OPEN_NEXT

Deliverable 5.1

Open source sociotechnical design components

This project has received funding from European Unions’ Horizon 2020 Research and Innovation programme under the Grand Agreement Number 869984.

OPEN_NEXT – Transforming collaborative product creation

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Duration: 09/2019-08/2022

Grant: H2020-869984

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History of changes

Version	Date	Description of changes	By
0.1	05.05.2020	Initial draft	Voigt
0.2	29.05.2020	Updated draft	Gloß, Hofer, Voigt
1.0	17.06.2020	Reviewed draft	Gloß, Hofer, Voigt
1.1	13.01.2021	Layout updates; optimised file format	Gloß

Details

Dissemination level	Open Access
Due date	30.06.2020
Issue date	30.06.2020
Contract No	869984
Responsible Partner	ZSI
File name	D5.1_Open source sociotechnical design components

Abstract

Main area of this deliverable is the identification and description of socio-technical design areas. To do so, this deliverable includes responses of six paired interviews and findings are presented under four headings: social, technical and business perspectives as well as the involvement of citizens. Each section of findings is summarised with key points, which can serve as orientation when planning makerspace-company collaboration. A notable concern was the lack of easily accessible business models around open source (OS), where Small and Medium-sized Enterprise (SMEs) and maker communities could benefit in fair ways, sharing risks and benefits of open source hardware (OSH) related product development.

Based on the insights and a literature review a phase model is introduced. The aim of this model is to support the collaboration between SMEs and makerspaces during the product development process of open source product-service-systems (PSS) by classifying the readiness level of the developed solutions. It also aims to provide a basis for comparison within the pilot study, to identify patterns, to work out heuristics and to provide recommendations and support for the development process.

Keywords: *open source hardware, socio-technical design, company community collaboration, SME, makerspace, citizen-centred innovation, product development process*

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List of abbreviations and terms

ASD	Agile Systems Design
C3	Company-community collaboration
CAD	Computer-aided design
CIR	Continuous idea repository
DIN	Deutsches Institut für Normung e. V.
DIY	Do it yourself
EC	European Commission
EU	European Union
FMEA	Failure mode and effects analysis
IPR	Intellectual property rights
MS	Milestone
NDA	Non-disclosure agreement
NGO	Non-governmental organisation
OS	Open source
OSH	Open source hardware
OSD	Open source (product) development
PCB	Printed circuit bord
PDP	Product development process
PGE	Product generation engineering
PSS	Product service system
R&D	Research and development
SME	Small and Medium-sized Enterprise
TRL	Technology readiness level
WP	Work package
VDI	Verein Deutscher Ingenieure e.V.

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1 Introduction

Main addressees of this deliverable are the key stakeholders in the process of company-community collaboration (C3), including makerspaces and SMEs. Extending this picture, it also includes the *‘community of makers’* behind the makerspace as an organisation and the citizens, who – under an open innovation paradigm (H. Chesbrough et al., 2006; Johar et al., 2015) – become prosumers or co-designers of innovative products and processes.

This deliverable is to provide an empirically informed foundation for Open Source Development (OSD) projects. First, the conceptual building blocks are described, based on existing research and a broad literature review. Conceptually, the project starts with four analytical areas such as:

1) social relations (motivations, modes of communication, integration of diverse groups),
2) technologies (needed know how and tools, technological readiness of stakeholders),
3) business approach (business drivers, expectations, skills and capacities) and
4) co-creation and innovation (citizen-centred innovation practices).

These areas are relatively complex in themselves, so this deliverable makes an effort to focus on the questions most relevant to C3, i.e. the questions that are most likely to require decisions concerning the process as well as the general setup for successful C3.

The primary source of empirical data is a series of paired interviews with each of the makerspace-SME-cooperations, the so-called *‘pilots’* (see chapter 4). The applied method of *‘paired interviews’* will be described in depth later in the methodology chapter, but it is a useful way to combine data collection, analysis and fostering a common understanding of what is needed to bring company-community collaboration (C3) forward.

Based on the literature review and the findings of the paired interviews, this deliverable will introduce a *‘phase model’*, which provides a procedural perspective on C3. The purpose of this phase model is

a) to consider path dependencies, i.e. the early negotiation phase between companies and makers will impact their collaboration long term, including the sustainability and added value of their collaboration; and
b) to support product development during the implementation of planned prototypes. The premise here is, that a suit of recommended activities can accelerate the integration of makers’ creativity and skills, still open for flexible adaptation.

While the focus of work package (WP) 5 is on makerspaces as demonstrator platforms, we closely aligning our work with WP4, which is emphasising the company perspective. Both work packages are clear in that any design or decision concerning the collaboration between makerspaces and companies has to be *‘owned’* and, if needed, adapted by all parties involved.

The main contribution of this deliverable is to create a terminological as well as conceptual foundation for the collaboration happening in the two phases of OPEN_NEXT. During the first phase, that is the pilot phase (September 2020 - June 2021), concepts like the phase model will be tested and further elaborated, e.g. as part of the work in the design labs. Later, during the second phase, i.e. the demonstration phase (September 2021 – May 2022) the adapted concepts will be an integrated part of the demonstrator framework, easy to be applied to novel formats of collaboration for OSH. Analogous to *D4.1: First release of co-creation demonstrator framework* the main output of *D5.1 Open source sociotechnical design components* for makerspaces will be a design framework, a guiding list of questions and a phase model, coordinating future collaboration efforts.

The following figure shows the argumentative flow in this document. Based on the concepts drawn from the literature (chapter 2) and the project’s description of action (DoA), interview questions have been derived and integrated in paired interviews, a method described in chapter 0. The responses obtained have been further transcribed and categorised, forming the baseline for the analysis (chapter 4). Based on these results, we introduce the phase model in chapter 5, providing clarity on the initial steps of C3 as well as suggesting a number of milestones to give chronological orientation to the pilots. Finally, in analogy to WP4, the deliverable concludes with a set of questions, whose answers help to exchange and therefore learn from each pilots’ specific actions and experiences.

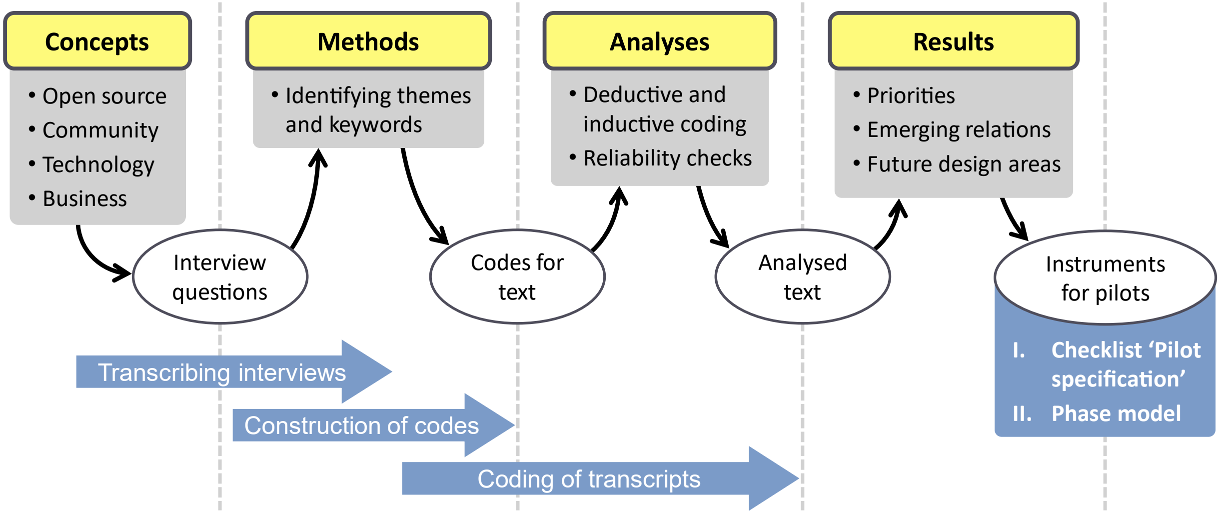


Figure 1: Methods and argumentative workflow of D5.1 Open source sociotechnical design components

2 Conceptual building blocks

Considering the broad objectives of OPEN_NEXT, existing findings from the literature need to be incorporated as much as possible. Or, similar research themes need to be checked for their suitability. For example, there is already a substantial body of literature concerning the eco-systems of open source software development and what challenges are still to be addressed (Jansen et al., 2009). Open source hardware (OSH) on the other hand has a different ecosystem and the main players in both worlds, soft- and hardware development overlap only minimally, however, research on crowdsourcing innovation (Majchrzak & Malhotra, 2013) or the use of platforms for community building (de Reuver et al., 2018) seems still relevant.

In order to make sure that existing research informs critical parts of OPEN_NEXT pilots, we suggest an early soft-systems model of an OPEN_NEXT pilot (see Figure 2) displaying interacting elements which compose a real-world problem (Checkland & Poulter, 2010):

1) The open source hardware (OSH) development *‘pilots’* (makerspace-SME cooperation)
2) Different stakeholder, having different expectations and interpretations of the process
3) A set of resources (e.g. research summaries, pilot glossary, checklists and stage models) intended to facilitate the process, although their effectiveness might be perceived differently
4) A number of relationships that show how elements within the model condition each other
5) A collection of potential outcomes (learning, technology, and processes)

The benefit of this early soft-systems model is that we can address relationships without being limited by imposing more rigid frameworks (hard systems) which typically present single worldviews from a particular stakeholder, e.g. favouring either companies or makerspaces.

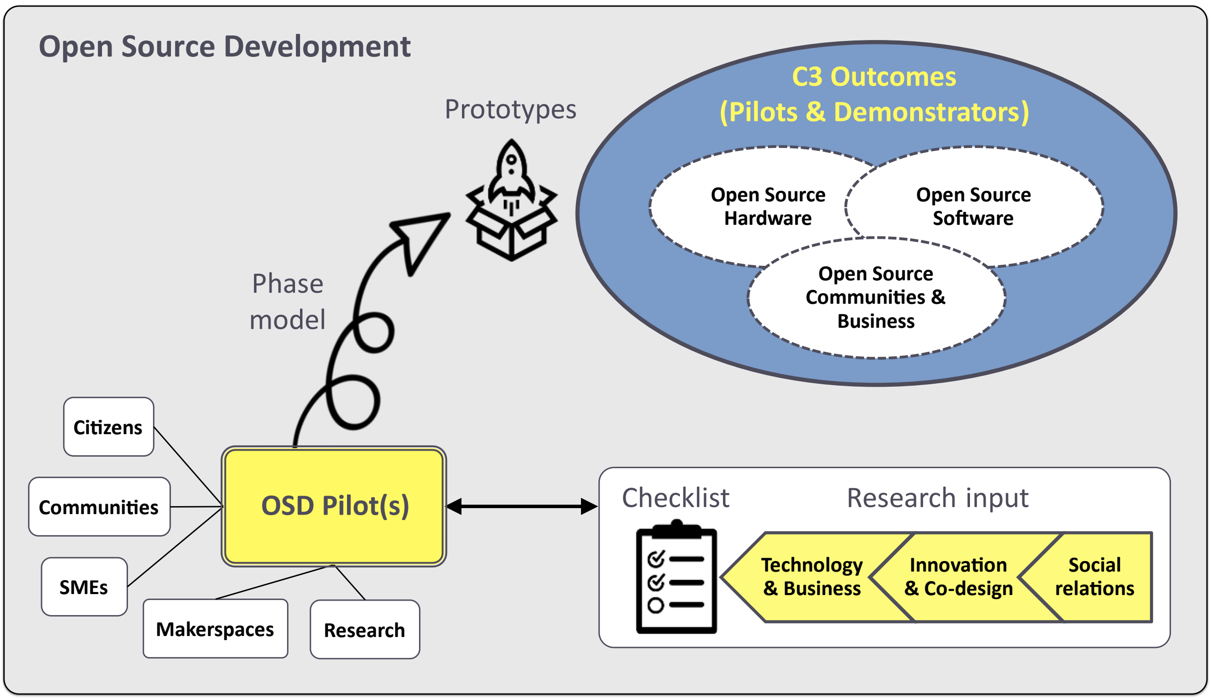


Figure 2: Soft-systems overview of a generic OPEN_NEXT pilot

Soft-system model’s primary objective is being comprehensible to many and to negotiate a common course of action, hence there is less emphasis on formalised presentation standards, commonly part of other modelling approaches, such as the Unified Modelling Language in the realm of software development. For example, in the right lower corner, we see *‘research input’* as one of the resources informing the writing of a checklist. Linking both elements together, acknowledges the *‘worldviews’* of academics and makers. Both views, emphasising practice and theory differently, define the resulting soft system.

Whereas the soft-system approach provides a rich picture of the context where pilots are going to operate, it also highlights a number of core elements which are revisited in the following sub-sections. Beside capturing underlying definitions, this brief literature review is also to support the formulation of paired interview questions with companies and makerspaces.

Hence, the following components are reviewed:

1) Open Source Development (OSD),
2) Stakeholder groups and their respective experiences with OSD,
3) Social relations within OSD, including the expectations and diversity of participants,
4) Technologies that play a critical role in OSD, including
    a. Platforms for community building,
    b. Tools and materials used for digital fabrication,
    c. Design tools for collaboration,
    d. Regulations
5) Economic incentives and
6) Citizen-centred innovation.

The components 1 and 2 were not explicitly questioned as they form the basis for participating in the OPEN_NEXT project, i.e. being willing to engage with OSD and being a stakeholder in the OSD process. Still, we found it useful to include these aspects of OSD and how they are reflected within the OS literature at large.

Components 3 to 6 have been addressed explicitly in our interviews (see Annex for a complete overview of the interview guideline). Our questions aimed at understanding the meaning and importance of OSD concepts for our interviewees as well as their motivation in engaging in OSD and their implications for future collaborations between companies and makerspaces.

The following sections (2.3 to 2.6 in particular) review existing literature in the four areas we explored by interviewing pairs of representatives of companies and makerspaces. Each section starts with current discussions and findings and concludes with an overview of the questions included in the interviews. However, the interview questions were not to replicate the literature review, but to give sufficient background knowledge for the probing of answers and qualitatively analysing the answers of interviewees. The four areas of our interviews include:

1) What motivates or engages a diverse community in OSD? (Section 2.3)
2) What technologies and processes are needed to participate in OSD? (Section 2.4)
3) What role play economic incentives in making OSD sustainable? (Section 2.5)
4) How can OSD contribute to more citizen-centred innovations? (Section 2.6)

2.1 OS Development

In the context of this deliverable, we understand the term *'Open Source Development'* as a combination of Open Source Hardware and Open Source Software. We emphasise the aspect of combination since the focus of the project is on OSH but we also understand that mechatronic systems require both, hard- and software related developments.

OSH is defined as suggested by the Open Source Hardware Association, which states:

> *"Open source hardware as a term for tangible artefacts – machines, devices, or other physical things – whose design has been released to the public in such a way that anyone can make, modify, distribute, and use those things"[1].*

In general, this definition is also in line with the four freedoms of *Open Source Software* as defined by the *Free Software Foundation*[2]:

1) The freedom to run the program as you wish, for any purpose (freedom 0)[3].
2) The freedom to study how the program works and change it so it does your computing as you wish (freedom 1).
3) The freedom to redistribute copies so you can help others (freedom 2).
4) The freedom to distribute copies of your modified versions to others (freedom 3).

Studies about the adoption of open source software show a trend where the main arguments for using open source centre around ease of customisation, community support, reliability, innovation, multiplatform capability and no vendor lock-in (Lenarduzzi et al., 2019), ultimately driving the sustainability of open source. Ethical considerations and the original idea of *'free use'* in the sense of free speech are not among the top ten reasons for using open source (Millard et al., 2018).

We did not find an equivalent survey nor literature for the use of OS technologies in the context of makerspaces, but also there the situation is far from homogeneous and not all claims can be verified in reality as access to digital fabrication is increasingly commodified, communities are not as inclusive as one could expect and maker identities being far less political than what is suggested though the narrative of the *'maker revolution'* (Davies, 2018).

2.2 Stakeholder profiles

Similar to the OS software ecosystem, we differentiate three broad categories:

1) Product users – ranging from individuals using a product for their own purposes to entire organisations using the product as part of their business,
2) Product maintainers – making decisions about what becomes part of the product and what stays out and
3) Product contributors – interested in advancing quality and feature set of a product.

[1] https://www.oshwa.org/definition/

[2] https://www.gnu.org/philosophy/free-sw.html

[3] The list of freedoms started with a reference to *'the right to modify'*, later however, the right to use a program for any purpose needed to be added as a foundational right, hence *'freedom 0'*.

Users

The suggested stakeholders can only serve as a first orientation, since each group can show different behaviours according to their motivations and context. For example, individuals can engage in OS Development (OSD) for the purpose of learning a novel technology or they can engage because they want to support a community in need of an OS product, such as an air monitoring community using mainly OSH components.

Likewise, organisations can differ in that NGOs with limited budgets choose OS primarily for cost reasons whereas for-profit organisations are more interested in high integration potential and the openness of standards used, which avoids the known vendor lock-ins known from proprietary products.

In the context of OPEN_NEXT, there might be a third element to be considered, which is the contractual support of company-community collaboration. This is most likely to happen when the open source product needs adaptation or requires training before it can be used *‘out of the box’*.

Maintainers and contributors

Both stakeholder groups establish governance models, largely regulated by contribution guidelines and licensing models. Not in the focus of this deliverable, but still a factor to be considered is the question of liability. Jurisdictions in various countries operate differently, however an overview of OS licenses concluded:

> *“The characterization of FOSS licenses as contracts or unilateral instruments has been controversial for a long time. Today, a clear majority of jurisdictions apply contract law principles. The resulting problems with the formation of contracts are mostly solved pragmatically”. (Metzger, 2015)*

2.3 Engagement of and diversity in communities

Expanding the understanding of communities of practice to also those of concerns. The primary reference for concern driven innovation is Latour’s critique of matters of fact and an introduction of matters of concern[4]. The emerging concern driven innovation is especially relevant to the general OS field with an emphasis on the process (open, traceable, documented) over the product:

> *“[…] participation should be considered a matter of concern rather than a matter of fact. If taken as a matter of fact, then the practices and processes involved in bringing participation into existence go unnoticed. Participation as a matter of concern, on the other hand, recognises and makes evident the work and processes required to bring things into existence. Moreover, in keeping with Latour, the problem with matters of fact is that they reduce the world and its many processes into somewhat concrete entities and imply an ontology in which things are ideally knowable and manageable”. (Andersen, L. B., Danholt, P., Halskov, K., Hansen, N. B. & Lauritsen, P., 2015)*

[4] see http://www.bruno-latour.fr/node/165

Communities that are concern driven, usually challenge different societal or environmental problems, issues or challenges that have no solution provided on a market. Thus, getting included in communities provides them with a great potential for learning.

> *“To further nuance the meaning of community, we distinguish between communities of practice and communities of interest. A community of interest may be connected through their interest or concern in a topic, such as air quality in Amsterdam or noise pollution Barcelona. A community of practice might share the same types of skills and can provide additional expertise or knowledge about the issue but is more concerned with technical or scientific advancement, regardless of its application or issue. This definition can also extend to those interested in the advancement of science, or in this case citizen science in general.” (M. Woods, D. Hemment, L. Bui, 2016)*

Given the different types of communities (practice, concerns and interests), a close look on motivation, benefit and conditions needs to be taken, especially when communities are connected to OS development. Communities (of concern) are very strong in identifying and formulating challenges, and also very motivated for new innovative designs, yet they lack means of developing and implementing these solutions. This has not only consequences for how requirements of new products are established and how intellectual property rights (IPR) are regulated, it also impacts a community’s innovation output and therefore the time to market for specific innovations (Linåker et al., 2016). OS and more specifically open innovation pushes companies to look for fresh ideas outside their organisational structures, thus the connection of company and community is beneficial for both sides.

2.3.1 Community engagement

A strong capacity to engage is integral to the growth and sustainability of a community. On the one side, a growing community adds to the importance of the values and ideas the OSD project pursues and on the other side, collaboration with communities is key for companies who want to adopt an open business model (Henry Chesbrough et al., 2006). Proven strategies on how to capture value and generate a profit in an OSD context are still rare, as the values of the communities need to be respected and the impression that the work of others has been wrongfully appropriated is often a serious threat to the survival of a community. A well-known example is MakerBot, which in 2013 was accused of patenting community designs[5].

Engagement and motivation apply to an individual as well as to a collective level. On an individual level building a reputation, responding directly to user needs and learners are often counted as extrinsic motivators. Intrinsic motivations include hedonic motivations, altruism and gift giving attitude. (Rossi, 2006). But also on a community level, open source development (OSD) has success factors (David, 2006):

1) Sufficient community support (generating attractive ideas)
2) Sufficiently high rate of innovation (demonstrating an active community)
3) Professionalisation to ensure maintainability (building trust in the longevity of the community)

[5] https://techcrunch.com/2014/05/28/makerbot-responds-to-critics-who-claim-it-is-stealing-community-ip/

Considering community motivation in the context of OPEN_NEXT, it is important to take into account the dynamics of individual motivations and community wellbeing. David's (2006) model can be understood as a progression from an emerging to a maturing community – in a later chapter there will also be an OPEN_NEXT stage model – and similar developments can be observed for contributors to OSD.

Another important factor in community engagement are the types of activities. Case research of more complex OS hardware collaborations (Mellis & Buechley, 2012) has shown that interactions benefited from highlighting the diversity of skills needed to accomplish the project as well as making a difference between activities needed to learn (e.g. soldering components, using git for exchanging code) versus activities needed to produce (e.g. creating a design in a CAD (computer-aided design) program or testing a variety of materials for a product). Although people can drop out or join in any stage, research from OS software development suggests a general pattern of switches between motivations going from *'pursuing a set of values'* to *'improving skills'* to eventually generating some income (Kilamo et al., 2012).

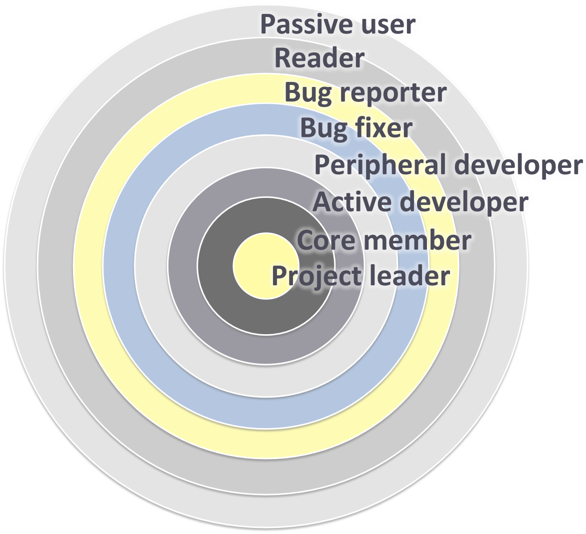


Figure 3: Onion model of OS communities acc. to Kilamo et al., 2012

2.3.2 Diversity

OS development in general and maker communities in particular, pride themselves of being open to a diverse community and independent. Still studies show that similar to other tech sectors, maker communities are predominantly white, male and wealthy (Carstensen et al., 2014; Sherrill, 2017; Voigt et al., 2017). A critical analysis of the Maker movement highlights how *'making'* is often commodified by state institutions to serve the education system or to push regional economic development (Davies, 2018). Hence, the necessary freedom of motivations and objectives, is often lacking and thereby ignoring the complexity of actually integrating a diverse set of people, beyond the mere statement of *'everybody can join'*. Thus, the social perspective has been split into areas of collaboration, motivation, influence, impact and diversity. To each of these areas, questions were formulated for the paired interview.

Table 1: The social dimension of company-makerspace collaboration (interview questions)

(1) Social perspective
Mapping communication modes, socio-cultural motivations, interests, and values to gain a deeper understanding of the impact of social aspects on OS collaboration in makerspaces and SMEs, with an additional focus on gender disparities.
1) Did you collaborate with external partners before, e.g. makers / companies respectively? a. Mention one example b. Learn about local tradition in collaboration / best practice c. If no, do you know of any best practice examples from somewhere else? 2) What are motivational factors to take part in this project? a. Enumerating a list is OK, for time reasons b. What would be your drivers to collaborate? For example: i. Company: Money, fresh ideas, ii. Maker: Skills enhancement, spontaneous jobs, novel community 3) In what ways could collaboration (as described above) influence you or your institution? a. Prestige for makerspace, individual decision to feed it back to the makerspace b. Maybe change equipment or process knowledge in makerspace / raise awareness 4) Big picture question: How could collaborations between *‘makers’* and *‘companies’* impact the way we produce and consume? (socio-cultural) a. Is OS a sustainable concept in your opinion? b. Are there limits to open sourcing, why or why not? (e.g. recovering R&D costs) c. Recap ‘open source’ if needed i. Free redistribution ii. Source code / open designs iii. Derived works are allowed iv. Must not discriminate against specific people / areas of application / other types of licences that are bundled with the same product 5) Are possibilities and experiences in maker - company collaboration influenced by participants gender or other demographic factors (age / migration background)? a. Where can we notice these imbalances? b. Anything we could change here?

2.4 Technologies, skills and processes used in OSD

2.4.1 Technologies

The use of technologies in collaborative settings can be either an early barrier, e.g. if a highly specific digital fabrication tool is needed – excluding large parts of the maker community – or an early enabler, e.g. if platforms are used to make documentations and design files accessible to many.

The former aspect (technologies for digital fabrication) is of particular interest for WP5, since digital fabrication tools impact the suitability of makerspaces, who have different sets of machines available and therefore attract different communities. An example for less common technologies provided in makerspaces might be welding technologies or clay and ceramic 3D printers, which are supporting the development of large-scale prototypes.

In general, makers define themselves more through their creativity, problem solving skills and their ability to find their ways when working with new technologies. Still, and also in line with the previous chapter, the collaborative setting should make provisions to facilitate access to both components of prototyping: parts and materials as well as technologies needed to transform or combine the materials.

The later aspect (technologies for collaboration and community building) is largely covered in WP3’s *D3.1: User stories of collaborative engineering needs*. The deliverable outlines specific use cases, (Wolf et al., 2014) where makers and companies specify, among other things:

- How to grow a community,
- How to exchange information efficiently,
- How to effectively collaborate,
- How to motivate contributors and
- How to manage the quality of the OS development project.

As we can see in the list above, these use case have technical as well as social components. For example, contributors can quickly be demotivated by technological factors such as cumbersome collaboration tools or when much needed information is hard to find. However, motivation also needs a shared understanding of what is expected from contributors, how outcomes of the OSD project are used and how the community is managed in general (benevolent dictatorship, an adhocracy model, meritocracy etc) (Kendall & Kendall, 2010). The more these parameters can be explicitly defined over time, the more the collaboration technology can match local C3 processes.

While there are notable platforms with hundredth of thousands of shared designs (e.g. thingiverse.com[6], instructables.com[7] and hackster.io[8]), these platforms are part of a larger business so that the content could disappear if the platform becomes too expensive to maintain or access to the content could be bared by a paywall. Most often, duplicating or extracting content from those platforms is not a feature to prevent the loss of digital assets (designs, instructions, bills of materials etc).

2.4.2 Processes and skills

Wolf et al. (2014) looked into the existing evidence for makerspaces giving back to the common pool of knowledge, either in form of designs or instructions about how to handle machines or get projects done. The authors brought forward two main arguments, reporting that:

1) Much of the information needed to replicate OSH projects are of a tacit nature (assembly skills, soldering strategies etc) which – while not impossible – takes an extra amount of effort to encode. Therefore, sharing knowledge among makers is as much about sharing existing information as it is about creating the information:

> *„From our work with the Fab Lab community during the last seven years, we however had the impression that it is notoriously difficult to convince even altruistic users of local public spaces who are aware of and agree with the importance of contributing*

[6] https://www.thingiverse.com/

[7] https://www.instructables.com/

[8] https://www.hackster.io/

new knowledge back into the commons to invest time and effort into documentation and open knowledge sharing at online platforms.“ (Wolf et al., 2014)

2) It is less the technology or a lack of skills which can impede knowledge sharing on a global scale and more the focus on local developments, that characterises makerspaces. Put differently, tacit knowledge can be easily shared in a social setting such as a FabLab, with the benefit that the sharer’s social capital is increased, equivalents such as likes or followers in a virtual world might be insufficient replacements. (ibid.)

Lastly, legal ramifications play a role in documenting and publishing OSD, as many are unsure what original information taken from somewhere else can be published or included, which would require another effort to comb the associated licences of reused designs.

Table 2: The technological dimension of company-makerspace collaboration (interview questions)

(2) Technological perspective
Mapping existing processes and know-how with regard to technological readiness, identifying necessary infrastructural elements for successful C3 and receiving best practices from both target groups.
1) Overall picture of company and makerspace a. Age b. Growth c. Current phase: opening a market, incumbent, phase out / transition 2) Any numbers describing the organisation (URLs are fine) a. Members / employees / freelancers b. Number of units (company) / number of machines (makers) c. Number of products brought to market 3) Forecast a. Expected future development (growth / decline) b. Any regulations that might have an impact in the future? 4) What are the phases for product and service development in your institution? a. Create common ground b. Only for relevant projects in OPEN_NEXT: Analyse, Identifying Potential, Concept building, Specification, Realisation, Release (not whole car, maybe rear mirror) 5) Where do you see most opportunities for C3? a. Speculative answers are allowed i. Exploration (finding ideas) ii. Evaluation (idea evaluation, user acceptance) iii. Demonstration (feasibility of ideas, concepts, functions ...) iv. Evolution (variants, generations) 6) What technical know-how is the core of your collaboration? a. Consider Triangle: Company <=> Makerspace <=> Sum of Maker Skills (Makers) 7) What infrastructural support would you use for the collaboration? a. Rooms, software platforms, meetings, surveys, calibration stations, certifications b. Which interfaces are there within C3?

2.5 Economic incentives

The question of value generation is important, as it influences

- the way OS projects are organised,
- open source development (OSD) projects’ ability to attract contributors in the future, and thereby become or stay sustainable.

This is a particularly interesting area of investigation as the economics of OS is less based on material compensations and more on the idea of creating an OS ecosystem which can sustain their contributors in multiple ways beyond selling the actual OSH. Still, Thomas and Samuel capture the essence of the business model challenge when stating:

> *“Most academic literature concerning open business model reliance on collaborative ecosystems is firm-centric. However, this phenomenon is spreading to OS product development ventures with undefined legal status. The complex art of choosing a business model becomes more difficult for such projects where non-market considerations are at the heart of the value creation process.” Thomas and Samuel (2017)*

An essential part of these *‘non-market considerations’* are the characteristics of OSD ecosystems. OSD ecosystems consist of players that act collaboratively, contributing their individual innovations to a common project (Bosch, 2009). Overall, ecosystems aim to – at least partially – share their costs and generate mutual benefits. The cost aspect is as broad as in any other development project and includes the resources needed for the technical development, but also marketing, community management, establishing legal frameworks or public relations, as the project growths. Even though we can identify roles and activities similar to commercial projects, OS ecosystems cannot be equated with markets. Markets regulate the flow of input resources by anticipating a revenue potential. Despite the wealth of research dedicated to OS development, an analytical framework for the economics of open-source ecosystems or established business models are still missing.

Classical business model logic is hard to apply in the context of OS development. First, the demand for a service or product is based on scarcity, i.e. a product needs to be bought because its design is protected by a patent or other forms of intellectual property rights and cannot be obtained otherwise (Pearce, 2017). However, with OS this legal barrier is often not there, so the scarcity of a product or service might be a short-lived advantage because

1) For products of low or moderate complexity (e.g. 3D printed key chains) – users can become producers when designs are freely available and the necessary means of production become more and more affordable, here the declining price of microcontrollers and 3D-printing is a telling example.
2) For products of high complexity (e.g. DIY handheld game consoles) – companies with lower cost of production offer alternative products, with equally good or even better specifications for a lower price. The crowded market of micro controller units (MCUs) is a good example, where Arduino boards[9] are mostly seen as entry pathways into physical computing and as soon as price, energy consumption, size or device connectivity become critical features, makers switch to more specialised boards.

[9] see https://www.arduino.cc/

These two sources of competition listed above are difficult to ignore for any emerging business using OSH (Open Source Hardware). However, studies of OSH business models show how other factors become more important for potential customers, when making their purchasing decisions:

- Supportiveness of communities and availability of examples on platforms such as the Stack Exchange Network,
- Quality of documentation,
- Training materials and
- Sustainable supply chains.

Reviewing OSH business models, Pearce (2017) highlighted the potential of specialised communities, on need for affordable medical or scientific devices. Pearce highlighted that *“Libre Hardware businesses should target technically sophisticated customers first and, as usability matures, target expanded markets of conventional consumers”.* (ibid.)

Commercialisation efforts can then include

- DIY kits,
- OSH services (calibration services, data analysis platforms or coordinated studies of hardware efficiencies),
- Selling the actual OS hardware (e.g. 3D-printers such as Ultimaker or Lulzbot and
- Agile manufacturing (iterating on OSH versions).

Another area where we can look for similarities are business models developed around *‘open innovations’*. Many open innovations are built by *‘users-as-innovators’*, following a mix of *‘private investment’* and *‘collective action’*, meaning that individual improvements are contributed to a common good made available to all (Hippel & Krogh, 2003). In that scenario, the OS product gets more aligned with the contributor’s needs, while he or she continuous to benefit from further developments accomplished by other contributors. Additionally, *‘contributors’* are increasingly large companies who can sponsor the *‘fulltime employment’* of developers[10] moving OS products forward. With the increasing involvement of large companies, it is necessary to look into governance structures, in order to understand whether the democratising effects of OS, often associated with OS, still hold.

Increasingly, policy makers are recognising the potential of OS development to strengthen their economies. However, misguided influx of public money into ecosystems build upon mostly voluntary contributions can quickly distort existing mechanisms ensuring the quality of OS or limit future contributions if there is an expectation of monetary rewards. Still, given the fact that OSH designs are made by professionals and lay people alike, many designs can be improved upon if communities can invest in specialised skills not yet available within the community. Pearce (2015) provided several models calculating the value of OSH using an example of an OS medical device (a syringe pump). His calculations included not only the benefit of lowering the cost for a hospital but also the decreased cost in running research in medical schools and the increase potential for improving the device due to it being openly documented.

[10] That is particular true in FLOSS where companies have a visible input to products such as Angular (Google) or Linux (Red Hat, IBM, and Microsoft), either because they open-sourced it or because the product is a critical part of their backend infrastructure.

Table 3: The business dimension of company – makerspace collaboration (interview questions)

(3) Business perspective
Mapping and diagnosing the business drivers and innovation potential of both target groups with regard to economic incentives, skills, capacities, and expectations in engaging in OSD projects.
1) How would you describe your business strategy / access to market? a. Niche, cost vs quality, b. first to market, c. online / virtual strategy (mechatronic) 2) What social and economic returns do you envision? 3) Could you imagine managing a joint innovation? if yes, how? a. IP management? b. shared risks and shared gains c. Third party support (e.g. regional or national funding)

2.6 Citizen-centred innovation

Citizen-centred innovation can be seen as part of a continuum between manufacturer-centric innovation, user centred innovation and citizen-centred innovation. With manufacturer-centric innovation, it is the manufacturer who identifies users' needs and responds with new products and services, protected by closed processes and patents. With user centred innovation, users make use of new design and prototyping opportunities coming with digital fabrication technologies and design sharing platforms. In that capacity, users of products who are simultaneously innovating these products can become either rivals to or complementary partners of manufacturers (Von Hippel, 2005). Citizen-centred innovation goes one step further, following a civil utopia and distancing *"[…] itself from the techno-deterministic paradigms of Industry 4.0 or smart cities".* (Bianchini et al., 2019)

Innovations emerge from a changed understanding of *'needs'*, a change enabled by an amalgamate of diverse types of background knowledges. Citizen-centred innovation does not aim to transform a street bicycle into a mountain bike – a classical example of user innovation (Luthje et al., 2003), but to innovate the concept of mobility in itself, e.g. by integrating a ride- and car-sharing app interfacing with specific car functionality such as publishing an upcoming ride-sharing opportunity or granting access to co-users of the car[11].

[11] https://www.spiegel.de/auto/sono-motors-baut-solar-auto-sion-tesla-aus-der-waldorfschule-a-00000000-0002-0001-0000-000170604470

Within the open design efforts, it is fundamental to recognise citizen participation in design efforts over a mere representation of users. Citizen’s situated insights into their societal and environmental urgencies reduce the uncertainties of the developing product or service. Citizens are not only users, even less consumers, but very motivated contributors:

> *”[…] design outcomes from collective processes can be greater than can be achieved by a preselected team of designers, participating in a collaborative process.” (Maher, M. L., Paulini, M. & Murty, P, 2011)*

Thus citizens are no longer valorising products but ensure utilisation of OSH innovations, by identifying societal relevance of OSH innovation and turning them into societal benefits (c.f. De Jong, S.P.L., 2015). In such context, we see societal benefits of citizen-centred OSH development beyond mere peer-to-peer knowledge transfer, and more in a context of sustainable, circular or even commons economies.

However, citizen-centred innovation is not only a desirable development due to its potential to counter negative impacts of mass production on the environment and countries with lower labour costs. Thomas and Samuel (2017) highlight the need to integrate *‘societal progress’* with actual value generation, which then leads to the need to find novel competitive advantages, hitting the triple bottom line (people, planet and profit). An example for turning an environmental problem (increasing textile waste) into a business value is realised with the concept of *‘slow fashion’*:

> *“In contrast to the successful ‘fast fashion’ business models, this company creates two collections per year and strives to make durable clothes that can be worn on different occasions, while minimising production impacts.” (Inigo et al., 2017)*

This does not mean that we should strive for *‘slow tech’*, however, the argument would be similar as in *‘slow fashion’*: Can we reduce waste by having more modular hardware architectures, so that we can replace components rather than entire gadgets. Modular products require a different type of design approach, as in *‘circular design’* where design is not driven by a product idea but by how well can it fit with our existing systems of energy or material supply (Moreno et al., 2016).

Table 4: The social dimension of company – makerspace collaboration (interview questions)

(4) Citizen-centred innovation perspective
Mapping citizen-centred innovation practices.
1) How does your organisation involve citizens in innovation processes or development processes? a. Market research (design approval, sampling) is not an equivalent of *‘citizen involvement’*? 2) Is the engagement of citizens a rather easy process, if so why? If not, please name barriers for the engagement of citizens. 3) How influential is the involvement of citizens in your production/decisions and processes?

3 Methodology

Complementing with empirical data, we followed a qualitative approach since only very few studies could be identified in the field of OSH and C3. Thus, the research follows a qualitative approach, based on semi-structured, paired interviews. This allows for more flexibility in contrast to fully standardised interview methods (Froschauer, U., 2003). It leaves enough room to clarify assumptions or misunderstandings as well as to follow up on themes which might not have been prominent on the interviewer’s agenda.

The decision for having interviews in a paired setting has been set since paired interviews are a suitable method when there is a need to elicit shared and/or dissimilar understandings of the researched phenomenon (Arksey, 1996). However, the information value of paired interviews can go far beyond identifying differences in pairs. Looking into non-verbal actions, we can also see how conflict is handled or who extends or corrects previous answers. Thus, we hoped to trigger by these types of interviews also the necessary communication and further collaboration exchange.

Whilst three of the interviews were done face to face, the other three interviews had to be done virtually (also due to Corona crisis). In total we interviewed 17 persons (12 men and 5 women) from 9 different partner institutes.

On top, the outcome of the analysis on the other hand contributes to an OPEN_NEXT process specification sheet. This sheet is supposed to help SMEs and makerspaces to substantiate their collaboration and develop a clear understanding on a C3 process, again covering the four identified perspectives (social, technical, business and citizen-centred).

Table 5: Overview Paired interviews – date, duration, gender

Collaboration pairs (Makerspace + SME)	Date	Duration	Interviewee’s demographics
WAAG + SODAQ	2020-03-24	1h 31 min	Gender: 2 males
WAAG + Fiction Factory	2020-02-24	1h 9 min	Gender: 2 females, 1 male
FabLab Berlin + Sono Motors	2020-02-07	1h 8min	Gender: 1 female, 2 males
FabLab Berlin + OpnTec	2020-03-09	1h 21min	Gender: 1 female, 2 males
Maker + XYZ Cargo	2020-03-17	50 min	Gender: 2 males
Maker + Stykka	2020-03-02	59 min	Gender: 2 females, 2 males

3.1 Paired in-depth interviews

The following section includes a brief description of the used instrument for data collection and the structured analysis.

3.1.1 The method

In line with our focus on understanding of user-centred OSD projects and collaboration, we structured our empirical research around four different angles, identified out of the literature research (see chapter 2): social relations (1), technologies (2), business approaches (3), and co-creation and citizen-centred innovation (4).

Since there is only limited empirical studies published on OSH development we decided for a qualitative method of paired in-depth interviews (Wilson, A. D., Onwuegbuzie, A. J., & Manning, L. P., 2016), aiming to extract an analytical understanding of the stakeholders’ resources and analyse specifically following areas of interest:

(1) Sociological perspective: mapping communication culture and modes, sociocultural motivations, facilitators and barriers for collaboration and values to gain a deeper understanding of the possible impact of social aspects on OS collaboration in makerspaces and SMEs. In addition, we were interested if gender and diversity is playing a significant role and how this aspect is handled by the partners.
(2) Technological perspective: was designed to map existing processes and know-how with regard to technological readiness, identifying necessary infrastructural elements for successful C3 and receiving information on best practices in collaboration from previous collaborations.
(3) Business perspective: mapping and diagnosing the business drivers and innovation potential of both target groups with regard to economic incentives, skills, capacities, and expectations in engaging in OSD projects.
(4) Citizen-centred innovation perspective: mapping citizen-centred innovation practices, already existing experiences and the level of integration of citizens in already established businesses.

Building on these perspectives, we formulated 18 main questions and several sub-questions (see Annex), framed within a semi-structured interview guideline. Thus, although the given questions would guide the interviewees through the different topics, the type of interview would leave sufficient room for further questions to investigate on possible issues or interesting aspects not considered so far.

This type of interview guideline facilitated well the twofold purpose that we aimed for. Of course, it was important to gain insights into the before mentioned perspectives. But moreover, the questions were also to facilitate communication and discussion among the interview partners themselves, fostering a common understanding and sharing views, expectations and condition for collaboration.

By opening up the interview for both of the pilot collaboration partners (method of paired depth interviews), not only specific information could be extracted, but it also facilitated stepping forward towards further collaboration within the pilots. By having the interview partners in pairs (SMEs and makers together) we hoped to trigger also further their common pilot activities in terms of concretisation and planning for actions since this method claims to trigger collective impact: seeing and hearing others, who are partners within the same pilot, speak openly about the topic at hand, can encourage them to also want to add their share of insights and ideas for improvement.

Interaction between the interviewees is a core element of paired interviews since it allows to capture (different) perception of topics, values, cultures and/or aims (Houssart, J. & Evens, H., 2011). Thus, the task for us was not only to gain pure information but also to stimulate a discussion and an exchange among the pilot partners. At the same time, for us as interviewer, we were challenged not only to lead the interview, but also to keep the balance between the discussion of the interviewees as recommended (c.f. Seale, C. et al., 2008), being equitably as possible.

Thus, the strength of these paired interview lies in the fact that the involved interviewees develop a common ground of understanding, clarify expectations and communicate needs for the pilots that might have not clarified up to this point. We also expected that participants would be able to detect domain-specific subtleties in each other’s responses and be able to then ask ever-important follow-up questions, using appropriate domain- and pilot-specific terminology.

Due to the geographical distance of the partners, only three out of six interviews could be done face to face with both collaboration pilot partners, while one interview (XYZ Cargo) had to be done without the cooperating partner (comment: the cooperating makerspace partner Maker was interviewed already with the SME partner Stykka, thus no partner was missing). The interviews were all recorded after ensuring the (written) agreement of the interviewees. They were transcribed and vary in duration from approx. 60 min to 90 min. Both, the recordings as well as the transcripts are stored at a secured server to protect the identity of the interviewees. For the analysis itself, the identities of the interview partners were anonymised.

3.1.2 Analysis

The content was analysed in a systematic manner after (Mayring, 2014), according to the rules and theory driven guidance with the aim to draw conclusions to our four perspectives. While there is a variety of techniques for interpretation available in qualitative research (Mayring, p. 63-64), classification and structuration are the most appropriate forms of interpretation for our purposes. Thus, each question was attributed by at least one code making sure to capture all answers (deductive). Applying this coding system allowed a systematic analysis of the data. The aim here is to explore the data material according to the rules and categories (codes) and describe the transverse section in the data and extract communalities and differences in the interviews. In addition, we allowed for inductive codes, that would allow also for the unexpected that were not captured by the deductive codes already. There, the categories or codes are directly distilled from the interview material. The inductive reasoning approach allows coming to new insights into how the SMEs and makerspaces work and helps to generate new theoretical insights derived directly from the data collected. Thus, it is applied to allow for any unexpected, but relevant, findings to emerge (Reichertz, 2013).

As mentioned, the transcripts of the interviews were analysed following a combined coding approach (inductive and deductive) and making use of the qualitative analysis software MAXQDA[12] supporting coding across multiple files. The resulting coding tree allows then for easy extraction of test snippets that have been associated with a particular code. By the end of the coding process, 421 codes were identified, classified in 31 categories (4 main categories and 27 sub-categories). The following chapter outlines detailed findings of this analysis, structured by the different perspectives and categories.

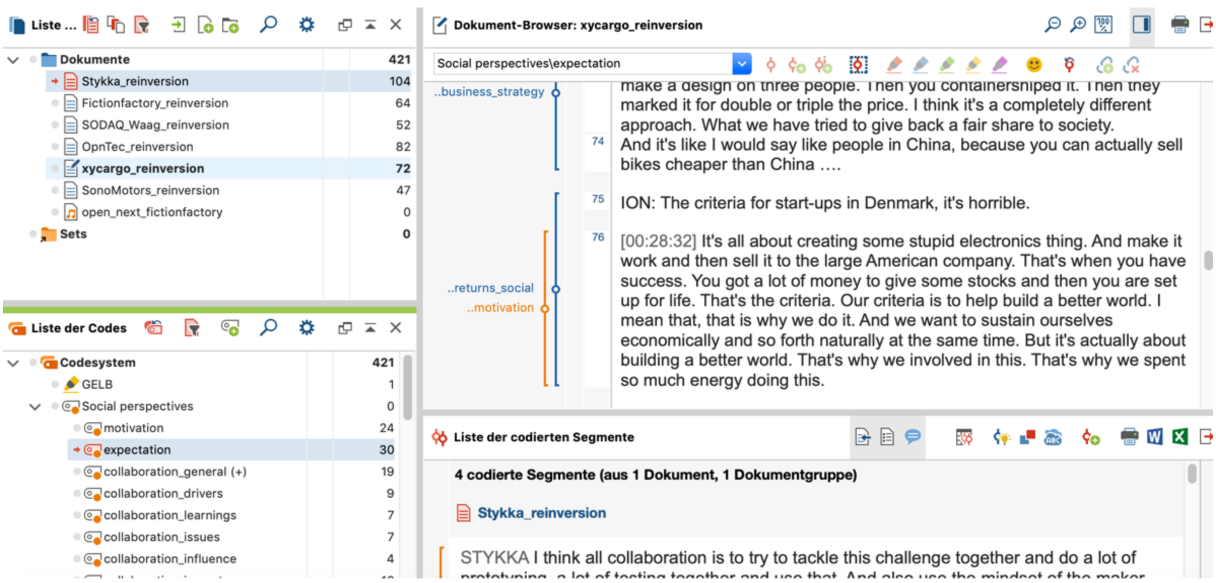


Figure 4: MAXQDA coding tree

[12] see https://www.maxqda.com/

4 Data Analysis and Findings

4.1 Social perspective

Good collaboration forms the basis for any successful outcome. Supplementary to the importance of aligning a challenge definition as a team that excites, inspires, and ensures focus, it is likewise necessary to complement with the social perspectives that each team member contributes with. Hence, the understanding of motivation and expectations towards the pilot as well as the conditions for collaboration for each participant is highly relevant for each pilot activity. While usually this process happens naturally in the first meetings, we tried to speed up and opened up the discussion by addressing motivation and specific expectations as well as several aspects of collaboration.

Table 6: Total numbers of snippets and percentage of codes for the social perspectives

Codes for the social perspectives	Amounts of snippets	Percentage
collaboration_limits_conditions	35	20.59
expectation	30	17.65
motivation	24	14.12
collaboration_general (+)	19	11.18
diversity	19	11.18
collaboration_impact	16	9.41
collaboration_drivers	9	5.29
collaboration_issues	7	4.12
collaboration_learnings	7	4.12
collaboration_influence	4	2.35
Total	170	100.00

4.1.1 Motivation

The question of motivation is important, as it influences the way the OPEN_NEXT pilots will be performed and able to influence the perseverance of participants. In total, 24 codes were generated during the coding process for the subcategory *‘motivation’*.

On a broad overview, there are several components that drive the motivation of the OS development partners. For once, it is a business-driven motivation. On the other hand, there is for some partners the sustainability thought a strong motivational factor as well as learning from others.

Some partners clearly identify their motivation in the highlight of boosting their business processes and a possible advantage towards competitors, also to reach by collaborating with new partners, respectively with *“[…] super talented people from the maker community and also the Danish Design Centre […]”* (N2A1) and getting some, possibly already existing ideas or concepts, up and running. Especially small companies rely on input from externals in order also to *“[…] speed up their innovation process”* (N2A1). And of course many of the SME’s are eager to find fitting business models that support their business in a fair way but still contribute to a good financial revenue.

Maker organisations emphasise rather the creation of jobs and new business concepts *“so one of our core motivations for being part of the OPEN_NEXT was really to see it as an opportunity to create market opportunities, business opportunities for our members and the members of our community in Copenhagen.”* (N2A2)

Doubtless new possibilities open also up for new learning experiences. Many – if not all interviewees mention the learning aspect that has been mentioned also as a motivation for participation. SME’s do see also their weaknesses and try to gain benefit from the pilot activity: *“What we observe through our projects and practices is that can do something quite strong in translating urgencies as concerns and needs into prototypes. But then you need the next step scaling up, accelerate. And that's something that's something that we are not good yet. So we are kind of incubator better, but the accelerator of, let's say, open-source technologies.”* (W2A3) Others see their learning in the experience with a new target groups as to improve their methodologies and collaborative tools (W1A2).

Obviously, developments in OS needs to constitute itself in the willingness to share. However, connected with this sharing is the fact that developers also learn from each other, which is to some extend also a motivation for makers to join OS. But also companies list this learning by sharing and common development. In specific to *“[…] accelerating and scaling up these kinds of developments then in the – let’s say – larger applications, nationwide or Europe-wide applications. And also working with more sophisticated technologies like SODAQ has.”* (N2A2) Thus, next to the business models, the scaling becomes interesting in terms of expansion in application, geographical spreading and sophisticated technologies. Makers claim a need for more information and more experience, and an understanding of the business model(s) of full OS products, being aware of existing business model of limited OS products (W1A1).

For many interview partners, the participation in OSH development is also connected to an ideological driven motivation, meaning to contribute either to a social issue or problem like sustainability and environment issues, health or e.g. supporting local communities. Makers *“[…] don't necessarily do it for the money, but they do it because they have something that it's very important to them”* (N2A2). Especially the local transportation and sustainability thought is highly connected to the motivation in taking part in the OSH development: *“But it's actually about building a better world. That's why we involved in this. That's why we spent so much energy doing this.”* (N1A1)

4.1.2 Expectation

Clarifying the expectations is possibly one of the most important momentum in launching partnerships and collaboration. It is essential to share a common understanding on efforts, timing, processes and the role each partner plays in these processes, costs as well as the readiness level of the outcomes (i.e. functioning prototype till production line) in order not to risk diverging the collaboration (c.f. N2A3). Thus, during the paired interview, we were asking all interviewees for their expectation when participating in the pilot. Especially in the face to face interviews we were able to observe first steps into interaction between the interviewees, giving comments and replies to mentioned expectations.

For once, a global expectation of the activities in the pilot can be well summarised as one partner outlines: *“I think all collaboration is to try to tackle this challenge together and do a lot of prototyping, a lot of testing together and use that. And also use the mindset of the maker community was to find super fascinating and try to use that as a way of developing a model for open innovation, which makes it beneficial for all parties to follow both the designers and the end users and also us as a company.”* (N2A1)

The focus lies for many partners in the collaboration *“I'm looking forward to meeting some skilled people, talented people that want to develop something because it's always like the most fun thing to do is to work with people where you can actually do some good things together.”* (N1A1)

Depending on how deeply the institutions are already involved in OSD, the level of expectation largely varies. While some expect to increasingly explore in what way they can use innovative business models, other institutions that are rather beginners in OSD expect hope to get a good grip on how to best handle OSD and how to best embed it into the existing company processes and identities. Again, the learning aspect is something that is expected by most of the interviewees, though on different areas like fitting business models specifically for OSH development, scaling up to diverse community groups, processes in OSH development but also documentation.

Some SMEs clearly expressed the need of a supporting partner within their pilots, either by adding engaged community groups *“Our expectations are […] how to establish relationships with the communities and from there, how to jointly develop products which we are capable to develop with our knowledge and which can fulfil a role in the life of the communities”* (W1A1) to adapt or develop products for specific target groups (or scaling them).

On a long-term perspective, the expectations become less concrete, and often emphasise a sustainable impact, often focusing on new start-ups: *“[…] Or we could also engage IT students and they would learn how to contribute in their capacity and they could then also like go on and collaborate with us or some future. Maybe we could even hire some and all they could like be inspired and start their own start-up become part of this ecosystem.”* (O1A1)

“So the idea is to make a series of different functions that would not only fit our cargo bikes, but also other producers of cargo bikes that people could copy free and make their own business out of that […] and I would actually expect from makerspaces really take the local production as more serious, but not only development, but also say, ‘Look, how can you really next to the problem should be a more manufacturing thingy or like a fabrication plant, produced in a fair way’.” (N1A1)

Summarising, the partners short-term expectations towards the OSD journey and its outcome target mainly:

- Prototyping, testing and scaling,
- Learning and knowledge sharing,
- Access to engaged target groups that are otherwise hard to reach as well as,
- Support in pilot specific tasks.

Especially the support dimension differs amongst the SMEs and makerspaces in terms of what type of support as well as to what extend the support is needed. Interesting is the fact that a long-term expectation from half of the interviewed partners hope to foster new start-ups with the innovative products that ensure sustainable and fair production.

4.1.3 Collaboration

Collaboration experiences

Indeed, collaboration forms the basis of any teamwork and common production. However, given the different company profiles and the possible different working cultures (especially with makerspaces), it was essential to get a grip on their understanding of collaboration, the drivers and barriers, assumed impacts but also limits that might occur, especially in the context of OSD.

In general, all the interviewed partners have (had already) collaborations with either external companies, industry, subcontractors for specific tasks or clients or in the case of the maker institutes *“[…] really a lot of years of experience working with makers. That's a very broad term, but both in* *terms of hobbyists over to the to the professional engineers and architects and the people that are members.”* (N2A2) Thus we can assume that they cover a broad range of target groups and sufficient experience when asked for collaboration.

In case of the makerspaces, they expressed also how these collaborations are handled and how they are influencing the collaboration. Firstly, the knowledge on motivation and the needed working environment: *“And of course, a big knowledge on what motivates these people also, especially in […] what they do and how they run their businesses and how they work is something that we both find extremely interesting to talk about all the time. So we will probably do that a lot. This kind of improvised collaboration that's going on that is not really facilitated by anyone, but just happens. And how do we create an environment that allows that something that I would like to experiment with also bringing into an online.”* (N2A2)

Secondly, the makerspaces bring in a good knowledge on co-design processes or are even experts in co-designing processes that involve different target groups *“[…] and we have a lot of experience in creating and facilitating these same experiences that create good foundations for productive co-design processes and development processes”* (N2A2) and often see even their function or institutional goal as makerspaces in being *“[…] really a kind of community incubator, providing conditions for these first steps and process and then, of course, emancipated.”* (W1A2)

Collaboration OSH development specifics

In the last years, many different papers have been published about the maker movements and the culture of OS. Having hardware developed in an OS manner raises still many questions. However, among all the different aspects, interview partners stressed specifically two aspects that they found highly relevant for the OHD of the OPEN_NEXT pilots.

For once, maker movement and OS underly a different *‘business culture’* or way of working. Some interviewees emphasised that the OSD differs to usual teamwork in traditional business relationships: *“And so there are other people that are already in our network. And even without having like a company agreement, we can already collaborate. And this is the magic of OS, right? You don't need to sign a contract or sign an NDA* (non-disclosure agreement) *and make an official agreement. Somebody could just like start to share something and start to share their knowledge about open hardware or even if they already have a prototype and you can engage with them and really learn from it and also give feedback. So this whole process of innovation starts right at the first meeting.”* (O1A3)

An interviewee describes it in the way that experimentation and exploration is key in the maker movement and thus products are developed in a more diffuse way of collaboration and working than in traditional product developments: *“So maybe it's more like a water system where the extreme finds its way to the goal […] and less like that go one step after the next.”* (O1A3)

Characteristically, makers usually act and develop in networks, thus differ significantly from traditional product development. While traditional businesses are done by a limited amount of employees, subcontractors or external companies, OSD movement can be spread like an entire network that is flexible scaled *“[…] if you are involved in OS community for a long time or even into makers movement, you know that there is always collaboration among different layers in the community”* (O1A2). *“But this doesn’t indicate an uncoordinated structure but requires especially for the OSH development a plan and goals in certain directions, but with sufficient flexibility for different solutions.”* (O1A3)

Conditions for collaboration

Collaboration does not simply happen but is indeed connected with different aspects that make a collaboration work or fail. From a social perspective, sharing a common value but at the same time being open to inputs from outside, is indeed an important factor for successful collaboration (N2A1). Or, as commented by a partner who claims that OSD requires *“[…] social components like values and integrity and the willingness to agree also to compromises”* (S1A1). Transparency about each partners goals and directions from the very beginning is key in any relationship or collaboration. The same holds true for the acceptance of each other’s motivation and the willingness of helping each other to achieve these goals. (O1A2)

Ensuring this transparency is also the basis for a trustful working environment that creates a system based on *‘increased development by sharing’* rather than – as known from traditional business – a system of competition. Ideas and solutions bloom when shared and discussed by many, in contrary to very small and singular perspectives of few.

Successful collaborations seek partners with complementing knowledge and skills and/or matching working opportunities (like machines, workspace) *“[…] and also because he needed us, and we needed him for the design.”* (W2A3) A win-win situation is being created. But these complementing skills often come from institutions that differ a lot from each other and can at some points challenge the cooperation (*“challenge of different cultures”* (W1A2)). Finding compromises is essential, but even in between those *“two different cultures it may be that in between another culture will emerge”* (W2A2).

One, very clearly communicated condition for collaboration was the fact that any type of collaboration requires that participating institutions do *”[…] gain some money together”* (W2A3). At the end, all participating institutions make their living by either (fostering) development (makerspaces) or development and selling of products itself (SMEs). Thus, financial revenue is key.

Both, SMEs as well as makerspaces, claim the need for business models in the OHD that can be well applied and adapted. But an OHD business model needs to give consideration to the credo to have a fair share of all participants, which is – given the nature of OS – tricky in many aspects.

In addition, an issue for makerspaces specifically is to communicate well the needed resources and time for planning, launching and performing OS processes, since this work is mostly underestimated. Thus, makerspaces often face right at the beginning the need to clarify these amounts of time and costs

Efficient working is highly appreciated with some of the SMEs, reflected by having short business processes like ordering, communicating and invoicing, but also simple production lines (i.e. already existing engineering) *“[…] and so it gets done, productive!”* (W2A3)

A limitation – not only for OS but for traditional business as well – is the shortage of skilled and capable people. Also, the less of resources for personnel compared to big industry creates a disadvantage for SMEs. Thus, the strategy where sustainability for projects can be reached is to make sure that SMEs can increase the level of the wider communities that people can take part in the movement (O1A2). However this leads sometimes to a significant number of users, but only very few contributors. Summarising, both, SMEs as well as makerspaces, seek for highly motivated and skilled people that are dedicated to goals, willing to share and cooperate in a network of different players.

Of course, OSH development also faces legal limitations like copyright issues or business specific restrictions. Interviewees claim that *“[…] the legal framework gives an advantage to established players and in large companies and instead of like supporting innovation from small companies like* *us."* (O1A1) And although the network of makers is willing to start contributing and collaborating right away, SMEs are well advised to have clear agreements documented to minimise possible risks. Monitoring and testing every single chain and step by maintainers can be one way to bring OS products finally to the market (O1A1).

Drivers for collaboration

Understanding the drivers for collaboration is closely connected to the motivation of participation in the OPEN_NEXT pilots and OSH development. The analysis has shown that there were no contradicting arguments mentioned, but rather strengthen the ratio of identified drivers:

Understanding the value of a commonly produced open product facilitates collaboration. Might it be the financial return, the gain in learning and inspiration, the increase of ideas or access to consumers or a challenging task itself that is being tackled within peers, it is a major driver for collaboration. If the conditions for collaboration is given, simplified speaking there are two elementary drivers, *"[…] either […] money or […] learning"* (N2A1).

In some cases, this simplification might indeed be reality but on a more detailed level, there are other factors that can boost collaboration. The understanding of fulfilling specific needs and creating a win-win situation can be claimed as a good motivation, thus fosters collaboration.

Especially for makers but also for SMEs the understanding that collaboration can support local communities and foster sustainable development can be a major driver for collaboration, especially when values and goals are shared. Tackling societal challenges is a driver that should not be underestimated, since many makers but also employees or founders of SMEs argue with high social/ethical motivation. With unequally spread nuances, we can often find a mix of all three drivers that create value for the participants.

Other factors like i.e. an increase of image and the branding of a company might have some slight positive influence for our interviewed partners but is an argument that can be rather neglected, although OS obviously needs to fit into the companies' philosophy and identity. However, as for some other prestigious companies this factor might still play a role in OSH development processes.

Learning, influence and impact of collaboration

Learning was mentioned as a key driving factor for collaboration. Consequently, we were interested where the interviewees would hope to gain further competences.

One layer of learning is directed towards the integration of OSH development. OSH development is in its beginnings, thus there is a need for exchange of the co-design processes and ideas on how to best integrate into existing SMEs or makerspaces as well as into start-ups. Especially makers could benefit by understanding on how to go beyond a prototype and scale up production and how to establish a start-up, simply by collaborating with SMEs as role model. Also, the learning of individual makers within a group or community is acknowledged as a benefit. The *'learning by doing'*, as it happens in OSD, is probably one of the most radical forms of learning. A prominent example for learning through replicating existing designs happens in the 3D printing community, where existing designs are minimally adapted (Voigt, 2018).

SMEs are often looking for learnings on the development process itself: *"Makerspaces can offer experience on creating and facilitating co-design processes that involve a lot of different stakeholders […]"* (N2A2).

The input from externals is valued a lot by SMEs especially since they bring in a new perspective that might influence the development process: *"Of course (you learn), any time you meet a new person on new design, a new company. Like an injection of vitamins into a company because you have sort* *of a fusion between the two you value. Of course, you need to have some common values, but you also get to always get inputs from their ways of working and their experiences.”* (N2A1) For sure, excellent businesses know how important skilled and motivated employees are for their success. As any business, also makerspaces try to identify and recruit talented contributors to their communities.

The participating SMEs value the fact that makers are often at the cutting edge of new developments and trends and often acquired the knowledge of specific production already (see O1A1).

They appreciate the sustainable approach of makers as well as the diverse way of product development: “*Of course makers can teach SMEs and the businesses a lot. Also, in terms of becoming more responsible in the way they produce, so becoming more open not just in terms of product development, but also in the culture and in the way that we develop new products and work with end users […]”* (N2A1). However, not all clients do see these aspects in the foreground of their employment at first but reflect on this value only during or after the collaboration.

Thus, collaboration on both sides, SMEs and makers, is (often) a win-win situation on learning as well, since the SME gains competences they do not find in-house while makers gain access to technical facilities, infrastructure and knowledge on business setups and strategies.

Like the other areas, again the mutual impact is important. Asking for the impact of collaboration on their institution many of the interviewees agree that it does have an impact on the company: *”Definitely our way of thinking. And hopefully we also influence them. So I think there's like this cross coordination between the two partnerships.”* (N2A1)

SMEs state that collaboration with externals definitely impacts their product development by bringing in new perspectives and new ways of thinking and working. This is one of the main reasons why collaborations are fostered and launched.

Issues of OSD collaboration

For many SMEs and makers that go into OS the development of a sustainable product is a key issue in development of products. OSH development ensures sustainability, since if one developer leaves, the product can still continue, and it can benefit people continuously. It allows people to have access to the entire knowledge and being in the position to create the same product or a further development. Thus, knowledge and development does not get lost (O1A1). OS receives increasingly attention, but still there are many open questions on how different institutions or even single persons can be part of this. People start to increasingly care about OS but, accordingly to the interviewees, many do not see the value of OS up till now. *“But the value of OS is not only about the outcome, the software or the hardware. Basically, the whole process.”* (O1A1)

An issue for many SMEs that are already involved in OSH development is the fact, that it seems to be impossible to control the quality of the rebuild. If rebuilds are made of poor quality, the brand identity is in danger to suffer bad reputation. According to the SMEs, quality control in OS hardware is a fairly important issue but has not been really tackled by now. A clear distinction between the code and the brand needs to be stated in order not to damage the companies branding. Starting product development right from the beginning as OS might ease some of these issues (N1A2).

SMEs report that they experienced a high investment in terms of time to support the community that uses the OSH, but on the other hand only very few contribute with further development (comp. issue of many users, few contributors). Next to many unanswered questions, this fear (or fact) contributes to the unfortunate situation that many companies or developers do not publicly share their products openly and make it accessible to the community.

Political support like the promotion of societal challenges might also support the role OS in future: *“But there's a rising. Conscious space in societies in Western Europe, at least about sustainability. Not only the environmental sustainability, but also the social versus sustainability.”* (N1A1) Still it would require major political changes in society to reach the ideal of sharing everything (N1A1). Though initiatives like the *‘right to repair’* movement – a coalition of European organisations pushing for system change around repair – gain increasing influence. *“And I think this would change a lot, if there's so many industries require to do things in a way documented open repairable way. And suddenly these things that we've been talking about at the moment would become standard.”* (O1A3)

4.1.4 Diversity

For most of the interviewees, diversity is an integrated part of their companies’ work cultures and environments *“[…] but we tried to have as many women working there as possible. And we also have a lot of interns that also come from different backgrounds […]”* (W2A5). Often a personal interest or belief is the main driver for a diverse team. Some SMEs understood that it adds more value to the company and creates a much more interesting place to work (W1A1).

Some makerspace partners even foster diversity by extracting marginal perspectives well aware that they reach a wider view on developments *“I mean, we don't look so much into the balanced situation as in diverse situations. So let's involve as many other perspectives and let's involve as many other concerns. So whatever marginal concern there is, it's relevant for us because it helps us understand something that the mainstream doesn't cover. So in our case, we are more interested in the marginal perspectives than in the mainstream.”* (W1A2)

Although the willingness for diverse working teams is clearly emphasised, at the same time the interviewees point out, that – as in all other fields – female technicians or handcraft employees are hard to find and this relates of course also to the Open Hardware community where specific skills are required. At the end, most of them decide to employ the most competent person, but try to also consider age, background, disabilities, linguistic differences, socio-economic status and cultural background. Table 7 summarises the relevant findings:

Table 7: Design components from a collaboration perspective

Design component	Explanation
Motivations	There are clearly two complementary sides to motivation, on one side companies and makers want to do good (pushing for mor sustainable consumption and production models) and on the other side there is a need to be financially sustainable to have an impact at all.
Expectations	Expectations included a multitude of aspect ranging from additional expertise, creativity, access to novel communities and the way they define a problem. More diverging expectation could be seen in the area of manufacturing, i.e. could makerspaces take on the role of decentralised, distributed production sites.
Conditions for collaboration	Collaboration was seen as a consequence of fitting motivations and complementary expectations. If these conditions are in place, then collaboration requires only a minimum of management, which is highly desirable given the emphasis on self-empowered OS communities.
Diversity	Diversity is clearly a topic for the maker community embraces in the sense that a variety of skills is valued. However, except of one pilot, diversity was not a driving factor in hiring or project selection.

4.2 Technological perspective

A particular focus on technologies during the interviews was also aimed at providing a socio-technical perspective in OPEN_NEXT based on known dual structuration effects between technologies and organisations/communities (Orlikowski, 1992). For example, a technology provided to exchange a design will enable reuse and modification of a design, while intrinsically also determining the intensity and flow of information between different communities such as engineers and designers.

As can be seen in the table below, technologies were mentioned when introducing the companies as well as the infrastructures available at makerspaces. However, the purpose was not to establish a complete overview, establishing such a baseline is more likely to be found in WP3, where first user stories have already been categorised.

In WP5, we are more interested in identifying the role of technologies in shaping and influencing company-community collaboration (C3). As shown in the following table, technologies played a role in describing opportunities for future collaborations, but also for identifying conditions for successful collaboration.

Table 8: Total numbers and percentage of codes for the technological perspective

Codes for the technological perspective	Amounts of snippets	Percentage
company_details	29	27.10
opportun C3	23	21.50
tech_know-how	19	17.76
OS	15	14.02
company_forcast	7	6.54
company_process	7	6.54
infra_collaboration	7	6.54
Total	107	100.00

Acceleration

As a baseline, *‘OS technology’* was seen as an accelerator where a group of motivated people could quickly try something, without worrying too much about NDA or establishing detailed conditions for kickstarting the collaboration, although those conditions might well be necessary at a later stage: *“Somebody could just like start to share something and start to share their knowledge about open hardware or even if they already have a prototype and you can engage with them and really learn from it and also give feedback.”* (O1A1)

Automation

Technology was also seen as an important ingredient to automate aspects of the collaboration between makerspaces, individual makers and companies, for example by speeding up the pricing and making a cost estimate: *“Usually when you design a cabinet, then you design this cabinet, then you need to produce all the files for the manufacturing centre, send them to the factory, then they need to try to calculate a price for you based on the material cost, the machine time and everything – in our design tool – we automated that process. You design your thing and then the tool will do all the cut files, the machinery, calculate the price and everything. Everything is built into the algorithm* *software."* (N2A1) In this context, the maker community would not only be a collaborator but also a user of a specifically developed tool for such a collaboration. Hence, their feedback and input as part of a user centred design process would be crucial: *"I think part of our emphasis is to go and interview designers or potential users of the platform, and then maybe we need to do some user testing with them and see how they interact with the platform. Or if you are an architect or maker, then what is your expectations of this kind of tool?"* (N2A1) Particularly when makers transition from designing or developing a product to producing smaller batches of products, technology can play a critical role in scaling the output of a project and providing a return on the initial investment: *"A maker had finished a product line of lamps. Laser cut lamps. And she was preparing them for a showcase. She spent forever on those lamps, because that's what happens. They stay up every night and then they make their own lamps to fulfil the order."* (N2A2) For that example, the idea was also that networks were needed on both sides, i.e. makerspaces would have access to a network of diverse experts, possibly providing knowledge around materials, designs, sustainability, energy consumption etc. and company partners might have access to a diverse range of production capabilities, fitting the nature of and materials used in the product (products including metal or textiles need other machines as products consisting of electronics and a casing.

Sharing

Lastly, talking about technologies led to questions of usability and standards and, most importantly, about informed choices: *"Can we share it with the community? Can we make sure to the museum on the other side of the world can use our drawings or techniques? I would love to do that, but we don't know how to do that because we've never done this before."* (W2A3)

Interviewees whose projects had data sharing at the core of their products (e.g. sensors collecting environmental data), had a particular interest in related regulations in the context of GDPR (general data protection rules). Essentially making sure that no personal identifying data were stored or processed without users content: *"Like for us, the discussion on privacy and data and how to go about it is, of course, also quite actual because people can start to collect data on their own and you see that there are different practices from, say, how Google or Facebook are dealing with it, to what for example, a citizen would prefer to share or not to share. So, I think that that whole area is where we are also contributing. What I'm trying to say is that we are contributing to better managing our planet and our lives with much more data. But that obviously raises the question about whose data is that? And with whom do I share my data and for what purpose, etc. So it's too big of a subject for this interview, but I think that that is really important for us."* (W1A1)

The following table summarises the most relevant finding in respect to the technological areas:

Table 9: Design components from a technology perspective

Design component	Explanation
Acceleration	Accelerating development through OS (fast prototyping)
Sharing	Easing the sharing of designs (considering OS viewers and editing tools) Sharing data in a GDPR conform way, also important for cloud services linked
Automation	OS add-ons support the efficiency or applicability of already existing solutions (e.g. additional OSH functionality for cargo bikes or the management of machine shops). An emerging question is the implications of such hybrid solutions.

4.3 Business perspective

The following six codes were used for analysing the interviews. As can be seen in the frequency distribution of codes in Table 10, questions around business strategies as well as financial or social returns dominated business related aspects. Statements regarding the conditions for joint ventures or joint innovations were relatively sparse. Considering this implicit ranking, we can anticipate that a thorough and transparent consideration of expected costs and revenues is paramount for C3, particularly during the second stage of the OPEN_NEXT project, when there is no base funding for the SME partners in pilots available.

There is no one-to-one relationship between codes and sub-chapters. For example, a comment on *‘social returns’* can describe the selection process of future collaborators or social returns are part of a strategy to reformulate the question of expected *‘returns on investments’*.

Table 10: Total numbers and percentage of codes for the business perspective

Codes for the business perspective	Amounts of snippets	Percentage
business_strategy	26	24.53
business_general	25	23.58
returns_social	23	21.70
returns_financial	12	11.32
cond_joint_venture	11	10.38
joint innovat	9	8.49
Total	106	100.00

4.3.1 Value proposition

Overall, it is important to discuss the value proposition in the context of a business model: *“If we start with OS hardware as the selling point, it's hard to get you to pay for that.”* (N2A2) Specially if makers or a SME want to address a challenge at a larger scale, e.g. pushing local production to reduce environmental harm due to transporting goods over long distances, they need to create systems where many people would be able to change their consumption habits (Unterfrauner & Voigt, 2017). Furthermore, an emphasis on DIY (Do it yourself) can be combined with the idea of upcycling: *“It's like changing the whole supply chain and not using stock, ... If you could design your own table, I think the probability of you holding onto that longer would be much higher instead of just buying something from IKEA. And also, the possibility if you just upcycle and you make some beautiful legs from your old table and you could use that.”* (N2A1)

A prominent question within segments related to *‘business strategy’* was around the sustainability of societies current patterns of (mass) production and (environmentally costly) distribution of products. XYZ Cargo for example named the local production of bicycles as one of the values their venture delivered: *“We wanted to try to see if it was possible to make a local production to work, to stay competitive, to be able to sell bikes at the same prices as other producers would do, even though we don't import from China. It's also a major sustainability problem, not only socially but also environmentally. It's also showing that in the future we could choose to have like a world where we produce things locally as far as possible and distribute resources in a fair way. So this is like it's also a very political project. It's about aesthetics, it's about ethics and it's about politics. It's not just* *about making money, but two of us have a very healthy companies that actually provides a livelihood for both of us.”* (N1A2)

OSH value propositions are also frequently reflected in a company’s own definition of *‘success’*: *“[...] make it work and then sell it to the large American company. That's when you have success. You got a lot of money to give some stocks and then you are set up for life. That's the criteria. Our criteria is to help build a better world. I mean that, that is why we do it. And we want to sustain ourselves economically and so forth.”* (N1A1)

There were also critical comments as far sustainability much more demanded when it comes to food or textiles, but when it is about hardware or electronics, far less people seem to care about the sustainability of shipping or working conditions on site.

Another value frequently mentioned was the adaptability of an OS product. Whereas standard bicycles are produced in a *‘few sizes fit all’* fashion, OS designs can be directly adapted to height, weight and personal preferences. Adaptability was also a theme for PCB (printed circuit board) developers: *“But like maybe we could adapt them more to our conditions. See, in Germany, I can just give a very simple example. We have this weather in Europe. Yeah. It's like from very cold to very hot. Right. But in other countries, you know, it's maybe subtropical weather. And, you know, if you adjust devices for different weather [...]”* (O1A1). So particularly sensors operate differently under very cold or hot conditions or air humidity. Hence, rather than having more costly sensors that can operate under a wide range of circumstances which they might never need (depending on where to they were sold), local production could produce versions in line with local operating conditions.

Social impact: If we look into social impact, we need to know how to actually measure impact. For example, instructions[13] on how to build the XYZ Cargo-one-seater bike are downloaded about 8,000 times a year, but it is not clear how many bikes are actually built.

To what degree this social impact is enabled depends on the effort put into *‘open sourcing’* information and experiences, for a project driven organisation this effort means allocating people to this task who would otherwise work on a project: *“But I had a chat with someone who said, OK. And then you make documentation and you write it all down, what you did and how you made it. And we're like, no, we never do that. We just make it. And when it's done, we move on to the next thing. So I think that's a difference between [makerspace] and us that we are a really project minded organisation.”* (W2A3) Hence a robust business model is important so that companies include the cost of *‘giving back’* to a community project already at the start (see section 4.3.4 for cost related aspects of OS business models).

4.3.2 From design to production

Design can already influence the options available for local production, for example cargo bicycles can be design in a way that allows local micro-factories to produce them without major investments in costly production equipment (N1A2). However, having designs is only one part of successfully manufacturing a product, quality control *“[...] is a big OSH issue as we found out [...] people rebuild [the bicycles] in a bad way, use bad material materials and someone sees that on the street or somewhere it doesn't work. It immediately comes back to us, not to the person that rebuilt it, but it immediately comes back to those who designed it. Quality control is a pretty important issue when it comes to OSH. It's not really tackled yet.”* (N1A1)

[13] http://www.n55.dk/MANUALS/SPACEFRAMEVEHICLES/DIY.pdf

Also, similar to micro-factories, local pick and place machines can support the scaling of PCB production: *"[...] in future we could have local pick and place machines really making products specifically for the local community, adapted to specific needs. So this is a really great vision. And yeah, this is good for people locally, but it's also good for the environment. So, the sustainability here in regard to the environment is that we don't have to ship products around the world."* (O1A1)

4.3.3 Conditions for collaboration

Collaboration with the maker community could evolve around specific add-ons. This idea seems to be particularly attractive in pilots with larger core-products (such as a cargo bike or an electric car). In such a situation, an add-on can contribute to the overall value of the eco-system around the core product, therefore enhancing the product's use value. For example, a fitting kitchen module would enable cargo bike owners to run a mobile food service. However, add-ons can also be attractive to producers of electronics hardware, if, for example, the hardware is providing data to a subscription-based cloud service. In the latter case, the cloud service would become more attractive when the number of compatible hardware increases. Collaboration in the context of designing and prototyping add-ons has the additional benefit that makers have the option to start their own business if they want to, since producing the add-on might not be interesting to the producers of the core-product. Standardisation is then also an important aspect of *'add-ons'*, in order to avoid lock-ins with a limited range of core-products: *"So the idea is to make a series of different functions that would not only fit our cargo bikes, but also other producers of cargo bikes that people could copy free and make their own business out of that."* (N1A1)

Another type of collaboration would be around local production sites, manufacturing according to the designs shared. However, as stated in the previous section, quality manufacturing is an ongoing issue and there need to be ways to develop trust in the production capabilities of local partners. This statement is also in line with another comment about the heterogenous nature of makerspaces, where a large community might develop a fair number of prototypes but a much smaller number of ideas is then intended to be brought to a more professional manufacturing process, because the developer believe that this would be a product interesting enough for a larger community to use.

A question discussed was also the aspect of accountability when different parties collaborate, i.e. if a product breaks and harms a person (e.g. furniture) or causes a fire (e.g. a short in a circuit), who is responsible? During the interviews there was a consensus that it is most probably the responsibility of the manufacturer of the product or even of the DIY kit.

4.3.4 Cost factors

If it is not a community project already, companies who develop hard- and software, naturally have R&D (Research and Development) costs. So most companies in the interviews made a distinction between core products, experimental product and add-ons: *"[...] in the core of our business, the R&D work, we work old fashioned in partnerships ... and the interest of our business partner is not to share the knowledge because they want to be the first or they want to be better, etc. So that is I think a bit the tension [...] we developed OS software because we thought it's nice for people to quickly get going with our boards and not everybody is eager to develop his or her own software. And that has been quite successful. But for example, we also had the hardware in our web shop. We published the schematics, but not really yet the Gerber files needed to manufacture the boards. And that is, I think, what we also would like to discover more in this project – should we be afraid?"* (W1A1) So in fact, open sourcing some components but not all of a project has specific purposes. For a seller of PCBs, open sourcing the software or libraries needed to run the PCB makes sense, since this increases the utility of the device. Publishing the schematics might help other makers to extend the board with additional hardware or even help with the debugging of circuits. However, open sourcing the Gerber file would lower the bar for low cost production sites, possibly undercutting the price point of the original developers of the gadget.

A lot of cost is associated with replying to questions from users who want to build an open source product but did not understand a couple of details: *"Then you find out you actually have to employ two people that kind of nurture the community and you don't get anything back. At this point it was just decided to do it completely different."* (N1A2) In that situation the project decided to be open source right from the beginning (opposed to open-sourcing something designed in-house) and therefore have designers and developers with the necessary sense of ownership in order to respond to the growing demand for support in case an OSH product becomes very popular. Hence not only does OSH design need to finance itself, also the support of local manufacturing of OSH needs to be self-sustaining and grow in line with the popularity of the OSH project.

An often underestimated cost factor in more informal collaborations is the actual time needed to make processes work. Though from a conceptual point of view, OSH might be a compelling opportunity, however, documenting OS products, supporting a growing community or, at least in the beginning, changing processes internally does require time: *"Oh, it's I think what is hard is to get them to understand the amount of time that goes into planning, these kinds of processes that get to to understand when they ask us for the price of doing some consultancy kind of like this. And we give them a price and they're like, well, well, I thought this was just something you did. So it's like, yes, we do, but we make money. It's time."* (N2A2)

The cost of collaboration in OSH development lies also in teaching potential contributors *"[...] Rhino*[14]*, I think that's the minimum requirement. You need to be able to teach yourself, right, because if we need to teach them some rhino first, then go through that whole process, like teach them how to use 3D printed design, then it's tough for us. I think you need some knowledge about that and how to design. That should be like the base line."* (N2A2) In this case, makers and the SME have established a minimum level of expertise for contributors. However, making that decision when to invest time in teaching someone a missing skill, might become a challenge especially when a project needs a more niche expertise unlike knowing how to use an off-the-shelf CAD (computer-aided design) programme.

Teaching prospective contributors is also related to the cost of an experienced work force, there are companies working on OS based smart speakers, from a product development perspective they would compete with bigger companies such as Google or Sonos for qualified engineers: *"The limitation for us is that we cannot compete with big companies, we also want good people, but we cannot pay that much money like big companies."* (O1A1)

4.3.5 Sources of revenue

Designers need to be able to ensure that the use of their current design pays for the next their designs. Hence, if everything is OS, then it is hard to find something a designer can get an income from (N1A1). One interview partner highlighted that OS development should not only rely on cross-financing: *"So you really have to find a more nuanced way for OS to progress that goes beyond you being paid by the governments or the private sector somehow for doing other things and then invest in OS. You have to find a way where OS could finance itself."* (N1A1)

[14] https://www.rhino3d.com/en/

Crowd funding has been repeatedly mentioned as a form of financing OSH upfront. However, kickstarting a successful crowd funding campaign might require substantial upfront investment, so that potential supporters can trust the seriousness of the project. For example, a recent campaign on Kickstarter for a sensor board monitoring an indoor environment[15] (humidity, particles, light, sound, temperature). At the time of writing the project had acquired 16,000 € already, offering boards for about 34 € a piece. With this example, part of the pledge was a fully functional prototype, a successful manufacturing pilot run to prove the assembly and quality control processes. So in that case, the crowd funding was aiming less to support the design of hard- and software, but to reach the minimum viable manufacturing run size.

Another idea was a more differentiated approach to licencing, so that, for example, up to 100 bicycles per year could be produced for free and after that a fee would provide a fair return to the designers and co-developers of the original product (N1A2).

Revenue through being open to collaboration as suggested by models of *‘open innovation’* is another source of revenue: *“So I think this was a welcome opportunity to actually collaborate with the team, super talented people from the maker community and also the Danish Design Centre, too, actually like, okay, can we get this up and running and can we make a model for open innovation that actually saved both the thriving community, but also a good business model? Because I think that's something at least I haven't seen that open innovation has been tested out as a functioning business model.”* (W2A3) Still, as the quote shows, there is no straightforward mechanism how bringing in external experts or pushing out internal skills and knowledge translates into revenue.

Lastly, rather than OS development financing itself through commercial ventures, universities could play a stronger role in driving and sustaining OSD. Universities are often publicly funded, and the knowledge create by universities should contribute to public knowledge.

Envisioning makerspaces as production facilities would only work if makers play an active part in the *‘how and why’* a makerspace should produce for a SME: *“[...] we're not really a production business per say. All of our members do their own production. So do they cover niches? Yes, they probably do, since they are so small scale, all of them.”* (N2A2) So makerspaces’ primary function is to share machinery and knowledge with people who do have their own projects already, presenting project ideas coming from the outside (SMEs, municipalities etc.) is indeed an option, but, based on our interviews, not yet part of makerspaces main activities.

However, once makerspaces and SMEs have settled on a promising prototype, SMEs can play their strength in readying a prototype for production, checking on size, energy consumption and manufacturability. However, even though the hardware documentation is OS, there is a need for a profit margin: *“So for us, there should be a certain margin which can also be reached because there is a certain cost reduction if you order larger volumes. So I can imagine that, for example, if you go for a stock of five hundred of these products, then there will be a margin for us on the one hand, because we can do the production cheaper compared to just 10 or 20 pieces plus, we could have like a certain profit margin on the shelves of the product. So, I see that really in the usual business way.”* (W1A1)

Similarly, the strength of a makerspace might not be first and foremost in its product development capacities, but in its deep knowledge of communities and networks using the makerspace. Hence, the makerspace as an enabler could identify *‘communities of concern’* and facilitate the origination

[15] https://www.kickstarter.com/projects/metriful/sense-indoor-environment-monitor

of project ideas (ideation): *“The [makerspace] is more of an incubator and not an accelerator, which is mainly what the Danish Design Centre is. And we both work on projects from start to end, but at different phases.”* (W2A2)

Following a short summary of design areas from a business development perspective.

Table 11: Design components from a business perspective

Design component	Explanation
Value Proposition	Upscaling and reusing materials Sustainable production Adaptable products Changed consumption (e.g. mobility)
Joint ventures (Maker + SME)	Add-ons Shared production sites Moving from prototyping to manufacturing (tested designs, training, accountability)
Costs	R&D (if you OS in-house developments) Community management around products Time for changing processes (if new to OSH) or for documenting Training for potential contributors
Revenue	Crowdfunding (e.g. Kickstarter, SODAQ with 4 successful products) Hybrid solutions (OSH and Licensing) Open business model (e.g. outside use of internal knowledge) Having (already funded) universities as OS developers Facilitation of conceptual development (e.g. community workshops)

4.4 Citizen-centred innovation

Table 12: Total numbers and percentage of codes for the citizen-centred innovation perspective

Codes for the citizen-centred innovation perspective	Amounts of snippets	Percentage
citizens_involvement	16	50.00
citizens_engagement	8	25.00
citizens_influence	8	25.00
Total	32	100.00

By far the most diverse answers were received when asking our interview partners about citizen-centred innovation processes. While many of the makerspaces see citizen-centred innovation processes as one of their tasks that they foster, SMEs understand citizen from a different angle. Thus, at this point we can observe that the focus and the aim of SMEs versus makerspaces differs but with high potential to complement each other. Especially the understanding of citizens was interpreted as consumers by the SME’s but on the other hand in the context of the makerspaces, citizens could also be the makers of course, since *“[…] there is not a clear cut anymore because the consumer can also turn into a maker or producer”* (O1A2).

None of the SMEs engage with citizens and stakeholders to a full extend, by involving them in the whole lifecycle of service and/or product development. Some companies do not include citizen-centred innovation at all, simply because their business bases on production that relies on the competence and knowledge of the ordering purchaser (business-to-business). Citizen-centred innovation is hardly applicable to them and they do not see opportunities at which stages the involvement of citizens could be beneficial or even possible for them: *“I think that we don't because we are really business-to-business. We don't really have a community like that. It's mostly companies and they have specific needs and we tried to meet their individual needs and it's not a general thing where a lot of people have opinions about.”* (W2A5)

They focus mainly on the provision of the tools or the products but not necessarily in engaging with citizens (*“[…] we are used to manufacturing [...]”* N2A1). Some companies have a very fast production line (from ordering to finalization of product) ranging from one day to max. three months. But citizen-centred innovation processes and co-development take time. Another barrier for including citizens in the process are insufficient documentation and making these documents *“[…] suitable for different people, human languages”* (O1A2). Thus, the need for transferability of documentation is essential when integrating citizens in the entire co-development production.

Certainly, several SMEs involve citizens in the user testing, collecting their feedback and possibly adapt the product. Although the willingness of a full integration of citizens can be observed, it has been made clear that this integration will happen in form of add-ons to the already established businesses of the SMEs. Some voices do have hesitations for a full integration since the same values might not be shared (i.e. emphasis on sustainability vs. capitalistic market thoughts) (see S1A2).

Starting from scratch with OS add-ons to the already existing products will clearly ease a co-development process with citizens and is considered as feasible within this project pilot phase.

On the other extreme, the makerspaces are highly experienced in citizen-centred innovation and define themselves – in some cases – even as incubator into society: *“So our main approach is co-creation. And we are strong in co-creation with communities and with society, with citizens. But we lack experience working with SMEs, with companies.”* (W2A2) Makerspaces are used to invite many different users from different backgrounds (including artists) with the aim to gain a wider perspective on the topic which adds some new insights that experts would not capture. The argumentation for citizen-centred innovation is very strong: *“And in this regard, there's quite a need for treating these citizens, not as consumers with their needs, but people that are literally struggling, they're literally concerned about something. And there's no solution out there that wouldn't involve their participation. So the whole innovation can emerge only through their participation because it's so site-specific for their local situation, whether that's airport pollution or a steel factory or water quality.”* (W1A2)

Indeed, the mix between makerspaces and SMEs in OPEN_NEXT is a very promising collaboration in terms of citizen-centred co-development since competences and skills are complementing each other. In the highlight of the citizen-centred innovation process, some OPEN_NEXT pilots are now in the process of consulting first with the community, identify their needs and urgencies and using this as point of departure (W2A2).

On a visionary view, the engagement of citizens plays an increasingly important role. They are not only considered as persons that should improve products, but should raise also issues in their environment, tackling occurring problems and performing societal actions (W1A2). *“If we think this several steps forward and several years into the future, if you think that localised production would become possible, this means much more customised products, much more adjusted products. Because what we see today, for example, products are made for like a huge market and then shipped around the world.”* (O1A3)

Table 13: Design components from a citizen-centred innovation perspective

Design component	Explanation
Citizens’ roles	Citizens were understood in multiple ways, as makers, consumers, testers, problem holders, providers of localised knowledge, supporters with time and finances or participants in shaping a solution.
Citizens as success factor	Makers were also aware that citizens were a crucial factor in changing public perception of *‘problems’* they were tackling with their products. For example, the demand for e-mobility or cargo bikes is directly influenced by the larger discourse of these topics within society.

4.5 Limitations

Obviously, the sample size indicates limitations to draw general conclusions. The study rather draws a picture of participating SMEs and makerspaces and gives insights in opinions, expectations and existing experiences of a limited number of participating partners. Thus, the analysis tackles the research question rather for the purpose of informing the pilots and to identify possible further actions and support needed, but does not draw significant relationships from the data, as this normally require a larger sample size to ensure a representative distribution of companies and makerspaces.

In addition, we hoped via the method of paired interviews also to be in the position to also analyse interaction and the communication flow between the interviewees and draw conclusions out of this interaction. As outlined only three interviews could be done face to face due to the Covid-19 restrictions. Although some interaction between the interviewees could be observed during the virtual interviews, we assume that the interaction was limited due to different communication behaviour in online platforms. Thus, the paired interview method could not be used to its full potential.

5 Phase model for product development

The aim of the phase model is to support the collaboration between SMEs and makerspaces during the product development process (PDP) of open source product development (OSD) by classifying the readiness level of the developed solutions. Whereby a product can be seen a material or immaterial commodity or service which is offered alone or as a system in order to satisfy the need of the market as well as the needs of users in a target-group-oriented way (Voigt et al., 2016). In the context of OPEN_NEXT, it may be useful to consider products as product service systems (PSS) rather than individually. A PSS is a system consisting of a physical product and an integrated associated service (Lindemann, 2016). It is central to the user-centred-design approach to understand products not only as what physically exists, but to explicitly embed them in practices and to help shape them. This leads to thinking in terms of product arrangements that are combined with intangible services. (Diefenbach et al., 2017) Accordingly, a PSS prototype integrates tangible and intangible elements of the overall system in a single prototype. (Gengnagel et al., 2016) The integrated development of services, business models and infrastructure inevitably increase the complexity of the development processes. (Müller, 2014)

5.1 Reference to the proposal

In the context of this work, the *'stage model for determining makerspaces level of technological readiness'* described in the proposal will be adapted, since a classification or assessment of the level of technological readiness (TRL) on the basis of manufacturing processes and technologies or the existing machinery does not provide sufficient support due to the complexity of PSS development projects and the wide range of product categories (e.g. Environmentally friendly mobility, built-to-order furniture, consumer electronics). Each of the subgroups of manufacturing processes in mechanical engineering according to the DIN 8580 standard, such as casting, pressing, moulding, rolling, bending, milling, turning, grinding, welding, gluing, painting, chemical coating, hardening and tempering, contain numerous technologies. (DIN 8580, 2003) The range of available manufacturing technologies such as Stereolithography, Fused Deposition Modelling, Binder Jetting, Selective Laser Sintering or Laser Engineering Net Shape in the field of additive manufacturing alone is very large (see Figure 5) and offer great differences, for example in the choice of materials.

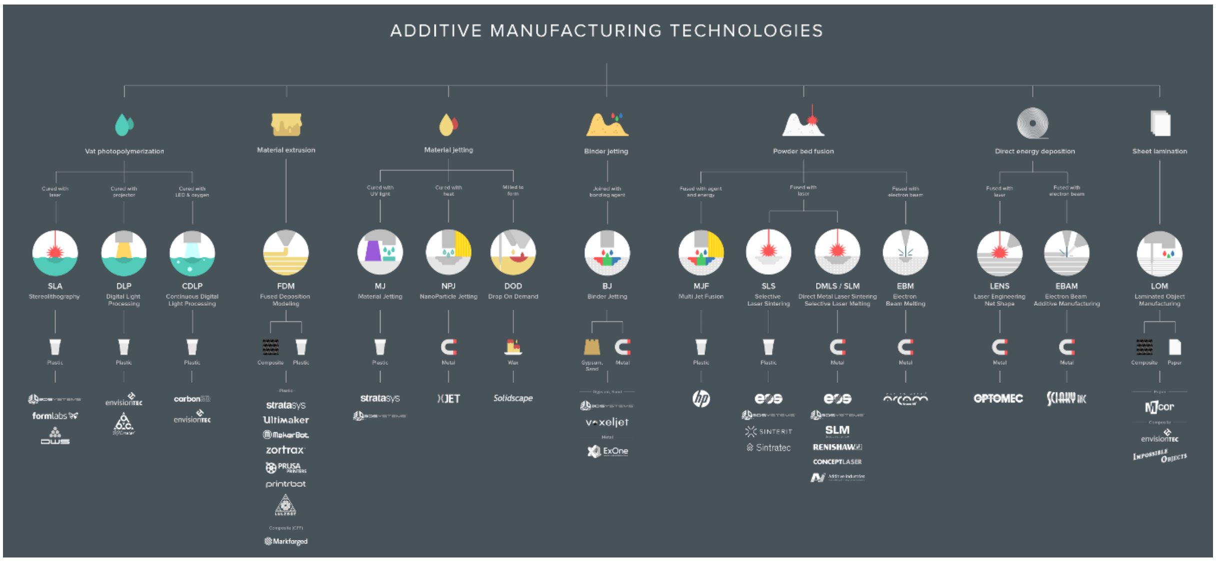


Figure 5: Overview & classification of the most common additive manufacturing technologies (What Is 3D Printing?, 2019)

Due to the iterative nature of PSS development projects (see Figure 6), technology selection at the beginning of the project is only possible to a very limited extent, since the early phase of a product development process is characterised by the fact that the quantity, robustness, and maturity of solution-determining requirements are still low and few properties of the final solution are defined. Due to the very vague system of objectives at the beginning, the uncertainties are very high.

In the context of this work, prototyping is considered as part of an iterative learning process (mindset), with the goal of reducing uncertainties as early as possible. A major motivation for agile approaches is to generate artifacts early on, to measure their impact on the environment, and to explore the user's interaction with the prototype. (Dennehy et al., 2016) In contrast to traditional prototyping, the goal of prototyping shifts from validation to experimentation. (Punkka, 2012) Prototypes are part of an iterative learning process and an important tool for exploring, evaluating, and developing new product ideas. (Hallgrimsson, 2019) They continue to represent both knowledge and insights in a physical or virtual model. (Lindemann, 2016)

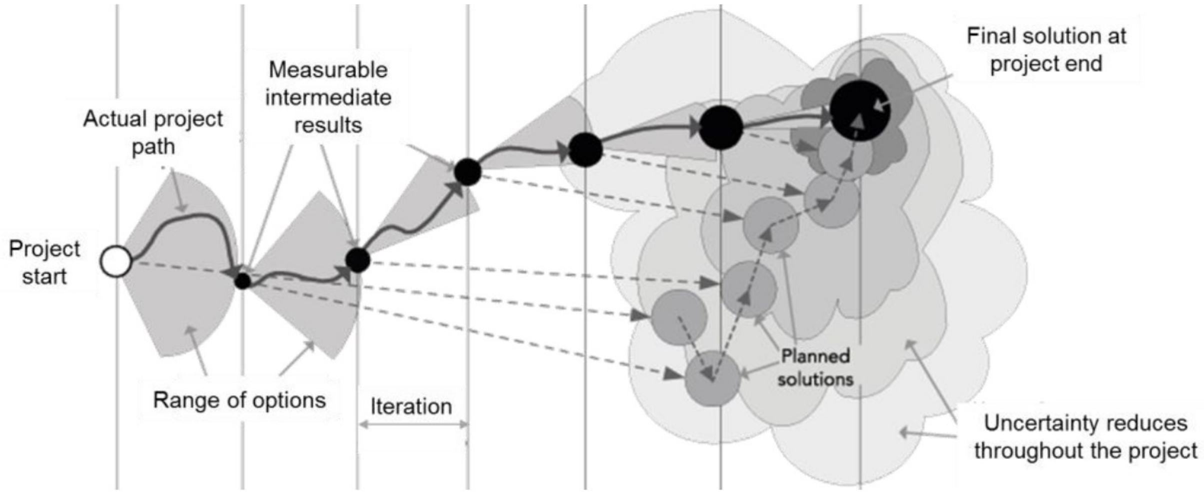


Figure 6: Agile project paths in the progress of the PDP (Oestereich et al., 2008)

The activities of prototyping are more than just the generation of a tangible representation. (Sanders & Stappers, 2014) Prototyping should be used to manifest and explore their ideas and to generate knowledge through prototyping in order to approach the final solution. (Lim et al., 2008) Furthermore, the production of prototypes supports the designers in identifying unknown problems and opportunities. (Dow & Klemmer, 2009) Especially the Use of prototypes and prototyping for exploration is highlighted. With regard to a user-centred perspective, the integrative aspects of prototyping allow participation of customers or stakeholders in the development process. (Hillgren et al., 2011) Prototyping also includes the conscious engagement of the problem-solving team with the stakeholder and the operational context for evaluation. With the conversion of knowledge and insights into something material, the creative processes represent the actual result of understanding. (Diefenbach et al., 2017) If not only the prototype is considered as a pure artifact, but as in Ulrich und Eppinger, the prototyping process is considered as a result and as an activity, four different purposes can be described within the product development process (Ulrich & Eppinger, 2012):

1) Learning – understanding the development problem and possible solutions
2) Communication – improve communication between the people involved and contribute to a common understanding of decisions
3) Integration – checking the interaction of the components and discovering unexpected phenomena
4) Milestones – to show that the design requirements have been met

Bertsche and Bullinger describe that prototypes are not limited to certain phases of the product development process, but provide answers to questions that arise. (Bertsche & Bullinger, 2007) Prototypes thus represent a cross-process and cross-phase driver of the innovation process, since they trigger, among other things, internal and external communication and feedback mechanisms. These are of great importance regarding interdisciplinarity and the development of product-service systems. (Vetter, 2011) Therefore, in the current context, it seems more useful to make an assessment based on the readiness level of the solution developed. In the context of the respective project idea, product category and industry, makerspace must discuss whether the necessary technical equipment and knowledge is available. This could, for example, be done based on accumulated project experience for a specific product category.

5.2 Phase model in the context of product creation

According to the Verein Deutscher Ingenieure (VDI) the technical product life cycle covers the areas of *‘product planning’*, *‘product development’*, *‘implementation/production’*, *‘product usage’* and *‘end of the product life’*, whereby the focus in WP5 is on ‘product development’. Therefore, it is important to note that the terms product creation, product design, product engineering and product development are seldom used with a clear distinction. The following Figure 7 is based on the Norm VDI 2221 (2019), which distinguishes *‘product creation’* – the dotted line box – and *‘product development’*, being one specific step within product creation. (VDI 2221 Blatt 1, 2019)

> *"[Product creation is] part of the product lifecycle consisting of the stages ‘product planning’, ‘product design’, and ‘production introduction’. […] If necessary, the production systems required are also designed in the […] product creation." (ibid.)*
>
> *"[Product development is understood to be an] interdisciplinary corporate process used to design a marketable product. The process is based on the definition of initial objectives and requirements for the product which are constantly further improved and iteratively adjusted in the course of the process.” (ibid.)*

As shown in Figure 7 in the context of OPEN_NEXT the focus lies on the two stages *‘product planning’* (No 1 in Figure 7) and *‘product development’* (No 2). Product planning includes besides research, product portfolio creation, and marketing also the project preparation in the context of the company-community-collaboration. The phase model of the product development (No 3) which is based on the Agile Systems Design (ASD) is divided into the phases *‘analysis’*, *‘identifying potential’, ‘conception’*, *‘specification’*, *‘realisation’* and *‘release’*. In order to analyse and evaluate the collaboration and communication of makerspaces, SMEs and communities, the layers of production system development, validation system development and strategy development, which are often carried out parallel to product development are not considered in detail. (Albert Albers et al., 2019)

The model presented here represents only a limited view which is in the nature of a model. Based on the definition according to Stachowiak, models have three characteristic features and always abstract the complex structure of a real system as a copy, model, or representation of an original. The mapping feature also refers to hierarchical super- and sub models, so that abstracted, model-related representations of further models are possible. Models represent the model elements that are relevant for understanding the model. Aspects of reality that are not essential for understanding the model are not depicted regarding the reduction feature. Thus, models are always simplifications of complex facts of the real system. Furthermore, models are based on a certain purpose, which is pursued via the pragmatic feature with a limited validity period. (Stachowiak, 1973)

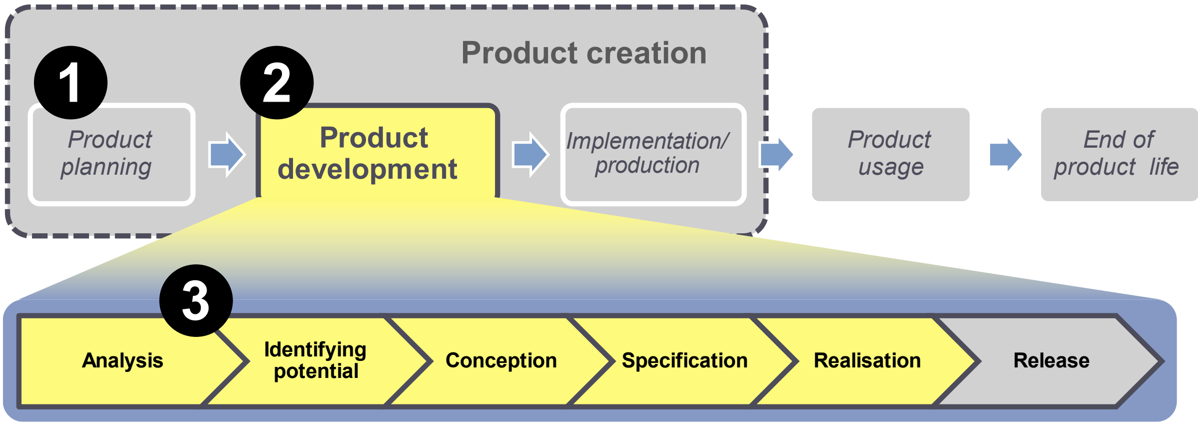


Figure 7: Phase model of the product development in the context of product creation

Thereby, the cooperation during the development process should be supported according to the situation. A more detailed elaboration of the phase model is carried out in *D5.3: First OSD Lab validation report* by a project-context-specific adaptation of the individual pilots of the clusters. A combination with an activity model in *D5.2: First release of prototyping improvement logic (PIL)* is also being sought. A possible goal of the pilot study is the development of a new product generation, which starts with the initiation of a project and ends with an evaluation of a product specification. This specification includes amongst others information concerning the applied technology and subsystems as well as their share of carryover and new development. The specification allows a valid evaluation of the planned product regarding relevant parameters such as manufacturability, necessary resources, and the technical and economic risk.

Insight for practice:

Within the context and time frame of the pilot study, the phase model represents a possible model for an OSD project. The aim of it is to provide a basis for comparison within the pilot study, to identify patterns, to work out heuristics and to provide recommendations and support for the development process. To summarise, the following working definitions will be used:

Product planning (inside or outside of the company) is the detailed description of a design request (i.e. challenge brief) depending on the project situation (e.g. pilot requirements, stakeholder, needs). A design request can thus have a large bandwidth and include ideas, wishes, visions and objectives, etc. as well as detailed applications and requirements regarding functions, characteristics or properties and interfaces of the product. This is necessary to align the makerspace and SME.

Product development is an interdisciplinary process, involving for example mechanical engineering, electronical engineering, and computer science, used to design a marketable product. The process is based on the definition of initial objectives and requirements (challenge brief) for the product which are constantly further improved and iteratively adjusted during the process. This can be supported by a user-centred approach or a design thinking mindset.

5.3 Stage 1: Product planning

For a successful product development and cooperation between makerspace, community, and SME, it is important to build the foundation to get the project off to the best start. The starting point for product development is frequently product planning inside or outside of the company, which results in a more or less detailed description of a design request depending on the project situation. A design request can thus have a large bandwidth and include ideas, wishes, visions and objectives, etc. as well as detailed applications and requirements regarding functions, characteristics or properties and interfaces of the product. In *D4.2: Final release of co-creation demonstrator framework* of OPEN_NEXT Stage 1 is described in more detail.

In addition to the requirements and checklists from *D4.1: First release of co-creation demonstrator framework*, it is important to develop a meaningful challenge brief and a project vision, so that the makers can also quickly gain an overview of the project. Good briefs drive great outcomes, hence based on the insights generated in stage 1, makerspaces should create one that truly tries to define the challenge area, sets the course, and frames the opportunity space. Additionally, it is important to align on a challenge definition as a team that excites, inspires, and ensures focus. If a challenge brief has strong foundations and is bought into by the team, then it is more likely that it will be referred to throughout the project. A good brief centralises thinking, maintains intent and helps keep everyone on track as participants may dip in and out of the project over time. It should be broad enough to spark new directions yet focused enough to help teams innovate. It is also important to ask the right question by centring on human need first, instead of starting with policy, business, product, or service goals. A challenge brief is responsive, not rigid. It is meant to provoke new thinking, invite contribution from various users, and create room to evolve. The challenge brief includes the following points:

- Title (Give the project a catchy title that arouses positive emotions and is easy to articulate.)
- Challenge claim: How might we...? (Set out an optimistic statement regarding what the outcome you hope to achieve is.)
- Why is this challenge important? How would you describe the problem you were solving for or the new opportunity you are looking to leverage and why it matters?
- Do you already have stated ambitions? If so, what are they?
- What research and resources do you already have? (Trends, bespoke research, etc.)
- What is the project plan? How will you achieve your goals in a given timeline?
- Who is involved? (Core, extended, leadership team, etc.)

5.4 Stage 2: Product development

"Ever tried. Ever failed. No matter. Try Again. Fail again. Fail better." – Samuel Beckett

Browning et al. describe product development as an *“endeavour process of multifunctional activities done between defining a technology or market opportunity and starting production“.* (Browning et al., 2006) Building on systems theory, the aim is to transform a system of objectives into a system of objects. (Albert Albers & Braun, 2011) As shown in Figure 8 (left), the initial system of objectives is created by product planning and, by means of activities in the different phases, synthesises the system of objects in which the realised results are available. Thereby the system of objectives includes all explicit objectives of a product to be developed, including their dependencies and boundary conditions. At the end of the development process the system of objectives corresponds to the product. The realised results are then analysed and help to further develop the system of objectives.

To adapt this general product development model for OSD, a number of adjustments must be made (see Figure 8, right). These include the contextual factors (e.g. cultural norms and values, number of persons involved, motivation, experience, leadership competence, knowledge of design methodology, openness towards new methods, IT tools, standards and support by management) that influence the activities in particular, as well as the process knowledge (e.g. renaming of activities and phases as well as prioritisation, parallelisation and iteration of activities) that is reflected in the description of the phases. In the following chapters, the focus is on the phases as a procedural model, which describes important elements of a sequence of actions for certain situations or objectives (Ponn & Lindemann, 2011).

Furthermore, the phase model is considered separately from the activity model. While the activity model contains activities, methods, and processes depending on the resources required, the phase model helps to assign them to one or more phases to place them in a chronological order. Thereby an activity consists of an action, an executing resource, a resource to be used and a time dependency. It is the smallest element of a process and can be carried out in parallel and occur repeatedly. Besides the macro activities of product development including product engineering activities such as *‘detect product profiles’* or *‘model principle solution and embodiment’* as well as basic activities like *‘manage knowledge’* or *‘manage changes’*, the activity model also includes micro activities of iterative (technical) problem solving. (Albert Albers, Reiss, Bursac, & Richter, 2016) An allocation of activities including situation- and demand-oriented recommendation of methods and tools, as it is e.g. presented in the InnoFox, does not take place within the scope of this work. (Albert Albers et al., 2015) The primary goal is to provide the makerspaces with an applicable basis for action based on the solutions to be developed. Within the methodology in *D5.2: First release of prototyping improvement logic (PIL)*, the interaction between activities, requirements, results, and methods will be considered.

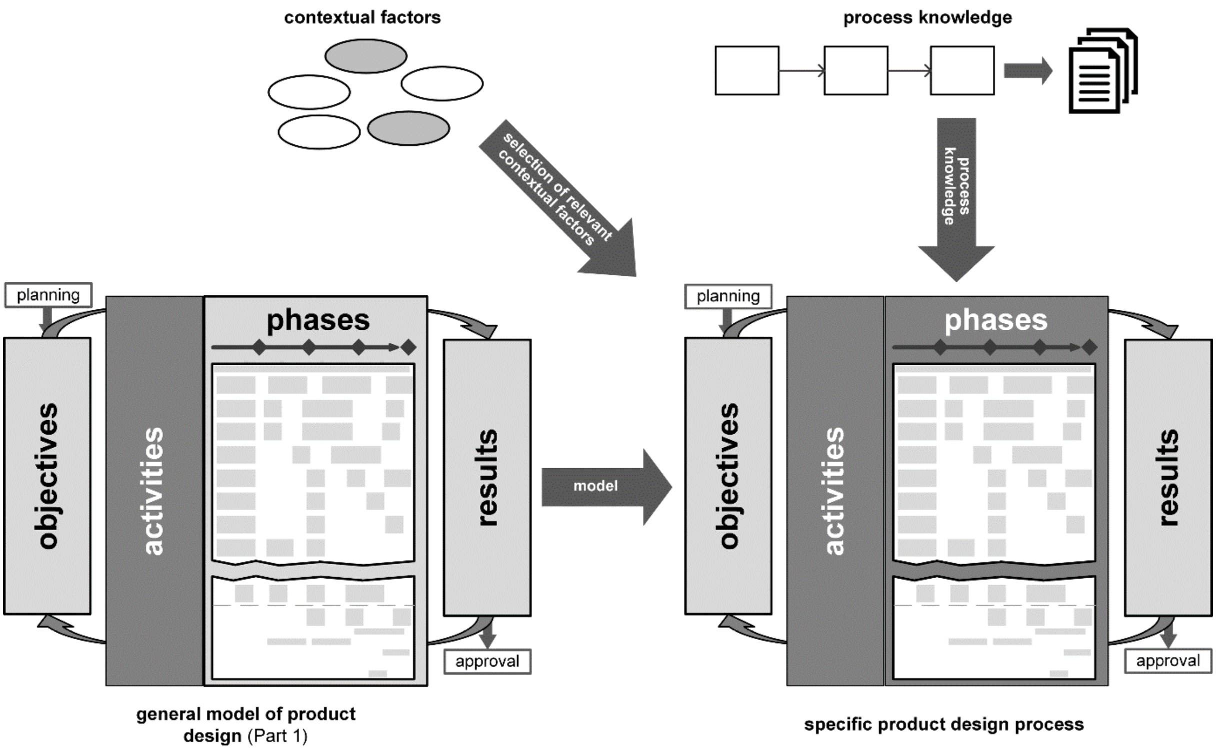


Figure 8: Synthesis of a specific product design process from the general model of product design (VDI 2221 Blatt 1, 2019)

As seen in Figure 9, the product development (see No. 1 in Figure 9) within OPEN_NEXT starts with a challenge brief in an extensive analysis and is completed when the developed solution represents a producible, marketable product. Thereby the development is divided into the phases *‘analysis’*, *‘identifying potential’*, *‘conception’*, *‘specification’*, *‘realisation’* and *‘release’* (No. 2). In order to apply and implement the phase model to the OPEN_NEXT context, each phase is opened with a kick-off event and concluded with a milestone, which requires a specific minimum readiness level of the presented solution to be able to move on to the next phase. Each phase is described in detail in the following chapters to guide and support the involved developers without overloading them with too much information at once. At the same time, they should enable the planning of the project by the makerspaces and reflect the expectations of the SMEs. The description of each phase contains the necessary input (No. 3), which should be available for the phase kick-off, a list of phase-specific materials (No. 4) like materials for training/workshops and the outcome (No. 5) generated at the end of the phase, which must be worked out for the milestone, e.g. in the form of deliverables, in order to advance to the next phase. In particular, the documentation of the development process, of design decisions and the justification of these decisions, which is necessary for OSH, should be ensured. With this existing and accessible information, new members of the community can better get involved in the ongoing development project.

To describe the process in more detail, each phase is divided into seven activities of problem solving (No. 6): Generation (I) and Concentration (II) of Situation Information, Generation (III) and Concentration (IV) of Solution Information, Generation (V) and Concentration (VI) of Decision Information as well as Best Practice Information (VII). Whereby step VII is performed after the phase milestone. In the context of product creation a problem is a task or an issue whose solution is not obvious and cannot be directly specified using familiar methods [adapted from (Ehrlenspiel & Meerkamm, 2017).

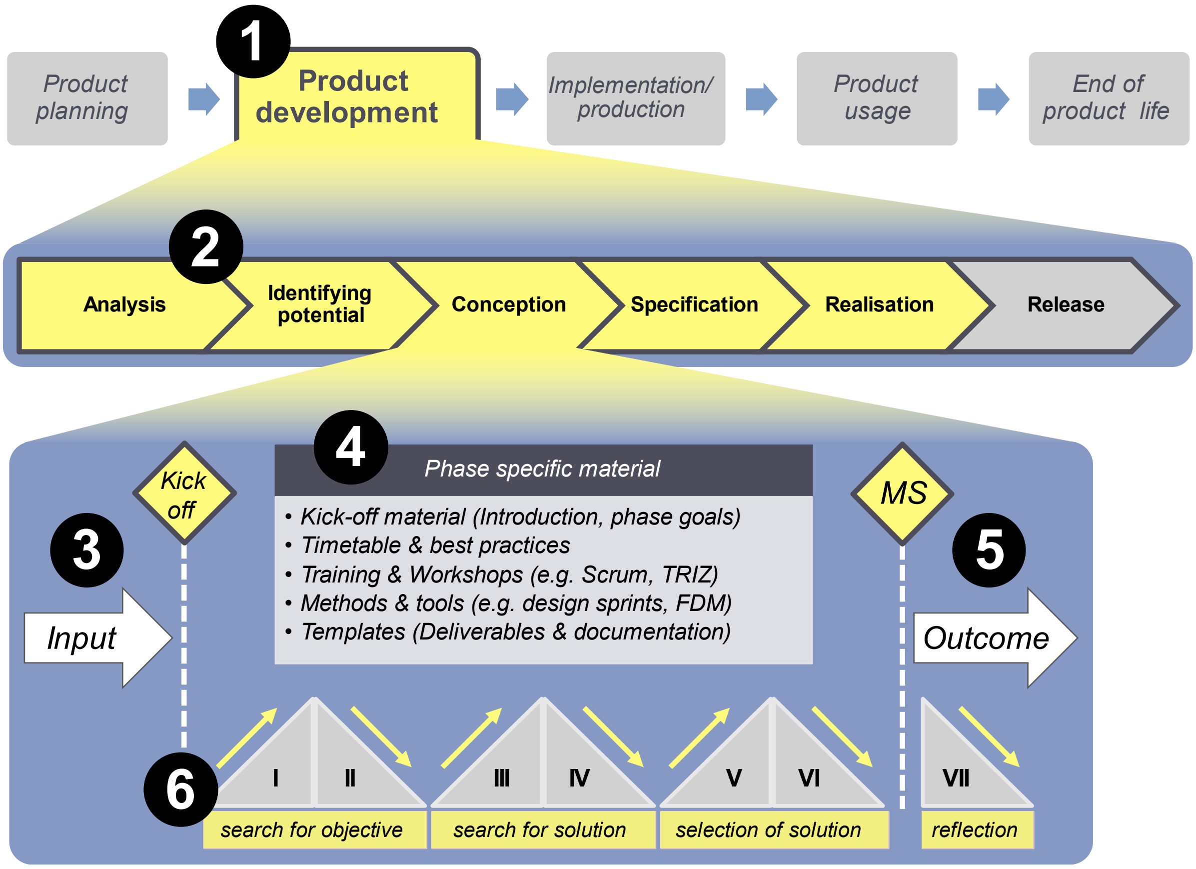


Figure 9: Structure of the phases in the context of product development

Basically, problem-solving processes often follow concepts which describe control cycles of our thoughts and activities. These activities can be shown in more detail by splitting them up into the activities listed in Table 14. Three important purposes of this are process planning, process navigation and process reflection. All activities are usually connected with follow-up effort and learning which allow the level of information to be constantly raised. This requires the documentation of all information collected or compiled. The constant reflection of the problem-solving process passed through allows experiences to be assessed and improvements to be realised. This permits reflection on the problem-solving process and, if necessary, adherence to knowledge for the purposes of future processes as well as the derivation of best practices (Albert Albers, 2002). The arrows in Figure 9 (No. 6) indicate that the activities do not always comply with a certain fixed sequence. Activities are often only displayed as following each other in a fixed sequence in order to display the basic connections more clearly. The iterations taking place in real-life problem-solving processes are usually only sketched in here.

Table 14: Steps of a general problem-solving process adapted from VDI 2221 (VDI 2221 Blatt 1, 2019) and the SPALTEN-methodology (Albert Albers, Reiss, Bursac, & Breitschuh, 2016)

Step	Description
I	*Analysis of the situation* – Every problem initially leads to a confrontation with more or less unknown factors that influence the solution of the problem. This confrontation depends on the level of knowledge and information available to the problem solver. It is often necessary or helpful to carry out an analysis that provides additional information about the initial problem itself and its focus, conditions and possible solutions. In the situation analysis all relevant information about the situation is collected, structured and documented. The information serves as a basis for the further problem-solving process.
II	*Problem containment and formulation of the objective* – The subsequent formulation and above all clarification of the problem to be solved or the desired final state facilitates the search for solutions, because it makes it possible to express the essential core of the problem and the requirements to be met in the language of the problem solver without insisting on specific solutions from the outset. Typical problem correlations should be identified. Furthermore, the variety of information should be specified.
III	*Synthesis of alternative solutions* – During the search for solutions, alternative solution concepts or even concrete solutions for the before described problem or parts of them are elaborated and combined. It is crucial here to develop or identify not just one solution, but alternative solutions too. For support different creativity methods can be applied. To cover the solution space complete and accurate, a high quantity in solutions should be aimed.
IV	*Analysis and selection of the solutions* – In a subsequent step, these alternative solutions are analysed with regard to their properties in order to obtain the information necessary for comparing previously generated solution alternatives and for selecting the right solution. The selection of the criteria is to be defined specifically according to the problem situation.
V	*Assessment and consequences analysis* – The characteristics of the alternative solutions are evaluated in relation to the objective to provide a basis for a final decision. In this process, risks and opportunities for the chosen solutions are also determined.
VI	*Decision and implementation* – This is followed by a decision in favour of one or more solutions suitable for further procedure, their implementation or iteration or the abandonment of the procedure. The aim of this activity is the transformation of the mental solutions into reality. With the conversion measure plans are generated and realised. The identified risk and chances are considered especially.
VII	*Reflexion and lessons learned* – The final step offers the chance to protect the resulted knowledge with lasting effect. The activity describes the reflection and the documentation of knowledge for future processes.

The composition of the problem-solving team is continuously reviewed between in the problem-solving-process and adapted to the specific requirements of the activities. Since the different activities also require different skills, the consideration of the problem-solving team plays a crucial role in this process. For example, creative people can make a valuable contribution to the activity of generating alternative solutions or additional experts are needed to support the core team. If these people evaluate their own ideas, an objective statement is rarely guaranteed.

In the course of the product development process, the degree of maturity of the system of objectives increases more and more and helps to approach a sufficiently documented, producible and marketable solution (see No. 1 Figure 10). The aim is to transfer all elements in the system of objectives into the system of objects (No. 2). It should be noted that the maturity level does not develop linearly within the phases and increases especially at milestones, as during these phases a focus is placed on the validation of selected ideas and concepts. During the development process the requirements should be documented because they are usually a central basis for communication when solutions are elaborated in parallel or in succession by several persons, departments or companies. Requirements are not just formulated and documented at the beginning of project design, but are constantly refined, derived and if necessary updated and changed again and again in varying degrees of detail. It is crucial to know, that requirements are not just formulated in terms of the product as a whole or its individual components and interfaces, but also with reference to the phases of the product lifecycle associated with the product and the development project itself.

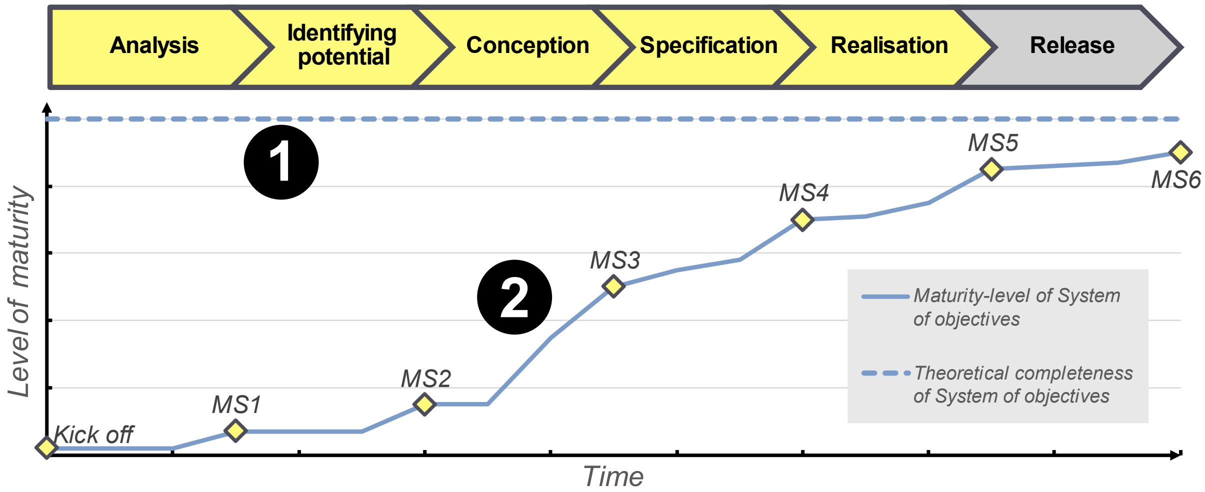


Figure 10: Expected increase in maturity of the System of objectives during the phases of OSD

An exemplary planning of the product development project for an overview within OPEN_NEXT is shown in Figure 11. The objective in terms of the pilots in OPEN_NEXT is to reach at least the 5th milestone at the end of the realisation phase. Especially in the phases *‘identifying potential’*, *‘conception’* and *‘specification’* the greatest added value for product development is expected to come from company-community collaboration. Of course, the presented planning is only one possibility to run an OSD project within the pilot study. Based on pilot-specific criteria (e.g. size of the community, product category, company strategy) the number of milestones can be adjusted.

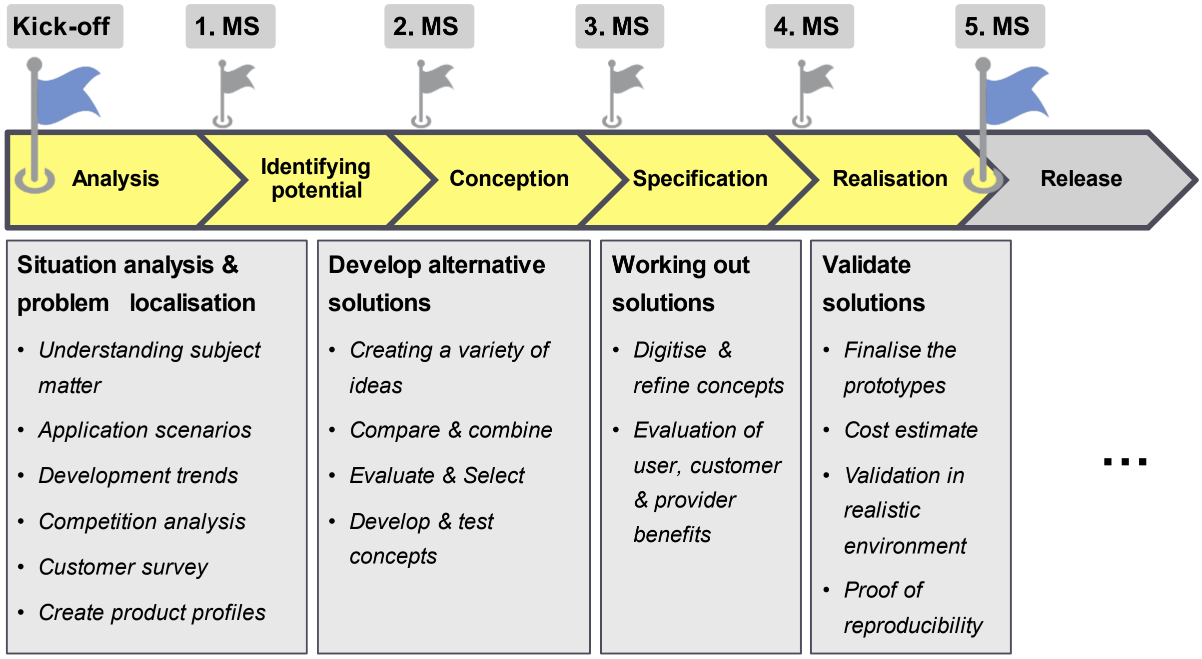


Figure 11: Proposal for the procedure of an OSD project in the context of the pilot study

To start the product development phase, the development project is opened with a project kick-off event, such as an open lab day. In the kick-off of the development project together with the partners of makerspace and SME as well as the makers, the following steps should be considered:

- Review the challenge brief and envision the impact outcomes together.
- Define your open source vision and share your values.
- Overview of the project schedule and structure
- Define what you think success looks like for yourself, the team and the organisation.
- Discuss team members strengths, and how team members can support each other.
- Share hopes, fears, and expectations.
- Understand work-life balance needs and who can be the team champion.
- Define the areas of learning and experimentation to push.
- Explain how to use the collaboration platform including access details.

5.4.1 Phase 1: Analysis

Digging deeper into your challenge area and gathering new perspectives

Once the project plan is set up and the partners have brought the right people together, it is time to get going. The first phase is about exploring the challenge further, considering what the partners already know, and what else they may need to discover. The team will now begin to dig deeper, and by delving into the detail and immersing themselves in the context they can uncover insights and see the challenge from new perspectives. A prespecified search field is examined based on a general definition of the task, necessary information on the relevant markets, technologies and future trends is analysed and knowledge stores are filled for subsequent phases.

Objectives

In the analysis phase, the developers first analyse the development context and collect data: through desk research, observations, user interviews, etc., in order to inform the next phase. The team should get an overview of the state of the art and identify the solution space. Of particular interest in this phase is the increase in knowledge regarding existing product generations which are fulfilling the customer’s needs at the moment, possible reference products and reference processes. To build a broad knowledge base for the subsequent development process the creation of robust and consistent future scenarios, the identification of existing and potential markets and an extensive examination of the competitive situation are important as well. This broad information analysis enables the development of a comprehensive collection of relevant information and enables an increase in the level of knowledge at the beginning of the development (see Figure 12). Thus, decisions made during the development process are based on a sound knowledge base.

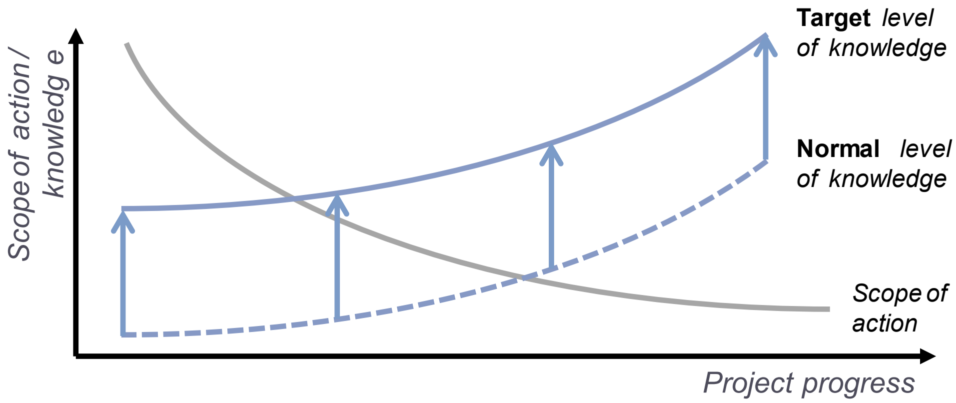


Figure 12: Early raising of the level of knowledge through targeted support adapted from (Grabowski, 1997)

Insight for practice:

In order to build up the knowledge base (e.g. Wiki), defined research fields are analysed, and adequate key questions are answered. Detailed, robust scenarios should be worked out as well. In addition to a list with one persona per possible stakeholder per research field as a future interview partner, a list of interview dates is also created as preparation.

In a continuous idea repository (CIR) all developed ideas are stored and extended over all phases. Even if the ideas cannot be implemented in the current project, they still provide valuable input for future projects of the SMEs.

5.4.2 Phase 2: Identifying potential

Identifying new insights and looking for new opportunities

In this phase, the task in hand is constantly further concretised. Once the research is completed, it is time to draw meaning from it all. With quantitative research, the data is normally numbers. With qualitative research, the data takes the form of stories which are used to increase the integration of the customer and the user group to allow an initial assessment of the innovatory potential to be made. From here on in, it is about using these to create new opportunities for solutions. Drawing out the value of stories is a disciplined process and the team need to allow time to do it well. The stories and views they have gathered during the research should remain at the focus of this phase. From the stories, the developers will start to spot patterns and themes. They begin to realise that the core needs of citizens and customers, say around healthcare delivery, are remarkably similar no matter their circumstances. From these themes, they can start to generate insights.

The stakeholder usually just stands for the needs of (groups of) persons or organisations, which have an interest of some kind in the product to be designed or are affected by it in some way. These can for example be customers, users, operators or owners, but also designers, manufacturers, sellers, suppliers, buyers, disposers, legislators or just viewers of a product. These all have very different requirements about the product and must be considered in the validation of the developed solution for a successful product creation. Validation is the continuous and systematic comparison of the accomplished objectives of the current situation with the planned state (objective). Only in validation, knowledge evolves, thus, sub-objectives and boundary conditions for the further controlled procedure are derived during the development process. (VDI 2221 Blatt 1, 2019) The validation of developed solutions and approaches is an activity that takes place continuously in all phases of the PDP with reference to the stakeholder.

Objectives

The aim of this phase is on the one hand to identify and characterise potential customers and stakeholders (compare with Figure 13) and to empathise with, for example, physical and mental limitations. Various methods (e.g. Persona method) support the developers in putting themselves in the position of customers and users. The team should spend time to deeply understand how they interact with products and services. This part consists of drawing out the experiences of the user into stories which can then be shared back to the team. On the other hand, the team has to synthesis its insights by taking the stories and use them to narrow down the design challenge. It also aims to investigate which products and solutions have been used to date.

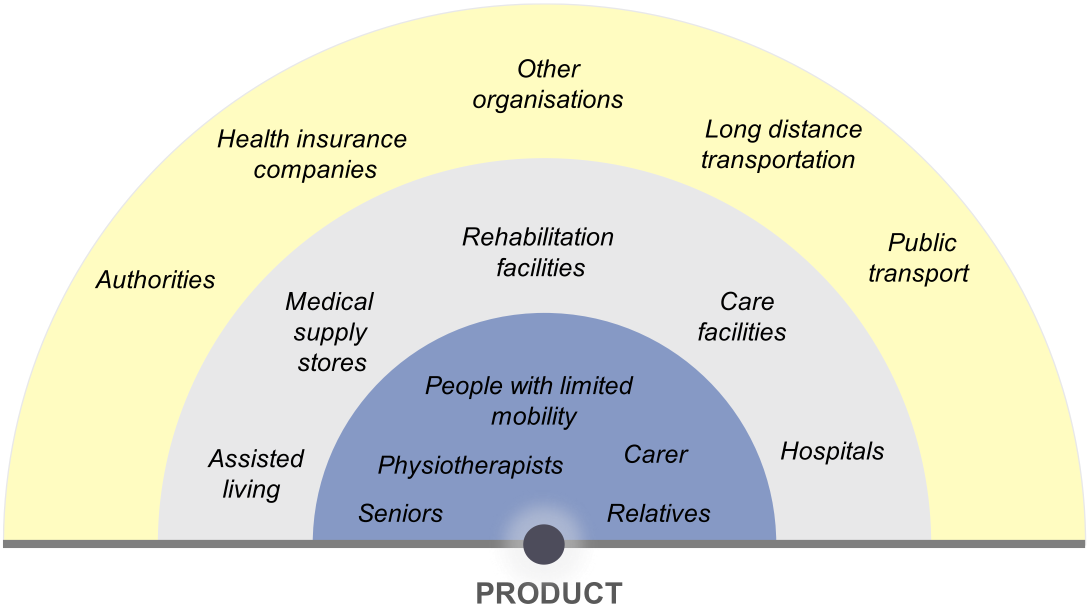


Figure 13: Possible stakeholders for solutions for mobility of elderly people

In this way product potentials can be uncovered, and benefits described. These benefits are modelled as bundles of benefits in product profiles and thus made accessible for continuous validation. In addition to market presence, the product profile plays an important role in turning the developed solution of a technical novelty (invention) into an innovation (see Figure 14). The concretisation of the system of objectives of a new PSS in the course of the development process is influenced by internal impacts and external impulses (e.g. markets, experts, competitors).

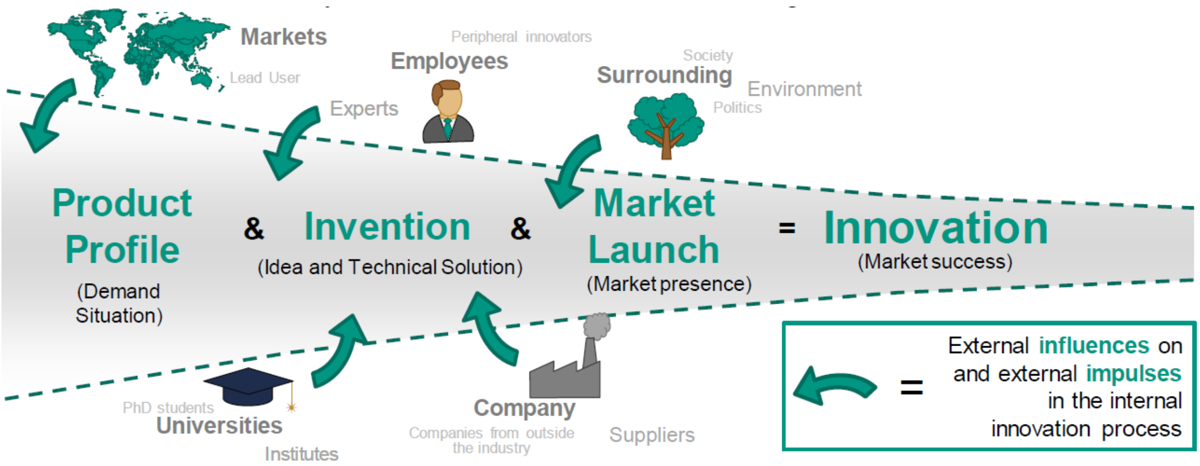


Figure 14: The elements of an innovation (Albert Albers et al., 2018)

Product profiles can be created at different system levels, while other subsystems of the mechatronic system can be transferred to the next product generation in the sense of product generation engineering (PGE) (A. Albers, Bursac, & Rapp, 2016). Initially generated ideas to solve the design challenge are stored in the continuous idea pool. A product profiles as seen in Figure 15:

- defines a demand situation in the market,
- characterises the future product in its main properties,
- emphasises the relevant use cases,
- considers the customer, user and provider benefits,
- shows the opportunities and risks and
- includes the boundary conditions.

From this point on a continuous validation of the created solution takes place. Thereby validation means to check as to whether the test results really show what is to be determined by the test. E.g. in terms of technical systems, this is the check as to whether the product is suitable for its purpose or achieves the desired value. The expectations of the technical expert and the user are taken into account here. Put simply, validation answers the question: *“Is the correct product being designed?“*. In contrast to that, verification means the evidence of the truth of statements. In terms of technical systems, this is the check as to whether an implementation corresponds with the specification. Put simply, verification answers the question: *“Is the product being designed correctly?“* (Albert Albers, Behrendt, Klingler, et al., 2016).

Insight for practice:

Based on several conducted stakeholder interviews and various creativity methods (e. g. 6-3-5, stimulus picture) the selected personas are sharpened, and a series of product profiles are elaborated, similar to the steps *‘Empathise’* and *‘Define’* of the design thinking mindset. The created profiles are ranked by the community and the best ones are evaluated using e.g. the Sounding board method. A storyboard or video could be created for the use case of the favourite profile to create a better understanding for the customer or stakeholder.

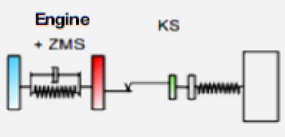
To familiarise the community members with the project, at least one workshop or field trip to the SME partner should be undertaken. Additionally, Lab and Teambuilding events should be considered.

Product Profile Claim

*We need a **system** that makes the **rotational irregularities** caused by the engine at low speed (1000-2800 rpm) in the powertrain from the **perspective of NVH** - with a **focus on transmission and body noise reduction** - **manageable**, making the product with the new combustion engines acceptable for the market.*

Initial Product Description

- **Integration** of the **engine flywheel** into the **design space** of the **clutch system**
- **Split** into two **rotational inertias** to change the **vibration system**
- No increase in the **shifting forces**
- No increase in **total inertia**
- **Service life** ≥ Engine operating life
- Fitting in previously given **design space**
- ...



Reference Products

- Engine flywheel
- Torsional dampers of KS
- ...

Use Case

- The higher rotational irregularities of newer engines and the trend to low engine speed operation to reduce fuel consumption lead to noise and vibration in the vehicle that will result in customer complaints and make these new vehicle solutions unsalable
- ...

Provider Benefit

- First to Market
- New product with excitement attributes for the customer (vehicle OEM) as it enables new potentials (efficient engines, low fuel consumption) in the vehicle
- High efficiency → new pricing
- ...

Customer Benefit

- Vibration reduction allows the use of new engines with better efficiencies and better performance
- Function integration in the given designspace, so that no major changes in the powertrains must be done
- Big development problem of the systems (new vehicle generations) is solved
- ...

User Benefit

- New vehicle solutions with improved engine, low fuel consumption, high fuel economy and improved driving pleasure
- Noise/vibration reduction
- Comfort
- ...

Competitive Context

- Torsion damper at their performance limit
- Competitive products can not fulfill the function
- ...

Demand

- New **engines** with higher **power density** and **low fuel consumption** should be realized in order to increase **please in driving** through even more agile vehicles while at the same time reducing fuel consumption
- Vehicles with diesel engines (average size: 1.6 ... 2.4 l displacement) should be introduced into new vehicle segments in order to realize fuel savings as customer benefit
- ...

Validation of the ... through

- Customer profile through market analysis and customer survey
- Construction of prototype vehicles and comparison through NVH assessment to ensure key advantage
- ...

Boundary Conditions / Framework

- Installation of the new clutch system must be possible in the defined, existing design spaces of the transmission bell housing between the engine and the gearbox
- Shifting forces and shift quality as well as starting quality and starting performance must not be impaired
- No negative effects on powertrain performance (acceleration, hill climbing ability, load capacity, ...)
- ...

Figure 15: Example of a product profile scheme by ALBERS et al. (Albert Albers et al., 2018)

5.4.3 Phase 3: Conception

Turning your idea into something tangible you can experiment with.

Once the initial needs analysis has been completed, the demand situation described and the product profile with its customer, user and provider benefits has been sharpened with relevant use cases, the first step is to generate product ideas and test them through prototyping. This is the moment where the developers move from problem to solution. It is above all a matter of finding basic (technical) solution principles for the product profiles and using creativity, inventiveness and unconventional thinking to refine the generated ideas. There is enormous value in making ideas more tangible by using visuals when doing this. This step includes the requirement analysis of customer and user behaviour, the description and function of (sub-) systems and components as well as technical specifications and solution principles as fundamental implementation of a function or of several linked functions executed by selecting effects or effective principles which includes the physical effect used as well as geometrical and material characteristics like effective geometry, effective movement and material (Albert Albers, Reiss, Bursac, & Richter, 2016; Kennedy, 2008).

At this point in time, five different people could have just as many proposed solutions for the conceptual implementation of a product idea in mind. Examples of this readiness level include drawings, paper prototypes, texts, mock-ups, videos, animations and concepts for use cases.

> *"A prototype is an artifact that […] is an approximation of the final product. A prototype therefore has a lot in common with an unfinished product, but with the difference that a prototype was created for a specific purpose and can therefore also be created from other materials or with a different technology. Depending on the material, the prototype can be touchable (e.g. made of paper) or experienceable (e.g. a video).“ (Kohler et al., 2013)*

There are many different elements that can be prototyped, from a physical product through to a service experience. Prototyping can be carried out at different levels, and the team will move through different tools and methods as their concept progresses. By the time the prototyping process is completed, the solution should be at a much more robust phase for planning its implementation.

Figure 16: Example of prototype made of simplest materials and validation by role play (Stinelin.Wordpress.Com, 2011)

In contrast to product ideas, concept development describes the solution space more precisely by combining solution principles and focusing on details. Ideas on paper can be interesting but bringing those ideas to life and testing them can be invaluable. By bundling the ideas and turn them into a concept helps to further concretise solution principles, before sharing them with the people that the developers have learned from and getting their feedback. It is necessary to move from a handful of ideas and insights into a fully-fledged concept including the embodiment modelling – one that the team will refine and push forward to assess the technical and economic feasibility. For this purpose, first physical prototypes are created, and simulation are carried out, which, in addition to validation, also serve as a basis for discussions in the team and for the documentation of decision paths. More and more iterations should be used to test it more broadly internally and especially with citizens. This gives the team the opportunity to learn about what works and what does not, so that it can adjust and improve the solution before actually implement it.

During the conception phase, it is possible to carry out different design sprints for the elaboration and testing of ideas as well as the prototypical implementation of concepts and their evaluation. In *D5.2: First release of prototyping improvement logic (PIL)*, these design sprints and different types of iterations are examined and work out more closely.

Objectives

In the concept phase, the solution concepts selected and the associated structural designs (systems architectures) are concretised, modularised, and then integrated into the product as a whole. In addition to design and validation, the production of the prototypes for this phase and the subsequent one is already planned here. The prototype that is created after this phase already integrates the basic functions but has a limited functional scope. Using the *‘X in the loop approach’* for instance, additional functions can be simulated, which gives the customer the feeling that the product is already final when it is validated at the milestone (Geier et al., 2009). However, only the implemented functionality is validated. Further subsystems can, for example, support validation in the sense of PGE – product generation engineering based on existing product generations or reference products.

To successfully complete the milestone of the conception phase, the early prototype should be tested with a small group of users (friends or colleagues) and device/system is demonstrated to be functional in workshop setting, which means it is proven to repeatedly work when used for a few hours. In addition to that the identification of potentials through implementation of the idea (numbers!) must be available as well as the detailing of price segment and quantity, the outlook on technical realisation of the final prototypes and the assessment of the technical/economic feasibility.

Insight for practice:

At the end of the conception phase, a more refined product profile and physical prototypes of several concepts are presented, information material for community evaluation (e. g. poster). In addition, ideas are stored in the CIS, various technical workshops (3D printer, laser cutter, etc.), method workshops (TRIZ, Wizard-of-Oz, Poka Yoke) and at multiple design sprints, which include testing and validating with users, are accomplished. These activities are similar to the steps *‘Ideate’*, *‘Prototype’* and *‘Test’* of the design thinking mindset.

To be better prepared for the next phase, a resource/cost plan for the next prototype iterations should be developed.

5.4.4 Phase 4: Specification

Convert solution variants into concrete products.

The knowledge gained through the phases and at the milestones flows continuously into further development in the subsequent phases *‘specification’*, *‘realisation’*, and *‘release’*. These phases are analogous to the conception phase with the aim of continuously increasing the maturity of the prototype as well as the consistent safeguarding of the prototype with increasing functionality towards customers and users. In this way, objectives and requirements of potential series design projects are further concretised and the innovatory potential is assessed once more. For this purpose, solution variants are converted into concrete products, computer-aided simulation for validation on the model and tests with functional prototypes are carried out.

Objectives

The readiness level is increased in this phase by producing a more detailed prototype and then validated while taking customer and user integration into account. Thereby the technology (and form factor if relevant) has been tested and validated in a simulated relevant environment with a small group of users demonstrating functionality in the field and fulfilling a need for the target user group. This means an improved prototype is tested with a group of users in the field relevant for the project. E.g. an interactive garment prototype for elderly people is tested with five elderly people for three days in their everyday environment.

Insight for practice:

With the help of further design sprints, several solution variants of the individual modules of the product are worked out with CAD tools, assessed by e.g. failure mode and effects analysis (FMEA) and evaluated. Especially in this and the following phases, makerspace has to discuss whether the required resources are available with a focus on the available, sometimes very specific, technologies and the relevant knowledge.

5.4.5 Phase 5: Realisation

Getting ready to launch your idea in the real world.

This phase is perhaps the most critical of the project. Preparing the prototype for implementation in the real usage context can be a challenging task because additional influencing factors occur, which may not have been considered relevant in the simulation and which also influence user behaviour, for example. This results in further important insights into the socio-technical system of the developed solution.

Even more important it is to be able to clearly articulate the developed solution concept and demonstrate its viability and value. Therefore, the team needs to make sure it has the right people and skills in place. This will help to win over new supporters who can potentially help to leverage any further funding or resources needed to get the solution off the ground. Furthermore, there is a need to plan what the team want to measure and be clear about how they intend to demonstrate impact. Getting a measurement and evaluation framework in place early to capture critical insights will allow to iterate and make changes more easily.

Objectives

In this phase the maturity of the solution is extended in two steps. At first the technology has been demonstrated in with a group of target users in the field/environment relevant for the project validating its efficacy in real situation. At this phase, the further improved prototype will be representative of the final form factor. E.g. an interactive garment prototype for elderly people is tested with five elderly people for three days in their everyday environment. Users confirm they like it and it does what it is supposed to do.

The next level is reached when the system prototype is demonstrated in a relevant operational environment. For this purpose, the technology is now integrated into prototype, is functional and tested in environment with the target users validating functionality and usefulness. In addition to this the technology and design are produced with intended production method and are reproducible.

Figure 17: Different development stages on the example of the FDM printer Sigma R17 by BCN3D Technologies (BCN3D Sigma, the Evolution of Our Flagship, 2016)

Insight for practice:

On completion of this phase, the minimum objective of the pilot study will be achieved. For this purpose, an improved prototype is implemented in the complete system (e. g. a sensor technology in a car), validated in the realistic environment, is presented. In addition, proof of reproducibility should be provided.

In particular, great importance is attached to the documentation of the insights from the user tests in the real context as well as the completion of the technical documentation.

5.4.6 Phase 6: Release

Document your success and spread the news.

The final phase of product development is the release phase which ends with the prototype ready to go into production. This phase describes the transition to the area *‘implementation/production’* which completes the product creation. Within this phase the prototype passes through the technical readiness level *‘System complete and qualified’*. For this purpose, the prototype is further iterated until it is completed, stable, validated and documented.

Objectives

The aim of this final phase of product development is it to have the actual system proven in operational environment, which means that the prototype is complete, documented, and ready for manufacture. At this point the prototype is reproducible, fully tested, and ready for the implementation/production.

6 Pilot specification list

Combining the socio-technical design elements (see chapter 4) with the requirements of the phase model (see chapter 5) we decided to provide a list with questions supporting the ongoing specification of pilots. This collection is included in the Annex and meant as a short and concise reference to possible product and process design areas, i.e. questions that need to be decided or made transparent during the company-community collaboration.

The questions in Annex are grouped chronological:

1) Specify your goal
2) Specify your strategy
3) Specify your evaluation plan

All questions have multiple or single choice options. Since the questions aim to capture the objectives and strategic orientations of the OS development, the questions shall be answered either collaboratively or by each partner and discussed during a later exchange and further discussion.

7 Summary

One of the overall objectives of OPEN_NEXT is to explore community-company collaboration processes. In order to do so, this deliverable provides an overview of the knowledge already available within the pilots as well as areas where questions exist, and future design activities are needed to test the suitability of possible answers.

The deliverable included responses of six paired interviews, with each interview taking about one hour. Findings have been presented under four headings: social, technical and business perspectives as well as the involvement of citizens. Each section of findings was summarised with key points, which can serve as orientation points when planning maker-company community collaboration. A notable concern was the lack of easily accessible, proven business models around OS, where SMEs and maker communities could benefit in fair ways, sharing risks and benefits of OSH related product development.

This notion was then frequently countered by widening the discussion around value propositions which went beyond adding to the financial bottom line. It is clear that in this space the pilot projects, which are about to start by autumn 2020, will have a learning journey leading to a widened perception of how communities can be integrated in meaningful ways.

Based on the desk research and the findings of the analysis, we introduced the phase model which has the critical function of establishing a timeline including milestones, so that pilots can track themselves whether they are where they should be or not. This part introduced a clear separation of *'product planning'* and *'product development'* both being part of the product life cycle. The product development was then broken done into six phases: analysis, identifying potential, conception, specification, realisation and release. Since each of the phases has clear outcomes, such as a wiki knowledge base, personas or product profile, the pilots have a more structured field for collaborating. Eventually observing and documenting this variety of collaboration processes will enable us to generate the *'best practices'* needed for a more widespread uptake of maker-company collaboration.

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Annex

A1 Interview guide

Introduction

- Establish time needed: The interview is planned to take not more than 90 min.
- Ask for consent and reference the consent sheet which needs to be signed so that we can use interviewees’ answers.
- Clarify the purpose of the interview: Collection of cross-case information around (1) social, (2) technological, (3) business and (4) citizen-driven innovations.
- Clarify role of interviewer: Interviewer is not to judge the answers, can explain questions, is not to share own opinion.

Interview Process

Unless stated otherwise, each question is directed to one interviewee first and followed up by the second interviewee, who can then answer in light of the previous statements, e.g. agree, correct, extend etc. There are 18 questions in total and each question includes two to four prompts, in order to guide the semi-structured format of the interview.

(1) The social perspective

(mapping communication modes, socio-cultural motivations, interests, and values to gain a deeper understanding of the impact of social aspects on OS collaboration in makerspaces and SMEs, with an additional focus on gender disparities /SP)

1. Did you collaborate with external partners, e.g. makers / companies respectively?
    a. Mention one example
    b. Learn about local tradition in collaboration / best practice
    c. If no, do you know of any best practice examples from somewhere else?
2. What are motivational factors to take part in this project?
    a. Enumerating a list is OK, for time reasons
    b. What could be your drivers to collaborate?
    c. For example:
        i. Company: Money, fresh ideas,
        ii. Maker: Skills enhancement, spontaneous jobs, novel community
3. In what ways could collaboration (as described above) influence you or your institution?
    a. Prestige for makerspace, individual decision to feed it back to the makerspace
    b. Maybe change equipment or process knowledge in makerspace / raise awareness
    c. Be prepared that some questions are difficult to answer, proceed to next one
4. Big picture question: How could collaborations between makers and companies impact the way we produce and consume? (socio-cultural)
    a. Is OS a viable foundation in your opinion?
    b. Are there limits to open sourcing, why or why not? (e.g. recovering R&D costs)
    c. Recap OS https://en.wikipedia.org/wiki/The_Open_Source_Definition
        i. Free redistribution
        ii. Source code / open designs
        iii. Derived works are allowed
        iv. Must not discriminate against specific people / areas of application / other types of licences that are bundled with the same product
    d. Enable cross-comments between makers and SMEs

5. Are possibilities and experiences in maker-company collaboration influenced by participants gender (gender imbalance)?
    a. Where can we notice these imbalances?
    b. Anything we could change here?

(2) The technological / infrastructure perspective

(mapping existing processes and know-how with regard to technological readiness, identifying necessary infrastructural elements for successful C3 and receiving best practices from both target groups /TP)

1. Overall picture of company and makerspace
    a. Age
    b. Growth
    c. Current phase: opening a market, incumbent, phase out / transition
2. Any numbers describing the organisation (URLs are fine)
    a. Members / employees / freelancers
    b. number of units (company) / number of machines (makers)
    c. Number of products brought to market
3. Forecast
    a. Expected future development (growth / decline)
    b. Any regulations that might have an impact in the future?
4. What are the phases for product and service development in your institution?
    a. Create common ground
    b. Only for relevant projects in OPEN_NEXT: Analyse, Identifying Potential, Concept building, Specification, Realisation, Release (not whole car, maybe rear mirror)
5. Where do you see most opportunities for C3?
    a. Speculative answers are allowed
        i. Exploration (finding ideas)
        ii. Evaluation (idea evaluation, user acceptance)
        iii. Demonstration (feasibility of ideas, concepts, functions ...)
        iv. Evolution (variants, generations)
6. What technical know-how is the core of your collaboration?
    a. Consider Triangle: Company <> Makerspace <> Sum of Maker skills (Makers)
7. What infrastructural support would you use for the collaboration?
    a. Rooms, software, platforms, meetings, surveys, test benches (product approvals)
    b. Which interfaces are there within C3?

(3) The business perspective

(mapping and diagnosing the business drivers and innovation potential of both target groups with regard to economic incentives, skills, capacities, and expectations in engaging in OSD projects /BP)

1. How would you describe your business strategy / access to market?
    a. Niche, cost vs quality, first to market, online / virtual strategy (mechatronic)
2. What social and financial returns do you envision?
3. Could you imagine managing a joint innovation? If yes, how?
    a. IP management?
    b. shared risks and shared gains

(4) The citizen-centred innovation perspective

(mapping citizen-centred innovation practices /CCP)

1. How does your organisation involve citizens in innovation processes or development processes?
    a. Market research (design approval, sampling) <> citizen involvement (e.g. design thinking: empathise, define, ideate, prototype, test)?
2. Is the engagement of citizens a rather easy process, if so why? If not, please name barriers for the engagement of citizens.
3. How influential is the involvement of citizens in production/decisions and processes?

A2 Questions to specify your pilot

The following questions will support the pilots to specify their goals, define your strategy and identify the gateways and barriers to your end-product. Thus the questionnaire will help you once you have identified your idea and necessary partners for an OS product. We recommend to clarify and exchange the answers with your collaboration partners and discuss with them in more detail or even try to fill them out together. By doing so, it will reveal motivation, understanding and expectations from each partner and will help to specify a strategy.

Hence the following questions serve as a guide to plan the collaboration in tangible ways. There are three specification areas:

1) Specify your goal
2) Specify your strategy
3) Specify your evaluation plan

All questions have multiple or single choice options. Since the questions aim to capture the objectives and strategic orientations of the OS development, the questions shall be answered either collaboratively or by each partner by him/herself for a later exchange and further discussion.

A1.1 Specify your GOAL

1. Name of your institution(s).
2. Give your project / pilot a name.
3. Describe in 5 sentences your project idea and the challenge you are tackling.
4. What goal(s) are you aiming for? (multiple answers possible)
    a. Boosting my business
    b. Contributing to sustainability
    c. Contributing to OSH development
    d. Helping others to benefit from my knowledge
    e. Learning myself
    f. Boosting innovation process of my company
    g. Helping others to establish a sustainable company
    h. Solving a societal issue
    i. Receiving financial benefit
    j. Contributing to local production
    k. Others
5. What is your timeframe for completing the OSH product development?
    a. Less than 3 months
    b. Less than 6 months
    c. Less than 1 year
    d. More than 1 year
6. The intended main beneficiaries are (multiple answers possible)
    a. General public – useful for anybody
    b. Specific users – useful for citizens with specific needs (specify which needs)
    c. Business – useful for other business partners
    d. Specific Communities (environmental, …)
    e. Other …. Who?

7. How much time would you need to invest per week (on average)?
    a. Less than 2 h
    b. More than 2 h
    c. More than 5h
    d. More than 10 h
    e. More than 20 h
8. How much time would others (e.g. your partners in the collaboration) need to invest per week (on average)?
    a. Less than 2 h
    b. More than 2 h
    c. More than 5h
    d. More than 10 h
    e. More than 20 h

A1.2 Specify a STRATEGY for your development

1. Whom are you going to involve? (multiple answers)
    a. Makers
    b. SME's
    c. Industry
    d. Universities and/or students
    e. Citizens
    f. Municipalities
    g. Policy makers
    h. Participants with specific knowledge like…
    i. Consultancies, agencies, or enablers such as…
    j. Ecosystems like…
    k. Others
2. In your opinion, what enables good collaboration most? (Select your top five conditions)
    a. Trust
    b. Similar values
    c. Similar business culture
    d. Ability to compromise
    e. Good communication (open, regularly, timely, …)
    f. Similar ideas
    g. Expert knowledge
    h. Dedication to the project
    i. Enthusiasm
    j. Inventive attitude
    k. Creativity
    l. Openness
    m. Entrepreneurial thinking
    n. Others

3. How do you plan to motivate new contributors to join your OSH development project? (select your top five) For example by offering…
    a. Learning opportunities from others – skill enhancement
    b. Financial rewards
    c. An active role in improving sustainability of production
    d. An active role in addressing a societal need (e.g. affordable care, learning or mobility)
    e. Being part of a (new) community
    f. Tinkering with new technology
    g. Contribution to local development and local production
    h. An opportunity to boost the image of someone’s company
    i. An opportunity to jointly innovate processes within someone’s company
    j. Access to other target groups
    k. Access to tools and (physical) workspace
    l. Growth opportunities and jobs created in the long run
    m. Contribution to a societal problem solution
    n. Other incentives
4. Why open? What contributions do you expect from the OS collaboration?
    a. To develop faster
    b. To lower costs
    c. To attract new employees
    d. To build new features
    e. To create new content
    f. To detect bugs
    g. To enable translation and reach new audience
    h. To scale-up
    i. Others
5. What learnings do you expect during the OS hardware pilot?
    a. Expert knowledge concerning OS development
    b. Working in OS development teams
    c. Learning on citizen-centred innovation processes
    d. Learning on how to involve citizens beyond user testing
    e. Learning on how to do a start-up
    f. Others
6. What information do you plan to share with others?
    a. OS compatible licence
    b. Design files
    c. Bill of materials
    d. Assembly instructions
    e. Editable file formats
    f. Others
7. What insights should you share with others?
    a. Data
    b. Education (knowledge)
    c. Branding
    d. (working) space
    e. Ownership
    f. Governance
    g. Other

8. What are the appropriate channels to collaborate and share your knowledge?
    a. Specific tools like…
    b. Social media
    c. Forum
    d. Wiki
    e. Regular physical meeting
    f. Workshops
    g. Chats
    h. Virtual meetings
    i. Voting platforms
    j. Media like Newspaper, TV, Radio
    k. Scientific publications
    l. Expert group meetings
    m. Conferences
    n. Non
    o. Others
9. How can you make money?
    a. Software as a Service
    b. Advertisement
    c. Marketplace
    d. Own Currency (e.g. Crypto)
    e. Training and manuals
    f. Selling physical product or add-ons
    g. Selling a service
    h. Selling customisation
    i. Events
    j. Others
10. What restrictions (legal, technical, safety and security, ...) do you face?
    a. I/we have identified existing restrictions and found already solution.
    b. I/we have restrictions, but until now no solution for it.
    c. I/we have no restrictions.
    d. I/we have not done yet any inquiry what restrictions we will face.
11. We will include citizens…
    a. when setting the focus of the project
    b. when defining the issue or problem
    c. when defining the necessary steps for the product development
    d. when testing reasons to adapt the product
    e. not at all, because…
12. A highly diverse team (i.e. gender, age, background, culture) will be…
    a. very beneficial for the development
    b. beneficial
    c. somehow beneficial
    d. not necessarily beneficial
    e. not at all beneficial, because…

A1.3 Specify your EVALUATION PLAN

1. When will you evaluate your efforts?
    a. After one month
    b. Right after the first stage
    c. Once the prototype is ready
    d. At the end of the project
    e. At the end of each phase
    f. Not at all
2. How do you ensure the quality of your product?
    a. Employees from my company
    b. The community
    c. External experts
    d. Citizens/ specific target groups will test the product
    e. Other
    f. Not at all
3. What evaluation methods will you use?
    a. User testing
    b. Expertise from outside
    c. Testing by colleagues
    d. Tested by the OS community
    e. Non
    f. Others