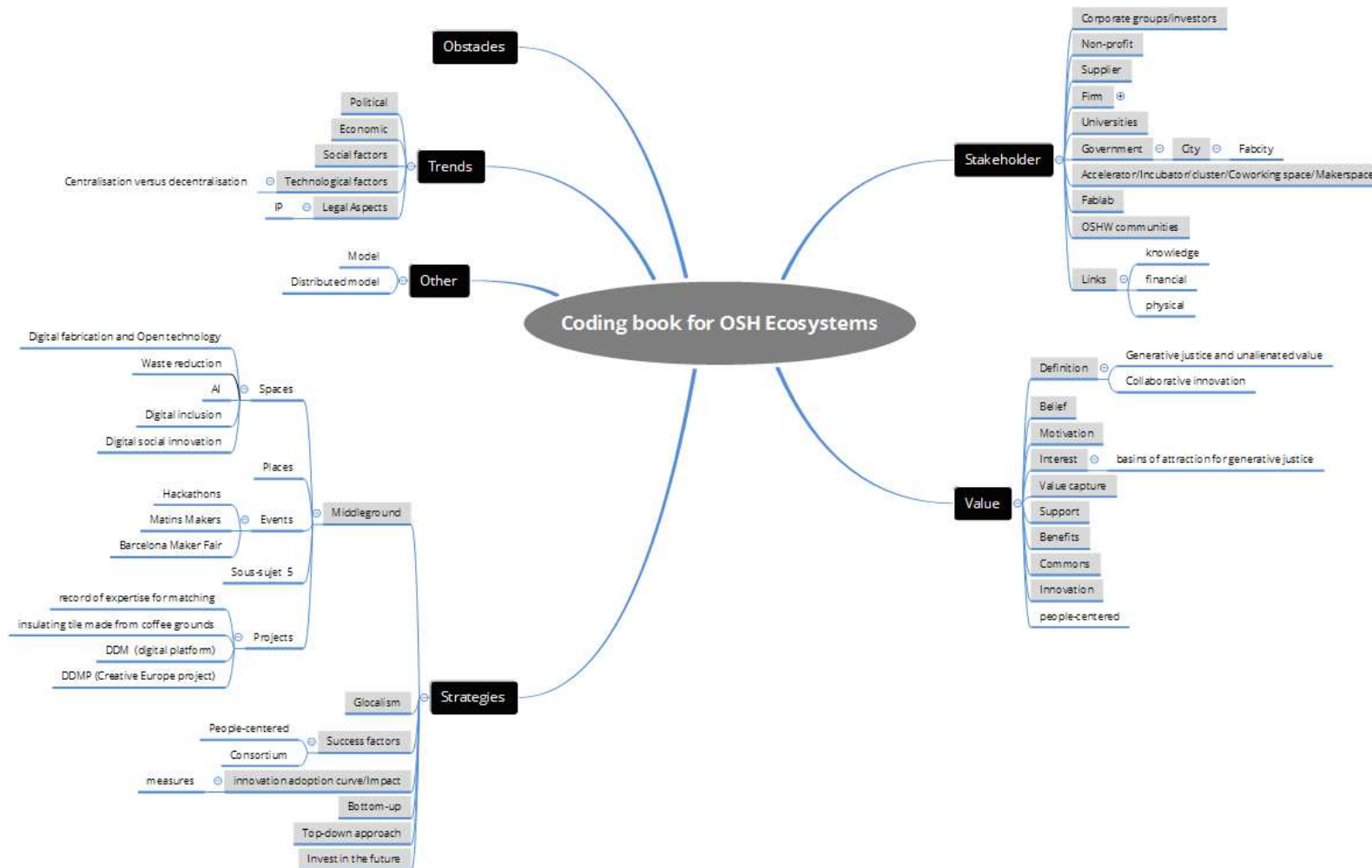
What other sources of value are deemed crucial, and what is put in place to measure them ex ante, during (control panels) and ex post (to correct gaps), which possibly will lead to a redesign (revise objectives)

Value Sharing

How would you define the rules of OSH community-company collaboration? Have you identified collective agreements (norms around quality, security)

What is the capability of enterprises to integrate the information obtained from the OSH communities

ECOSYSTEM LEVEL CODING



ECOSYSTEM LEVEL ANALYSIS

On 305 observations, 305 have effective responses (100%) and 238 were coded.

Name	Frequencies	%
Strategy	167	54.8%
Middleground	100	32.8%
Business model	37	12.1%
Glocalism	25	8.2%
Innovation adoption curve/impact	19	6.2%
Success factors	17	5.6%
Bottom-up	14	4.6%
Top-down	6	2%
Invest in the future	1	0.3%
Stakeholder	139	45.6%
Accelerator/Incubator/Cluster/Coworking/Makerspace	59	19.3%
Start-up	47	15.4%
Fablab	41	13.4%
Government	26	8.5%

Corporate groups/Investors	25	8.2%
Communities	22	7.2%
Firm SMEs	20	6.6%
links	16	5.2%
City	14	4.6%
University	13	4.3%
Non-profit	10	3.3%
Crowdfunding	8	2.6%
Supplier	2	0.7%
Values	105	34.4%
Motivation	55	18%
Belief	20	6.6%
people-centered	20	6.6%
Interest	17	5.6%
Support	14	4.6%
commons	13	4.3%
Value capture	12	3.9%
Definition	8	2.6%
Other	24	7.9%
Model	15	4.9%
Distributed model	9	3%
Multi-sided markets	1	0.3%
Specifics_of_Barcelona	23	7.5%

Culture	17	5.6%
History	12	3.9%
Trends	16	5.2%
Economic	8	2.6%
Social factors	6	2%
Political	4	1.3%
Technological factors	4	1.3%
Legal Aspects	2	0.7%
Obstacles	8	2.6%
hard to implement bottom-up approaches	5	1.6%
smoke and mirrors	3	1%
infrastructure needed for relocalizing production	2	0.7%
Participative democracy	2	0.7%
Dynamize community	1	0.3%
Total findings: 305		

Table 26: Summary of thematic grid for ecosystem level analysis

APPENDIX 5: TRANSVERSAL ANALYSIS

STATE OF THE ART ON CURRENT LITERATURE CONCERNING OSHBM

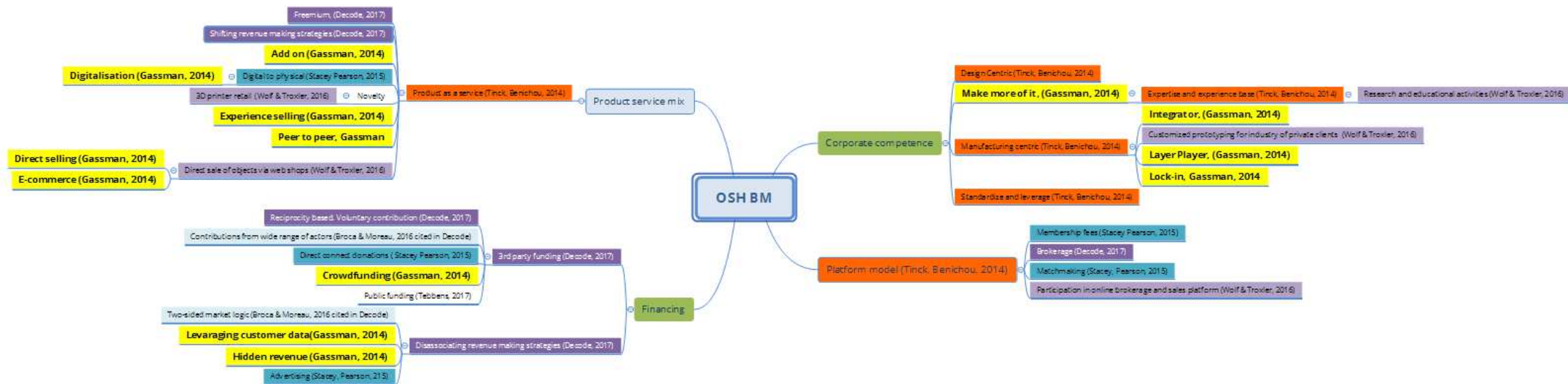


Figure 57 : Progression of mind mapping of literature on OSHBM (author's categories) version 2

Category	Core BM component focus of attention	Pattern Title	Pattern Description	Corresponding authors	Link to Gassman's 55 patterns, 2014	Business Model Navigator Pattern Definition
FINANCING	Partners/Revenue streams	3rd party funding	An institution funds the production/conservation/expansion of a common as part of its own mission, or to pursue commercial interests	Decode, 2017	Crowdfunding	Taking finance by swarm. Outsourcing the financing of a project to the general public. To limit the influence of professional investors
	Partners/Revenue streams	Reciprocity based voluntary contribution	Where individuals and organizations make voluntary financial contributions to sustain the production of a common on the basis of reciprocity	Decode, 2017		
	Partners/Revenue streams	Contribution from wide range of actors		Broca & Moreau, 2016 <i>cited in</i> Decode, 2017		
	Partners/Revenue streams	Direct Donations		Stacey & Pearson, 2015		
	Revenue streams	Disassociating revenue making strategies	Revenue models in which a positive externality created by the main output is produced and used to create revenue	Decode, 2017	Leveraging customer data	making use of what you know. Leveraging customer data is a major area benefiting from present day technological progress. Companies whose main activities center on the acquisition and analysis of data are already thriving
	Partners/Revenue streams	Two-sided market logic		Broca & Moreau, 2016 <i>cited in</i> Decode, 2017		
	Partners/Revenue streams	Advertising	In this version of multi-sided platforms, advertisers pay for the opportunity to reach the set of eyeballs the content creators provide in the form of their audience.	Stacey & Pearson, 2015	Hidden revenue	the primary source of revenue is derived from a third party, who cross-finances the attractive fee or low priced offerings made to customers i.e ad-based funding

Table 27: Comparison of different OSHBM types and their characteristics related to financing

Category	Core BM component focus of attention	Pattern Title	Pattern Description	Corresponding authors	Link to Gassman's 55 patterns, 2014	Business Model Navigator Pattern Definition
Product service Mix	Value proposition	Product as a service	Rose to prominence in 1959, when Xerox introduced the "pay per copy" printing model. It is now spreading throughout industries in light of trends such as the sharing economy and the circular economy	Tinck & Bénichou, 2014		
	Value proposition	Freemium	the selling of an extended/more performant version of the original digital common.	Decode, 2017		
	Value proposition	Shifting revenue making strategies	In order not to charge for the common produced, revenue making is shifted towards the selling of something else.	Decode, 2017		
	Value proposition	Digital to Physical	giving away the bits and selling the atoms (where bits refers to digital content and atoms refer to a physical object).	Stacey & Pearson, 2015	Digitalisation	Digitizing physical products. Advantages: elimination of intermediaries, reduced overheads and more streamlined distribution
	Value proposition	Novelty	Drawing on the current state of a new technology such as 3D printing	Wolf & Troxler, 2016	Lock-in Add-on Experience selling Peer to Peer	Forcing loyalty with high switching costs. "Additional charge for extra". Core offering is priced competitively, numerous extras drive up the final price. In the end customers pay more than anticipated, but benefit from selecting options that meet their specific needs Products appealing to the emotions. The value of a product or service is increased by an additional experience offered with it. refers to transactions between private individuals such as lending personal items, offering services and products or sharing information and experience
		Direct sale of objects via web shops	selling designs directly via a webshop of their own, around main business of selling products.	Wolf & Troxler, 2016	Direct Selling E-Commerce	Skipping the middleman. Products are made available directly by the manufacturer or service provider, rather than via an intermediary channel. Online business for transparency and savings. Products and services are delivered via online channels, thus removing overheads associated with running a physical branch infrastructure.

Table 28: Comparison of different OSHBM types and their characteristics relating to the product service mix

Category	Core BM component focus of attention	Pattern Title	Pattern Description	Corresponding authors	Link to Gassman's 55 Business Model Navigator Pattern Definition patterns, 2014	Business Model Navigator Pattern Definition
Corporate Competence	Key activities	Design Centric	Most common in OSHW. Organization focussed on product design and R&D, while manufacturing is handled by another party. In this model brand and community are key strategic assets.	Tinck & Bénichou, 2014		
	Key activities	Expertise and Experience base	Model directly inspired from FLOSS, where most common BM consists in monetizing expertise and services.	Tinck & Bénichou, 2015	Make More of it	
	Key activities	Research and educational activities	3D printing courses, creating physical objects for educational purposes, or improving 3D printing technology. Excluded sharing of knowledge	Wolf & Troxler, 2016		
	Key activities	Manufacturing Centric	The organization's core value proposition is to manufacture and distribute OSHW for an affordable price.	Tinck & Bénichou 2014		
	Key activities	Customized prototyping for industry or private clients	To repair broken objects or to create personal things.	Wolf & Troxler, 2016	Lock-in	Forcing loyalty with high switching costs.
	Key activities Key activities				Layer Player Integrator	Benefiting from specialised know-how. The company controls most or all parts of the supply chain. From sourcing, to manufacture and distribution. Enables economies of range and efficiency.
	Key activities	Standardize and Leverage	Opening up one key product, which can be profitable in itself, but the openness serves to make the associated technology a de facto standard in the industry.			

Table 29: Comparison of different OSHBM types and their characteristics relating to corporate competence

Category	Core BM component focus of	Pattern Title	Pattern Description	Corresponding authors	Link to Gassman's 55 Business Model Navigator Pattern Definition patterns, 2014
Platform model	Key activities/Key resources/Customer Relationships	Membership fees	A traditional nonprofit funding models. In the Made with Creative Commons context, they are directly tied to the reciprocal relationship that is cultivated with the beneficiaries of their work.	Stacey & Pearson, 2015	
	Key activities/Key resources/Customer Relationships	Brokerage	Based on matchmaking two parties such as a driver and rider or host and guest	Decode, 2017	
	Key activities/Key resources/Customer Relationships	Online Brokerage and sales platform	consists of internet based infrastructure allowing suppliers to expose themselves to a potential clientele and helped customers to find services and products from a range of suppliers.	Wolf & Troxler, 2016	
	Key activities/Key resources/Customer Relationships	Matchmaking		Stacey & Pearson, 2015	

Table 30: Comparison of different OSHBM types and their characteristics related to the platform model

GOVERNANCE MODEL

Project	Social business	Hybrid	Non-profit	Hobby	Only prototypes
1			1		
2				1	
3				1	
4					1
5					1
6				1	
7				1	
8				1	
9				1	
10			1		
11					1
12	1				
13				1	
14				1	
15					
16			1		
17					
18	1				1
19					
20	1				1
21				1	
22	1				
23					1
24					1
25					
26					
27					
SUM	4	3	9	3	6

Table 31: Type of Legal Status (A)

ECONOMIC MODEL

Projects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
OSH revenue streams	Crowdfunding + Corporate structure taking care of operations + Sales	3rd party funding + brand license	user and grant funded	self-funded + 3rd party funding	Grants Direct Donations	Sales + sell workshops	Sales + sell workshops	kits, workshops, kickstarter campaign (although ended up better to do it locally in Berlin without US servicing fees), and	3rd party funding Selling modules	3rd party funding	self-funded hobby	Oxfam/ crowdfunding/ sell product	self-funded	self-funded	sell kits and workshops / crowdfunding	kits/ Crowdfunding/ 3rd party funding	final product sales/ Kit Crowdfunding	3rd party funding Self funded	self-funded/ subscriptions Kits	workshops+ membership + sale of spare parts + commission on sales of finished products	self-funded or through donations	Crowdfunding Sponsorship Sales	sales	sales	(renting platform)	matchmaking	N/A
business model type	3rd party funding + product as a service + expertise based	3rd party funding + franchise	3rd party funding	3rd party funding + sales	3rd Party Funding	3rd party funding product as a service	3rd party funding product as a service	3rd party funding, sales, product as a service	3rd party funding Sales	3rd party funding	self-funded hobby	3rd party funding/ direct donation s/ Institution funds	N/A	N/A	Sales/Product as a service/ Direct Donations/ 3rd Party Funding	3rd party funding/ product as a service	SMEs Sales	3rd party funding Self funded	Platform model Subscription Self-funded	platform model: product as a service Subscription Sales	3rd party funding Peer to peer	3rd party funding Product as a service Expertise & experience based Sales	sales	sales	platform ; Matchmaking profiles and companies	matchmaking	N/A
partnerships	Network partners Global ecosystem of suppliers	Network partners Hospitals	Network partners Non-profits + University + USDA	Network partners STEM	Art Grants Universities Network Partners	Network partners	Network partners	Network partners	Network partners	Network partners	University /Carpenters	Oxfam / POC 21/ Humanitarian innovation fund	universities, laboratories , makers	N/A	Accelerator from BNP Paribas/ Agro Paris Tech/ Education/Fabl and Maker Spaces	IAAC/ Education	Network part: POC 21	N/A	Non-profits + SMEs	Global Fab lab network partners industry sponsors Education	University	University + OS vehicles	Consortium of research institutes and innovative firms	N/A	N/A	N/A	N/A

Table 32: Business model analysis

Project	Self-funded	Kits	Workshops	Subscription	Sales	Crowdfunding	3rd party funding	License	Consulting	Renting platform	N/A	
1						1	1	1				
2							1		1			
3				1								
4	1					1						
5												
6				1		1						
7				1		1						
8	1		1	1			1					
9			1			1						
10	1									1		
11	1											
12						1	1	1				
13	1											
14	1											
15			1			1	1	1		1		
16			1				1	1				
17			1			1	1					
18	1										1	
19	1		1		1							
20				1	1	1						
21	1										1	
22						1	1	1				
23						1						
24						1						
25										1	1	
26						1						
27											1	
SUM	9	6	5	2	13	7	15		1	3	1	1

Table 33: Type of revenue streams (A)

INNOVATION PARTNERSHIPS

Project	Sharing	No partners	Network partners	Industry Partners	Sponsors	Health/ Hospital sector	Non-profits	Education/ Universities	Gov. Institutions	N/A	
1	S		1		1						
2	S		1				1				
3	S		1					1	1	1	
4	S		1					1			
5	S		1			1					
6	S		1						1		
7	S		1								
8	S		1								
9	S		1								
10	S		1					1			
11	S		1		1				1		
12	S		1				1				
13	S		1					1			
14	S		1							1	
15	S		1			1		1			
16	S		1					1			
17	S		1								
18	S		1				1				
19	-									1	
20	-		1		1						
21	S		1				1				
22	S		1			1		1			
23	S		1					1			
24	-		1		1						
25	S		1		1			1			
26	-				1					1	
27	-				1					1	
SUM		0	24		7	3	2	3	11	1	4

Table 34: Innovation partnerships (A)

KNOWLEDGE OPENNESS

Projects	open-o-meter score	Are design files published?	Do they allow partial or full redistribution for commercial purposes?	Is the bill of materials published?	Are assembly instructions published?	Are the published design files in editable format?	Is the contributing guide published?	Is the published bill of material editable?	Is the published assembly instructions editable?
1	5	1	1	1			1		
2	5		1	1	1	1		1	1
3	6	1	1	1	1	1		1	1
4	4	1	1	1	1	1			
5	6	1	1	1	1	1	1	1	
6	6	1	1	1	1	1		1	1
7	6	1	1	1	1	1	1	1	
8	2	1	1						
9	5	1	1	1	1	1	1		1
10	6	1	1	1	1	1		1	1
11	7	1	1	1	1	1	1	1	1
12	1							1	
13	3	1			1	1			
14	3	1			1			1	
15	2		1				1		
16	6	1	1	1	1	1		1	1
17	2	1				1			
18	0								
19	0								
20	0								
21	7	1	1	1	1	1	1	1	1
22	3	1			1		1		
23	5	1	1			1	1	1	
24	2		1					1	
25	2	1					1		
26	0								
27	0								
SUM		18	16	15	14	12	11	8	8

Table 35: Open-o-meter transversal assessment (yellow = 0 openness, bright green progressively more open)

Project	Sharing	GNU GPL 3.0	CC BY-SA 4.0	CERN Open Hardware License	MIT License	CC BY-NC- SA 3.0	N/A
1	S		1				
2	S		1				
3	S			1			
4	S			1			
5	S		1				
6	S			1			
7	S			1			
8	S						1
9	S				1		
10	S				1		
11	S		1				
12	S						1
13	S						1
14							1
15						1	
16	S			1			
17	S					1	
18	S						1
19	S						1
20	–			1			
21	–			1			
22	–			1			
23	S			1			
24	S			1			
25	S						1
26	–						1
27	–						1
SUM		4	10	2	2	3	6

Table 36: Knowledge policy: User-generated content license (A)

SOCIAL RESPONSIBILITY & IMPACT

Project	Freedom & independence	Entrepreneurship	Energy sovereignty	Technological sovereignty	Food sovereignty	Diffusing useful design	Imagination	Empowerment through Education	Decentralized problem solving	Reducing waste & carbon footprint	Using 3D printing to change the lives of children	Biophilia	Community building	Changing perceptions by demonstrating change	Faster cheaper more efficient solution	N/A	
1	1			1													
2						1										1	
3				1				1					1				
4				1				1									
5				1													
6				1									1				
7	1	1				1							1				
8		1				1		1		1							
9			1														
10						1											
11							1	1									
12										1						1	
13								1									
14										1							
15				1				1									
16				1		1				1							
17							1										
18				1		1				1						1	
19											1						
20		1		1									1				
21						1				1		1				1	
22				1	1			1					1				
23										1			1				
24														1			
25											1			1		1	
26																1	
SUM	2	3	1	10	1	7	2	7	6	3	1	1	5	2		6	1

Table 37: Values for OSH initiatives

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