MAKER NETWORKS AND REDISTRIBUTED MANUFACTURING MODELS

David Campos da Silva Gomes

Dissertação de Mestrado apresentada ao Programa de Pós-graduação em Engenharia de Produção, COPPE, da Universidade Federal do Rio de Janeiro, como parte dos requisitos necessários à obtenção do título de Mestre em Engenharia de Produção.

Orientadora: Carla Martins Cipolla

Rio de Janeiro

Fevereiro de 2024

MAKER NETWORKS AND REDISTRIBUTED MANUFACTURING MODELS

David Campos da Silva Gomes

DISSERTAÇÃO SUBMETIDA AO CORPO DOCENTE DO INSTITUTO ALBERTO LUIZ COIMBRA DE PÓS-GRADUAÇÃO E PESQUISA DE ENGENHARIA DA UNIVERSIDADE FEDERAL DO RIO DE JANEIRO COMO PARTE DOS REQUISITOS NECESSÁRIOS PARA A OBTENÇÃO DO GRAU DE MESTRE EM CIÊNCIAS EM ENGENHARIA DE PRODUÇÃO.

Orientadora: Carla Martins Cipolla

Aprovada por: Profª. Carla Martins Cipolla
Prof. Francisco José de Castro Moura Duarte
Prof. Jorge Roberto Lopes dos Santos

RIO DE JANEIRO, RJ – BRASIL

FEVEREIRO DE 2024

Gomes, David Campos da Silva

Maker Networks and Redistributed Manufacturing Models/David Campos da Silva Gomes. – Rio de Janeiro: UFRJ/COPPE, 2024.

XVI, 180 p.: il.; 29,7 cm.

Orientadora: Carla Martins Cipolla

Dissertação (mestrado) – UFRJ/COPPE/Programa de Engenharia de Produção, 2024.

Referências Bibliográficas: p. 153 – 180.

1. Maker Networks. 2. Redistributed Manufacturing. 3. Design Propositions. I. Cipolla, Carla Martins. II. Universidade Federal do Rio de Janeiro, COPPE, Programa de Engenharia de Produção. III. Título.

DEDICATÓRIA

Dedico esse trabalho à minha mãe e meu pai, minha companheira e meus amigos.

Minha mãe, Terezinha Campos, Professora de Edificações, Arquiteta e Técnica de Construção Civil, sempre me deu suporte emocional, material e motivacional desde que nasci, me aconselha e compreende, me cobra foco e lembra de meu potencial.

Meu pai, Rubens Jorge, falecido aos meus 22 anos, infelizmente não viu eu me formar Engenheiro. Felizmente já havia contribuído com meu gosto pelo conhecimento científico desde pequeno e sempre me incentivou sobre a possibilidade da carreira acadêmica. Economista e Técnico em Química, era com ele que fazia experimentos desde criança, fosse com kits em casa ou em exposições de divulgação científica que me levava na Universidade Estadual do Rio de Janeiro, Casa da Ciência da Universidade Federal do Rio de Janeiro, Observatório Nacional e Planetário da Gávea.

Os dois são fundamentais na jornada que fiz até aqui, principalmente tendo pavimentado os primeiros quilômetros da caminhada.

Minha companheira, Thaysa Pereira, que já há mais de um ano vem dividindo a vida comigo, me incentivando e motivando na dedicação ao mestrado, com muito carinho e apoio em todos os momentos.

Meus amigos, família que pude escolher, que sempre fizeram exatamente esse papel, todos irmãos e irmãs nessa caminhada. Caren Freitas, Eder Oliveira, Elisson Saldanha, Flávio Muniz, Gabriela Ribeiro, Ícaro Rossignoli, Lilian Gomes, Marcio Lauria, Morgana Romão, Nayara Vicente, Poema Eurístenes, Tássio Farias.

A maioria de meus amigos também integram a carreira acadêmica em suas vidas. A esses agradeço em especial pelos conselhos e por me lembrarem até na hora do boteco que tinha um mestrado pra terminar.

Falando em carreira acadêmica, a jornada de formação de um pesquisador pela qual eu estou passando tem desafios que não consigo comparar com nenhum outro campo da ação humana no mundo. Basicamente a ideia é orientar alguém, que teoricamente já sabe (introdução) aprender por conta própria (teoria), a achar um jeito (método) de descobrir algo novo (resultado) que faça sentido (discussão), enfim (conclusão) a construir o conhecimento científico.

A respeito dessa jornada, gostaria de sugerir uma letra de música que me lembra esse processo de certa forma. Foi um professor de Física do meu ensino médio, que depois se tornou meu amigo, Sérgio Duarte, que me apresentou essa música. É uma das músicas mais conhecidas do Peter Gabriel, vocalista original da banda Genesis. Ele gravou essa música aqui no Rio de Janeiro e um dos elementos da harmonia é o triângulo usado no forró.

Originalmente 'Mercy Street' em nada tem a ver com a interpretação que estou dando. Foi baseada no poema '45 Mercy Street' de Anne Sexton, autora estadunidense que escrevia bastante sobre sua própria vida e, no caso daquele poema, usava seu eu-lírico de forma crítica à situação da mulher na sociedade. Fortuitamente, assim como no conhecimento científico, a arte não se limita a apenas uma interpretação possível para o mesmo objeto.

Escutar essa música, sempre me ajudou ficar mais tranquilo em momentos difíceis. Embora eu já conhecesse essa música há bastante tempo, e eu mesmo tenha dado diversas interpretações para ela em outros momentos, ao tê-la ouvido durante a preparação da dissertação fiz a associação que me leva a sugeri-la aqui.

AGRADECIMENTOS

Agradeço imensamente à sociedade Brasileira pela possibilidade de construir o caminho acadêmico em instituições financiadas pelo erário. Ou pelo menos a parte da sociedade Brasileira, que assim como eu pensa que esse é o correto.

É através da infraestrutura da Universidade Federal do Rio de Janeiro (UFRJ) e da minha orientadora que pude dar esses passos do mestrado, tão fundamentais na formação de um pesquisador.

À UFRJ agradeço imensamente por toda a estrutura proporcionada através do Programa de Engenharia de Produção, incluindo as pessoas ligadas à área administrativa, às quais agradeço pela dedicação em seu trabalho fundamental para o funcionamento do programa. Em especial agradeço a servidora Roberta de Mattos Arruda que sempre auxiliou e tirou as dúvidas em todos os trâmites burocráticos.

À minha orientadora, Carla Martins Cipolla, agradeço imensamente a dedicação que prestou nas orientações e em todos os outros momentos que proporcionou através da coordenação do Laboratório de Design, Inovação Social e Sustentabilidade (Rio DESIS Lab) onde tive oportunidade de interagir de forma proveitosa com vários colegas, incluindo os coorientandos e graduandos que atuavam no laboratório.

A esses, os colegas, agradeço pela troca extremamente proveitosa em vários momentos, nas disciplinas do mestrado, com relação a dissertação, e nos programas de extensão que contribuí.

No caso das disciplinas, também agradeço a todos os professores que contribuíram com a minha formação enquanto mestrando, o que sem dúvida reflete-se nas visões que trago no presente trabalho.

Agradeço também aos membros da banca de qualificação e defesa, Amanda Xavier, Francisco Duarte e Jorge Lopes, os quais deram feedbacks extremamente proveitosos para que o texto da qualificação evoluísse até o qual está sendo apresentado neste trabalho.

À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior agradeço na mesma proporção que me financiou para realizar o trabalho de pesquisa.

Resumo da Dissertação apresentada à COPPE/UFRJ como parte dos requisitos necessários para a obtenção do grau de Mestre em Ciências (M.Sc.)

REDES MAKER E MODELOS DE MANUFATURA REDISTRIBUIDA

David Campos da Silva Gomes

Fevereiro/2024

Orientadora: Carla Martins Cipolla

Programa: Engenharia de Produção

Redes Maker contribuíram significativamente para trabalhadores da saúde na linha de frente durante a pandemia de COVID-19 produzindo equipamentos de proteção individual (EPI). O principal objetivo desse trabalho é analisar Redes Maker através do paradigma do modelo da Manufatura Redistribuída (RDM). A metodologia abrange uma revisão da literatura sobre RDM e o Movimento Maker, identificando um enquadramento teórico para analisar iniciativas do Movimento Maker de acordo com o modelo RDM e traduzir esse enquadramento em um instrumento analítico a ser utilizado em um estudo de casos múltiplos descritivo de iniciativas do Movimento Maker no Sudeste do Brasil. O estudo de caso permite derivar propostas de design para orientar novas iniciativas maker sobre o modelo RDM. Além da limitação geográfica na seleção dos casos, essa pesquisa focou em redes tendo um nó relacionado à uma universidade, usarem Impressão 3D para a fabricação de protetores faciais e doarem suas produções para hospitais públicos próximos. A presente pesquisa apresenta uma nova forma de observar iniciativas do Movimento Maker no Brasil no que diz respeito a sua capacidade de fabricar produtos necessários localmente, quando organizam sua produção de acordo com o modelo RDM, mesmo ao enfrentar uma emergência como a pandemia.

Abstract of Dissertation presented to COPPE/UFRJ as a partial fulfillment of the requirements for the degree of Master of Science (M.Sc.)

MAKER NETWORKS AND REDISTRIBUTED MANUFACTURING MODELS

David Campos da Silva Gomes

February/2024

Advisor: Carla Martins Cipolla

Department: Production Engineering

Maker Networks significantly contributed to frontline health workers during the COVID-19 pandemic by producing personal protective equipment (PPE). The main objective of this work is to analyse Maker Networks through the paradigm of the Redistributed Manufacturing (RDM) model. The methodology encompasses a literature review on RDM and the Maker Movement, identifying a theoretical framework to analyse Maker Movement's initiatives according to the RDM model and translating that framework into an analytic tool to be used in a descriptive multiple-case study of Maker Movement's initiatives in the Brazil Southeast. The case study results allow the derivation of design proposals for orienting new maker initiatives on the RDM model. Beyond the geographical limitation in the selection of cases, this research focused on networks having a node related to a university, using 3D Printing to fabricate face shields and donating their production to nearby public hospitals. The present research delivers an unprecedented way to observe initiatives from the Maker Movement in Brazil regarding their ability to manufacture locally necessary products by organising their production according to the RDM model, even when facing emergencies like the pandemic.

CONTENTS

LISTA DE ILUSTRAÇÕES

Figuras

Quadros

LISTA DE TABELAS

LISTAS DE ABREVIATURAS E SIGLAS

Abreviaturas

BCE	Before Christian Era
Biofabris	Biofabrication Institute
CE	Christian Era
Fab Lab	Fabrication Laboratory
kya	kilo years ago
ya	years ago

Siglas

3D	Three-Dimensional
ABS	Acrylonitrile Butadiene Styrene
AI	Artificial Intelligence
AM	Additive Manufacturing
ARPANET	Advanced Research Projects Agency Network
BCV	Brasil Contra o Vírus
CCC	Chaos Computer Club
CE	Circular Economy
CERN	Conseil Européen pour la Recherche Nucléaire
CNC	Computer Numerically Controlled
COVID-19	Coronavirus Disease 2019
CPAPNIV	Continuous Positive Airway Pressure Non-Invasive Ventilator
CPPS	Cyber-Physical Productive Systems
D&M	Design and Materials
DIY	Do-It-Yourself
DM	Distributed Manufacturing
DMS	Distributed Manufacturing Systems
ECE	Environmental and Circular Economy
EPSRC	Engineering and Physical Sciences Research Council
ERM	Enterprise Resources Management
ERP	Enterprise Resources Planning
ERP II	Enterprise Resources Planning (second version)
FDM	Fused Deposition Modelling
GRI	Grassroots Innovation
H&S	Hardware and Software
I1.0	Industry 1.0
I2.0	Industry 2.0
I3.0	Industry 3.0
I4.0	Industry 4.0
I5.0	Industry 5.0
ICT	Instituto de Ciência e Tecnologia
INTO	Instituto Nacional de Traumatologia e Ortopedia
IoT	Internet of Things
IP	Intellectual Property
IPT	Instituto de Pesquisa Tecnológica

JIT	Just-In-Time
K-12	Kindergarten to Twelfth grade
KBV	Knowledge-based View
LED	Light Emitting Diode
LM35	Linear Monolithic 35
MCC	Makers Contra a Covid-19
MIT	Massachusetts Institute of Technology
MNE	Multinational Enterprise
MRP	Material Resources Planning
MRP II	Management Resources Planning
NTP	Normal Temperature and Pressure
OSH	Open Software and Hardware
PCR	Polymerase-Chain Reaction
PET	Polyethylene Terephthalate
PETG	Polyethylene Terephthalate Glycol
PLA	Polylactic Acid
PPE	Personal Protective Equipment
PUC	Pontifícea Universidade Católica
PVA	Polyvinyl Alcohol
PVC	Polyvinyl Chloride
R&D	Research and Development
RBT	Resource-based Theory
RCIF	Repair Café International Foundation
RDM	Redistributed Manufacturing
RHMS	Rio Hacker Maker Space
SARS-Cov-2	Severe Acute Respiratory Syndrome Coronavirus 2
SLA	Stereolithography
SME	Small and Medium-sized Enterprise
SOS	SOS 3D COVID19
STEAM	Sciences, Technology, Engineering, Arts and Mathematics
TCE	Transaction-cost Economics
TM	Trem Maker
UFMG	Universidade Federal de Minas Gerais
UFRJ	Universidade Federal do Rio de Janeiro
UK	United Kingdom
UNICAMP	Universidade Estadual de Campinas
USA	United States of America
USP	Universidade de São Paulo
VSD	Value Sensitive Design
WEF	World Economic Forum
Z3	Zuze 3

1 INTRODUCTION

This study contributes to the academic discussion on the Maker Movement and cases related to a production model called Redistributed Manufacturing (RDM). This discussion has been growing substantially in the last ten to fifteen years (CHEN; WU, 2017; HENNELLY et al., 2019).

The Maker Movement generally consists of people imbued with a do-it-yourself approach to fixing and building things while sharing their knowledge openly and collaboratively. It also consists of the events organised by these people (which, from now on, we call *Makers*) as well as spaces shared by them, like shared workshops (DOUGHERTY; CONRAD, 2016).

RDM is a production model under the umbrella term Distributed Manufacturing, where production is supposed to be closer to the end users and considers their inputs in the production process (SRAI; HARRINGTON; TIWARI, 2016).

The path to this research lies in the author's background concerning the Maker Movement. It includes two more essential components besides evoking much personal interest. One was teaching several classes on Arduino basics for an undergraduate Product Design course at the same university as the author's Masters. The other one was participating in the extension program Lab Escola 3D (LAB ESCOLA 3D, 2020).

The personal interest comes from previous education and indoor do-it-yourself (DIY) practices. The present author is a Telecommunications Engineer and an Electronics Technician, which are specialities found in the Maker Movement. In turn, those specialities are linked back to childhood, when tinkering with household devices, sometimes to parents' despair, and sometimes very beneficial to school projects. Nowadays, it is still a significant part of the author's life: be it in DIY household practices, like repairing appliances, be it his central research theme, or as the underlying theme of the projects he takes part in, like Lab Escola 3D.

The classes previously mentioned totalised three introductory lessons on Arduino basics. The first was a review of Electricity's basic concepts, simple circuits, Digital Electronics, the components of an Arduino UNO R3 and several sensors to use with it. The second focused on the idea and operating principles of transducers (electronic devices that allow an electronic system to interact with the world), such as a microphone (a sound sensor, for that matter) and a speaker. The third and final activity consisted of reading the code (in C++ programming language) for a specific pair of transducers, like a temperature sensor and a light-emitting diode (LED) or a touch sensor and an LED; then, the students had to wire the circuit accordingly. The circuit consisted of the Arduino board, a breadboard (a prototyping board for circuits), the transducers and the wires.

Lab Escola 3D may be understood as the evolution (or adaptation) of the previous “Graja Maker” project. The latter consisted of exhibitions held in a public square in the Grajaú neighbourhood in Rio de Janeiro. The integrants brought a 3D Printer to the place, printed several objects, and allowed some people to play with a 3D-printed chess game. In addition, people interested in the demonstration received brief explanations about the technology and possible usages, like personal fabrication and prototyping.

The project’s turning point coincided with the present research’s turning point. Lab Escola 3D is a project that produces videos not only in the same subject as Graja Maker but also expanded to include classroom assistive technology and Arduino-related content. The impossibility of presential demonstrations due to the arrival of the coronavirus disease of 2019 (COVID-19) pandemic in Brazil around February and March 2020 brought this change to videos.

The cases the present study explores are initiatives from the Maker Movement that started fabricating personal protective equipment (PPE) in response to the fast-spreading of cases, alongside the increasing need for that equipment in hospitals worldwide. Therefore, the pandemic also represented a turning point in the present research.

Before the COVID-19 pandemic, this study had a previous theoretical development. That development concerns the Maker Movement and a production model, developed in spaces and with technology related to the Maker Movement, like shared workshops and 3D Printers, respectively, as seen next.

That development began at a discipline enrolled by the present author during the Master’s discipline cycle, called ‘Maker Culture’. The objective was to write an academic paper based on the Maker Movement’s presence in the city (Rio de Janeiro).

Through this effort, the author could investigate a shared workshop called "Polo Maker" (POLO MAKER, 2021) in the Rio Comprido neighbourhood.

With that in mind, it was possible to find a research paper dealing with the same type of shared workshop the present author investigated (HENNELLY et al., 2019). That paper has a theoretical discussion in shared workshops called *makerspaces* about their presence worldwide and in literature. The authors explored the existence of a production model called *Redistributed Manufacturing* (RDM) in those workshops. Their work became a fundamental theoretical support to the present author's research, including this work.

1.1 CONTEXT AND MOTIVATION

1.1.1 The Relevance of the Maker Movement

The Maker Movement influences society in at least as many ways as there are fields of knowledge to study the Movement. For example, Occupational Sciences study how the Maker Movement impacts the lives of unemployed people (MENICHINELLI et al., 2017; UNTERFRAUNER et al., 2020). It is an object of study in Psychology because there are behavioural characteristics inherent to makerspaces (BARTON; TAN; GREENBERG, 2017; KEUNE; PEPPLER, 2019; VON BUSCH, 2012). In Sociology, scholars are worried about what it represents as a cultural group, either as a subculture, a counter-culture, or even an alternative culture (IRIE; HSU; CHING, 2019; LINDTNER, 2015; TABARÉS GUTIÉRREZ, 2018). These areas are just an example of many others; nonetheless, most of the literature focuses either on the presence of the Maker Movement in education or its influence on economic-related subjects, such as Entrepreneurship or Local Economy (CHEN; WU, 2017).

In the case of education, there has been an increasing adoption of making in K-12[1] education (MARSHALL; HARRON, 2018; MARTIN, 2015). In their article, Marshall and Harron (2018) propose a framework for understanding the role making has in STEAM[2] education. See Table 1.

[1]Kindergarten to twelfth grade refers to the basic education cycle before high-school.
[2]Acronym for Science, Technology, Engineering, Arts and Mathematics.

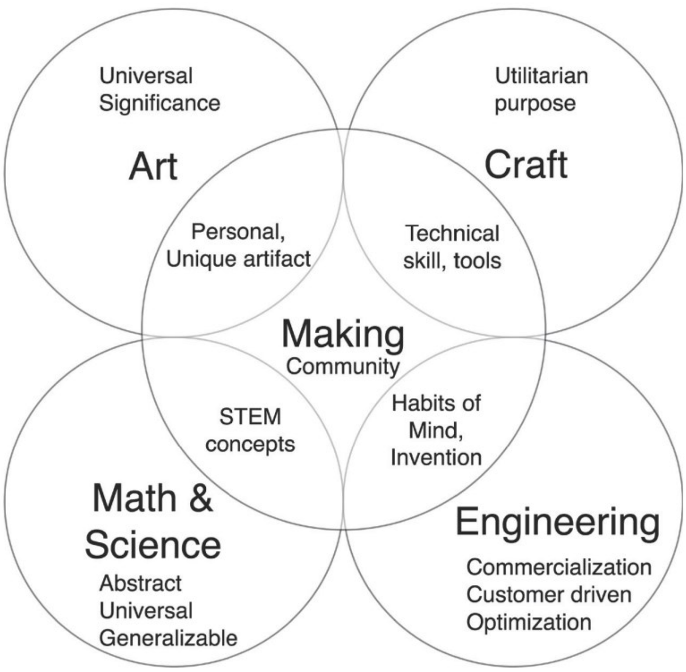
Table 1 – Framework for Making in STEAM Education.

Element	Qualities
Ownership/Empowerment	Personally meaningful
	Playful, enjoyable
	Individualised/original
Maker Habits	Failure positive
	Growth-oriented
	Self-reliant
Production of an Artefact	Physical manifestation
Collaboration	Community connection
	Sharing of tools and products
STEAM Tools	Digital tools
	Manufacturing tools

Adapted with the rightsholder permission from Marshall and Harron (2018, p. 6).

In the context above, “making has connections to art, science, crafts, and engineering, but is not comfortably contained within any of them” (MARSHALL; HARRON, 2018, p. 2). See Figure 1 for a visual representation.

Figure 1 – Relationship between Making and Craft, Art, Math and Science, and Engineering.



Source: reproduced with the rightsholder permission from Marshall and Harron (2018, p. 4).

Martin (2015) explores the characteristics of the Maker Movement, allowing its integration with Education. The author lists seven reasons for that:

a) alignment with curricular demands that require engineering skills;
b) through making, youth have access to many sophisticated building and thinking tools;
c) the recursive feedback inherent to building something, seeing how it performs and sharing it with others is a powerful drive for learning;
d) playfulness and high tolerance to errors are inherent to making and necessary for a beneficial learning environment;
e) making supports a mindset where, given effort and resources, anyone can build any imaginable project;
f) making stimulates growth in resourcefulness by incentivising autonomous behaviour; and
g) the communitarian nature of the Maker Movement, either in an online or in-person fashion, gives the youth a supportive social context that reinforces their learning.

The Maker Movement is usually associated with using two branches of technological tools identified by Martin (2015): *digital physical tools* and *digital logic tools*. The former are tools depending on an object's digital model, generated in a computer, to produce that object. The latter are devices programmed to perform the logical control of a physical system that embeds it.

Digital physical tools include 3D Printers, CNC routers, digital embroidery machines, laser cutters, and vinyl or paper cutters. Similarly, digital logical tools are the many types of microcontroller and single-board computers, usually seen in projects built in the context of the Maker Movement (MARTIN, 2015), like Arduinos, BeagleBone and Raspberry Pi.

Altogether, these digital tools are a set of equipment that allows the people inside the Maker Movement to build their projects and even finished products. That fact, by definition, allows us to see this equipment as the production media of the Maker Movement. Moreover, together with other tools in shared workshops (like makerspaces), that very equipment enables the people and places associated with the

Maker Movement to participate in new production models, like what RDM proposes (SRAI; HARRINGTON; TIWARI, 2016).

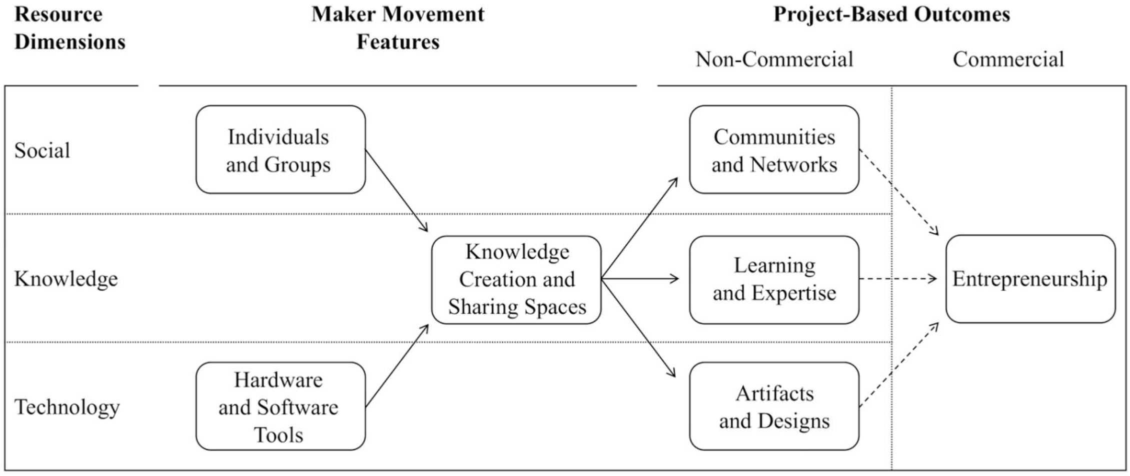
This scenario also contributes to the emergence of entrepreneurship and may help develop local economies (BROWDER; ALDRICH; BRADLEY, 2019; VAN HOLM, 2017; WOLF-POWERS et al., 2017).

A recurring question about the Maker Movement in entrepreneurial research is how making may lead to entrepreneurship. For example, Browder, Aldrich and Bradley (2019) argue that the Maker Movement has three axes leading to entrepreneurship: 'social', 'knowledge' and 'technology'. The last one coincides with the digital tools, logical and physical, identified by Martin (2015) and, as outcomes of this technological domain, makers produce artefacts and designs.

The outcomes of the social dimension are communities and networks. "Maker communities form as people work on and share projects through in-person interactions in physical spaces within a bounded geographic territory" (BROWDER; ALDRICH; BRADLEY, 2019, p. 466).

In the knowledge domain, the outcomes are the learning and expertise that arise from people sharing spaces and participating in knowledge creation (BROWDER; ALDRICH; BRADLEY, 2019). Figure 2 depicts the process of these three domains leading to entrepreneurship in the context of the Maker Movement.

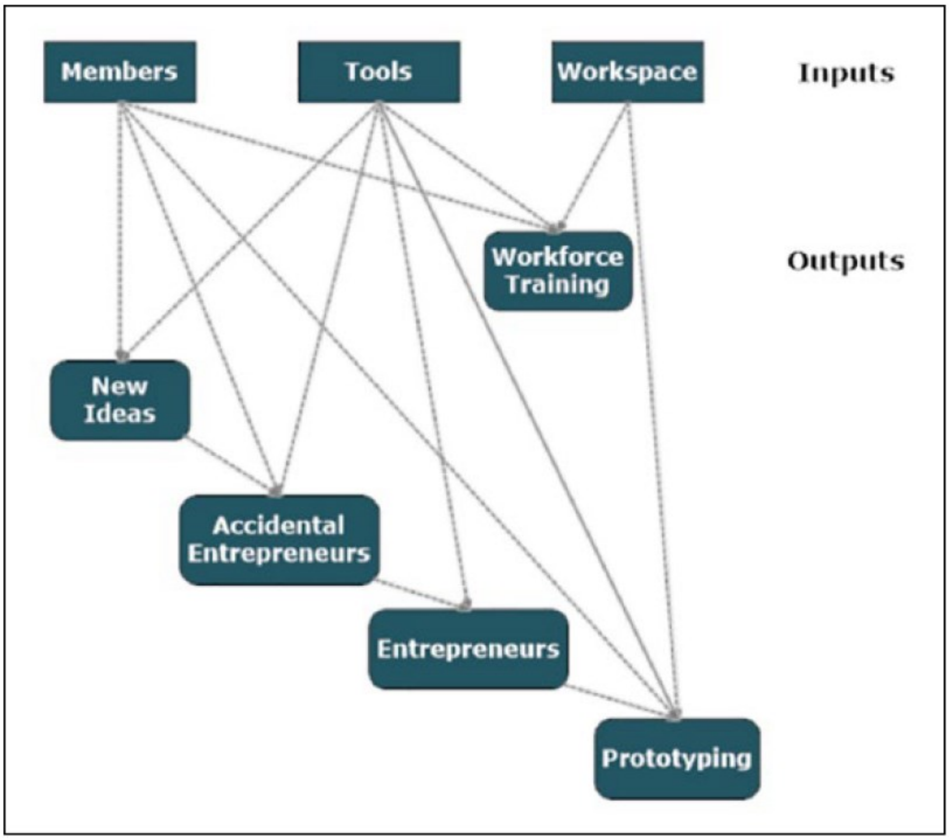
Figure 2 – Conceptual model of the maker movement phenomenon and its relation to entrepreneurship.



Source: reproduced with rightsholder's permission from Browder, Aldrich and Bradley (2019, p. 463).

In van Holm (2017), a proposition with a similar structure exists. It describes a makerspace in terms of an entrepreneurial environment. In this case, the author focuses on the physical tools available in makerspaces. He argues that this availability is fundamental to the possible interactions inside the makerspace, see Figure 3 As a result, we have a prototyping-oriented environment that allows entrepreneurs, accidental or intentional, to implement their ideas into something to test before heading to the market.

Figure 3 – Makerspaces and their inputs and outputs.



Source: reproduced with the rightsholder permission from Van Holm (2017, p. 165).

The works above account for the principal Maker Movement's societal impacts (CHEN; WU, 2017). These societal impacts are what this work means with 'the relevance of'. The same is valid for the following subsection.

1.1.2 The Relevance of RDM

Production spread over a local territory, either by means of re-shoring or by implementing a distributed production model, is a phenomenon worth analysing from three perspectives (SRAI; HARRINGTON; TIWARI, 2016). The first is how organisations can take advantage of RDM, a global perspective. The second is how worth RDM is for developing economies: a local viewpoint. Lastly, what would be some impacts on society, economically speaking?

In the face of the dichotomy between mass production's efficiency and the flexibility associated with a distributed model, RDM also embeds the possibility of taking advantage of both. This possibility is called organisational ambidexterity (ROSCOE; BLOME, 2019). In this context, ambidexterity is when an organisation pursues two simultaneous disparate activities (ADLER; GOLDOFTAS; LEVINE, 1999).

In their investigation of RDM, Roscoe and Blome (2019) point out how a focal firm may take advantage of structural ambidexterity, the supply chain perspective on ambidexterity. In this sense, an organisation directs its partitions so that some specialise in routine tasks while others specialise in non-routine ones. Therefore, the organisation can benefit from the cost advantage of repetitive routines whilst simultaneously exploring new flexible manufacturing systems during non-routine work (ADLER; GOLDOFTAS; LEVINE, 1999).

One of the steps Roscoe and Blome (2019) took in their research was to check with specialists and managers of Multinational Enterprises (MNEs) and Small and Medium-sized Enterprises (SMEs) about the most probable ways in which RDM are to be adopted in the near future.

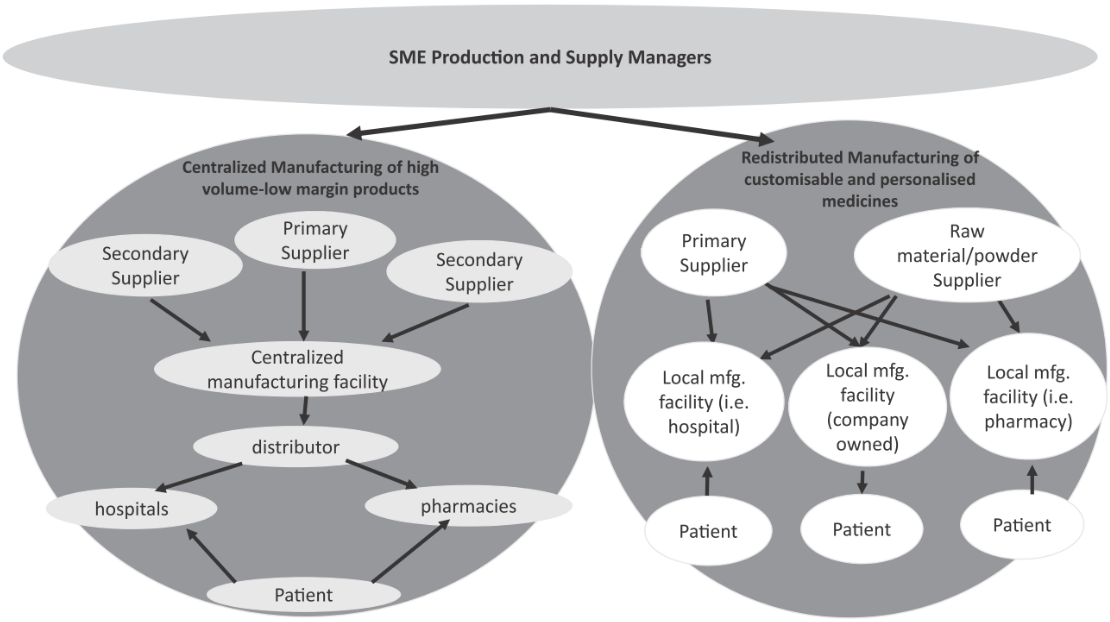
They find that those companies taking significant advantage of mass production's lower costs are less likely to adopt a major role in a distributed production model such as RDM. Conversely, the opposite holds for companies that, even by how they organise their structure, constantly find opportunities regarding flexibility in their production. Generally, the first case coincides with MNEs and the second with SMEs (ROSCOE; BLOME, 2019).

From a systemic perspective, RDM has its place in the supply chain alongside centralised mass production instead of as a substitute. Thus, some companies aiming to deliver specific, customised products (usually with a high margin) would easily adopt RDM to organise production. On the other hand, companies with a business model headed towards delivering low cost and low variety, high volume, and highly standardised products will remain to play this role for a long time, considering current technology. Nonetheless, this latter type of company may be part of the supply chain of the former type, as a raw material source, for example (ROSCOE; BLOME, 2019).

The literature refers to the supply chain link described above as structural ambidexterity. Figure 4 represents a supply chain involving companies from the medical sector, as studied by Roscoe and Blome (2019).

In the case of Figure 4, we have the context of an SME providing medicines via two paths where facilities are geographically separated (ROSCOE; BLOME, 2019). The company plans its production considering gains associated with the more common medicines market, mass-manufactured, whilst utilising local facilities to deliver customised products, like radiotherapy pills, that may be specific for each patient.

Figure 4 – Contextual ambidexterity of SMEs.



Source: reproduced with the rightsholder permission from Roscoe and Blome (2019, p. 506)

These local facilities may be owned by the company itself, but also by some partner or client, like a hospital or a pharmacy.

Considering what has just been put, RDM's characteristics, like supply chain flexibility and product customisation, represent a way for companies to organise their production beyond the more usual mass-manufacturing while maintaining a flowing supply chain that is not compatible with a centralised model (SRAI; HARRINGTON; TIWARI, 2016).

Now, let us look at RDM in the context of developing economies.

Amid the literature underpinning the present research, the unique work focusing on covering RDM in the context of an emerging economy is from Luthra, Mangla and Yadav (2019). First, they extract from the literature in RDM possible barriers to implementing this production model in general and then specifically to the context of the Indian economy.

The authors assert the possibility of extending the results of their research to other developing economies similar to the Indian one (LUTHRA; MANGLA; YADAV, 2019).

In order to support this possibility, especially for extending those results to Brazil, we need an assessment of the economic similarities between India and Brazil. In the work of Assouad, Chancel and Morgan (2018), there is enough evidence correlating the economic dimension of these countries to allow for a possible extension of an economic analysis of a production model, as the one developed by Luthra, Mangla and Yadav (2019) about RDM.

Therefore, based on their work (LUTHRA; MANGLA; YADAV, 2019), it is reasonable to assume that the Brazilian context has the following two main challenges impeding RDM: the lack of developed standards, and the lack of government policies, poor regulatory frameworks and certification programs. Those challenges are extracted directly from the conclusion of the paper.

Besides that, the authors offer five managerial implications to be followed by managers trying to take advantage of RDM in the context of emerging economies: (1) the necessity of a regulatory environment and institutional support; (2) understanding and setting the benchmarking process and standards; (3) provision of funds and investments; (4) need of technological updates and innovation; (5) integrating RDM practices to the value chain for sustainable performance (LUTHRA; MANGLA; YADAV, 2019).

Following the beginning of this subsection, it is time to cover some possible impacts of RDM in society, economically speaking.

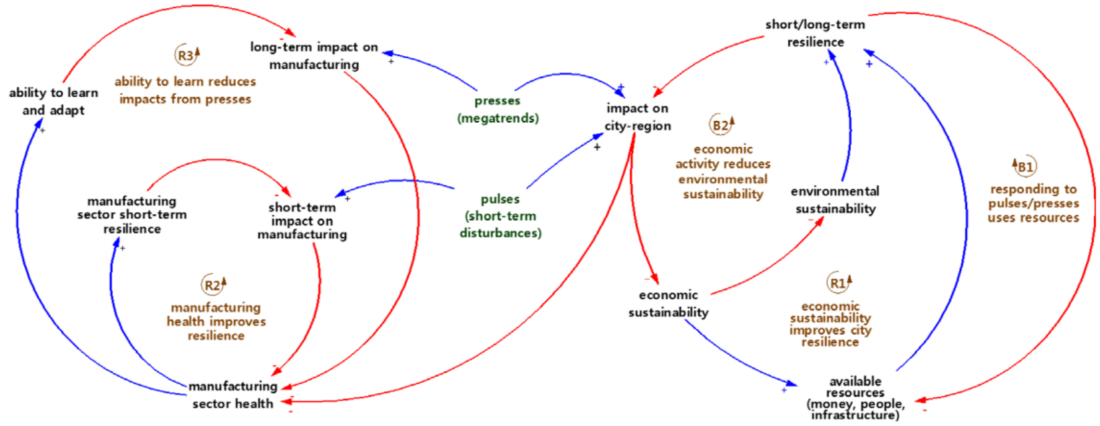
Since RDM is a production model, we must observe how society affects manufacturing and vice-versa. Here, the main topic is resilience: what are the types of disturbances faced by societies impacting manufacturing (and vice-versa), and how well can the production systems recover from those disturbances?

Freeman, McMahon and Godfrey (2016, 2017) assessed this issue by investigating the relationship between the main types of resiliency and disturbances that affect society and the manufacturing sector. Figure 5 depicts these relationships. From that model and further inputs from literature review and experts, the authors point out several ways RDM would compare to the current mass-manufacturing model (FREEMAN; MCMAHON; GODFREY, 2017).

Three questions guide this comparison: "(i) How much RDM could thrive within the city as it exists now, (ii) How much RDM might thrive in the face of strong future disturbances and (iii) How well the outcomes of more RDM might align with the goals of regional sustainability and resilience". (FREEMAN; MCMAHON; GODFREY, 2017, p. 9).

To answer those questions, the authors derive seven key points from comparing RDM and the current mass manufacturing model. Those points are listed in Table 2, accompanied by a summarisation of the implications for RDM. A thriving RDM scenario also includes several examples or consequences of those implications in its characteristics.

Figure 5 – 'Strawman' causal loop diagram representing an initial theory about the causal relationships between different types of resilience and sustainability and the manufacturing sectors, as presented to workshop participants.



Source: reproduced with rightsholder permission from Freeman, McMahon and Godfrey (2017, p. 3). Notes: Positive causation is represented by arrows with a '+' sign, and negative causation is represented by arrows with a '-' sign. Balancing (i.e. goal seeking) loops are named B1, B2, etc. and reinforcing (i.e. growth) loops are named R1, R2, etc.

Table 2 – Summary of key points and their implications for RDM.

Key point	Implications for RDM considering traditional mass manufacturing	Example or Consequence
Similarities	The same conditions would support it.	Manufacturing clusters, skills and technology innovation, local ownership and leadership.
Physical space	It will, in general, require smaller physical spaces.	Maker community (makerspaces).
Resilience through responsiveness	Should be more agile and able to respond positively to disturbances.	Changing global markets or changing availability of material resources.
Environmental impacts	Products could be less environmentally impactful.	If made 'local for local'.
Additions and losses in jobs	Creating semi-skilled jobs would require different business models or public support.	Local parts manufacturers could use RDM to shorten supply chains.
Competitiveness	It is unlikely that RDM products could compete with cheap, mass-produced products.	Increase the competitiveness of high-value and niche goods for local or global markets.
Skills and innovation	It could be more challenging to achieve.	Increase the importance of manufacturing clusters and academic and government support.

Based on Freeman, Mcmahon and Godfrey (2017, p. 9–10)

The key points and their impact on RDM, as listed in Table 4, also represent several economic implications of this production model for society (LUTHRA; MANGLA; YADAV, 2019; SRAI et al., 2016). Therefore, the work of Freeman, McMahon and Godfrey (2016, 2017) gives us an understanding of the economic importance of RDM to society.

1.1.3 The Connection Between the Maker Movement and RDM

The definitions of RDM and Maker Movement are intertwined. Although the concepts of RDM in the literature vary, they usually concern the move from a centralised mass production model to a localised and distributed production model (SRAI; HARRINGTON; TIWARI, 2016). Likewise, the practices constituting the Maker Movement relate to the local development of projects and networks imbued with a DIY or do-it-together principle (BROWDER; ALDRICH; BRADLEY, 2019; PEPPLER; BENDER, 2013; VAN HOLM, 2017).

A model contrary to a mass-oriented and centralised production model is low-scale and distributed. For example, what the Maker Movement is able to offer through its so-called makerspaces. These shared workshops may function as small-scale centres of production much closer to the end user, which, allied to the engaging spirit of the Maker Movement, facilitates their participation as *prosumers*[3] (PRENDEVILLE et al., 2016).

As explored by Hennelly et al. (2019), makerspaces vary somewhat in terms of activities scope depending on the "awareness of modern manufacturing technologies; conceptual design utilising these emerging technologies; prototype production; and indeed, full production capability" (p.540). Nonetheless, some makerspaces are functioning and well-equipped enough for a commercial paradigm. Thus, they may work as a productive node of a supply chain closer to the end user, especially in the context of the *last mile*[4] (HENNELLY et al., 2019).

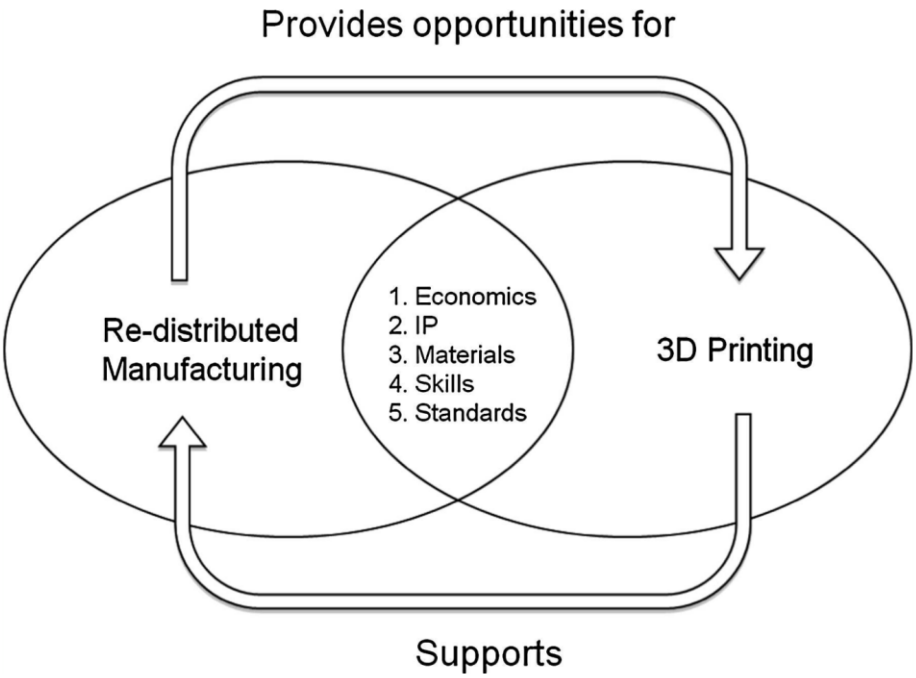
---

[3]Prosumer is the customer participating in prosumption. Prosumption happens when the consumer participates in the production process of a good or service (RITZER; JURGENSON, 2010).
[4]Last mile refers to the final leg of a journey of goods and people. It happens between the ultimate transportation hub to the eventual destination (KULL; BOYER; CALANTONE, 2007; LIM; JIN; SRAI, 2018).

In these workshops, there is a variety of tools allowing them to play such roles in a productive model like those associated with some craftsmanship, like woodwork, metal work and textile crafts, and advanced manufacturing technologies such as 3D Printers, CNC[5] routers and laser cutters (BARRETT et al., 2015; SHERIDAN et al., 2014). For instance, let us focus on this digitally-enabled type, specifically in 3D Printing.

In their feasibility study, Ford and Minshall (2015) collected a series of expert views on a possible 3D-print-enabled RDM. They extract the following excerpt from PwC and NAM (2014): "Companies are re-imagining supply chains: a world of networked printers where logistics may be more about delivering digital design files – from one continent to printer farms in another – than about containers, ships and cargo planes" (p.1). The authors created the image in Figure 6 to summarise their conception of the relationship between 3D Printing and RDM (FORD; MINSHALL, 2015).

Figure 6 – The conceptual logic for the 3DP-RDM network.



Source: reproduced with the rightsholder permission from Ford and Minshall (2015, p. 158).

The topics in the middle of Figure 6 are explained as follows (FORD; MINSHALL, 2015, p. 157):

[5]CNC stands for computer numerical control. Router machines carve material from a solid block, like from wood or metal, to form the final shape, which corresponds to a digital model.

> 1. Economics: the economics of 3D printing, including assessment of the cost advantages and disadvantages;
> 2. IP: the protection of intellectual property and value appropriation, particularly the protection of copyrights and design rights;
> 3. Materials: attributes such as quality, durability and recyclability;
> 4. Skills: the education and development of a 3DP-skilled labour market;
> 5. Standards: manufacturing standardisation.

Printer farms are setups where multiple printers work in parallel. These arrangements permit production scalability in makerspaces without necessarily losing other Maker Movement characteristics, which are absent in traditional manufacturing plants, like a cooperative and learning environment (KEUNE; PEPPLER, 2019). In the latter article, the authors explore the development of that scaling process and a makerspace member's evolution linked to it.

Darnel (pseudonym) began as a makerspace user (KEUNE; PEPPLER, 2019). He had the chance to assemble the first 3D Printer kit they bought – which, by the way, makes it a prosumption experience. When more printers were bought, he became the person responsible for overseeing them. Darnel's experience influenced him to begin a 3D Printing business by demand, using the machines from the makerspace and becoming a member of it. It reached the point of having 12 printers assembled in line queued by software. Thus, with an automated digital file-feeding process.

The environment described above, set in the Maker Movement context, includes various characteristics of an RDM business model, such as the technology in use, the actor transformation (in this case, Darnel) and user participation (SRAI; HARRINGTON; TIWARI, 2016), indicating the link between the Maker Movement and RDM.

1.1.4 Motivation for this Research

Although some studies about the Maker Movement have reported its influence on generating innovative solutions and economic development (CHEN; WU, 2017), few works explored a networked production model with a deep relationship to the Maker Movement.

Some works describe Makers organising themselves in networks and the local society benefiting from their initiatives (GIUSTI; ALBERTI; BELFANTI, 2020; HAMALAINEN; KARJALAINEN, 2017; JOHNS; HALL, 2020; LINDTNER, 2015; ROEDL; BARDZELL; BARDZELL, 2015; SMITH, 2017).

It is possible to find works linking production dynamics to Makers. For example, Makers taking part in 'social manufacturing' and in 'peer production' (HAMALAINEN; KARJALAINEN, 2017; HIRSCHER; MAZZARELLA; FUAD-LUKE, 2019; KOHTALA; BOSQUÉ, 2014; MENICHINELLI et al., 2017; WOLF et al., 2014; WOLF; TROXLER, 2016; YANG; JIANG, 2019).

Still, the literature has few examples exploring the production model of cases where a network of people and organisations from the Maker Movement are collaboratively manufacturing some good or delivering some service under the paradigm of Redistributed Manufacturing (e.g., Section 2.3). Regarding Brazilian initiatives, the present research is the only work dealing with such a perspective as of 2023, considering the literature review. See Section 3.1.

1.2 GENERAL AND SPECIFIC OBJECTIVES

Besides the theoretical development giving base to this work (Chapter 2), there is a practical objective orienting the path of the present research. Next, the central objective is split into four specific goals, guiding the steps to make this research possible.

1.2.1 General Objective

The main objective of this research is to analyse Maker Movement initiatives through the paradigm of Redistributed Manufacturing.

1.2.2 Specific Objectives

The general objective encompasses attaining the goals described below:

a) Conducting a literature review on the topics of the Maker Movement and Redistributed Manufacturing;
b) Identifying in the retrieved literature an adequate theoretical framework to analyse initiatives from the Maker Movement through the lenses of the Redistributed Manufacturing model;
c) Translating the theoretical framework from the last step into an analytic tool for assessing the RDM characteristics of initiatives from the Maker Movement;

d) Utilising the analytic tool from the previous step for developing a case study of several initiatives from the Maker Movement operating with RDM characteristics in the Brazil Southeast;
e) Generating design proposals from the cases studied to advise new initiatives correlating the RDM model and the Maker Movement.

1.3 METHODOLOGICAL FRAMEWORK

Chapter 3 details the methodology used throughout this work. Below is a glimpse of that methodological path.

In order to become acquainted with the theme, the present author conducted a literature review. It partially follows the path given by Thomé, Scavarda and Scavarda (2016). This review focuses on gathering the relevant literature for the theme. It does not focus on generating an extensive systematic review. That is why it only follows the correspondent part (the first steps) of the complete systematic review methodology (THOMÉ; SCAVARDA; SCAVARDA, 2016).

Once the present research finishes the review, it conducts a multiple case study, considering the objectives. The methodology employed stems from the works of Eisenhardt (1989) and Yin (2018) (Chapter 3). Their path allowed for choosing the cases, analysing them based on the framework identified in the literature, and then describing the cases to grasp the Design Proposals (Chapter 4).

The last step of the present work is to evaluate the results. Thus, a review of the pertinent literature is carried out similarly to the first, allowing an expansion of the theoretical background (Chapter 2). Finally, that background supports the discussion of the results (Chapter 5) and the proposition of future works (Chapter 6).

1.4 CONTRIBUTIONS OF THIS WORK

The present study's contributions to the current knowledge on RDM and the Maker Movement are threefold.

In Chapter 2, the reader can find a detailed exploration of the concepts and history behind the Maker Movement and RDM, as well as what connects them to the purpose of this work. That theoretical development, per se, adds a comprehensive theoretic discussion to the current literature on the theme.

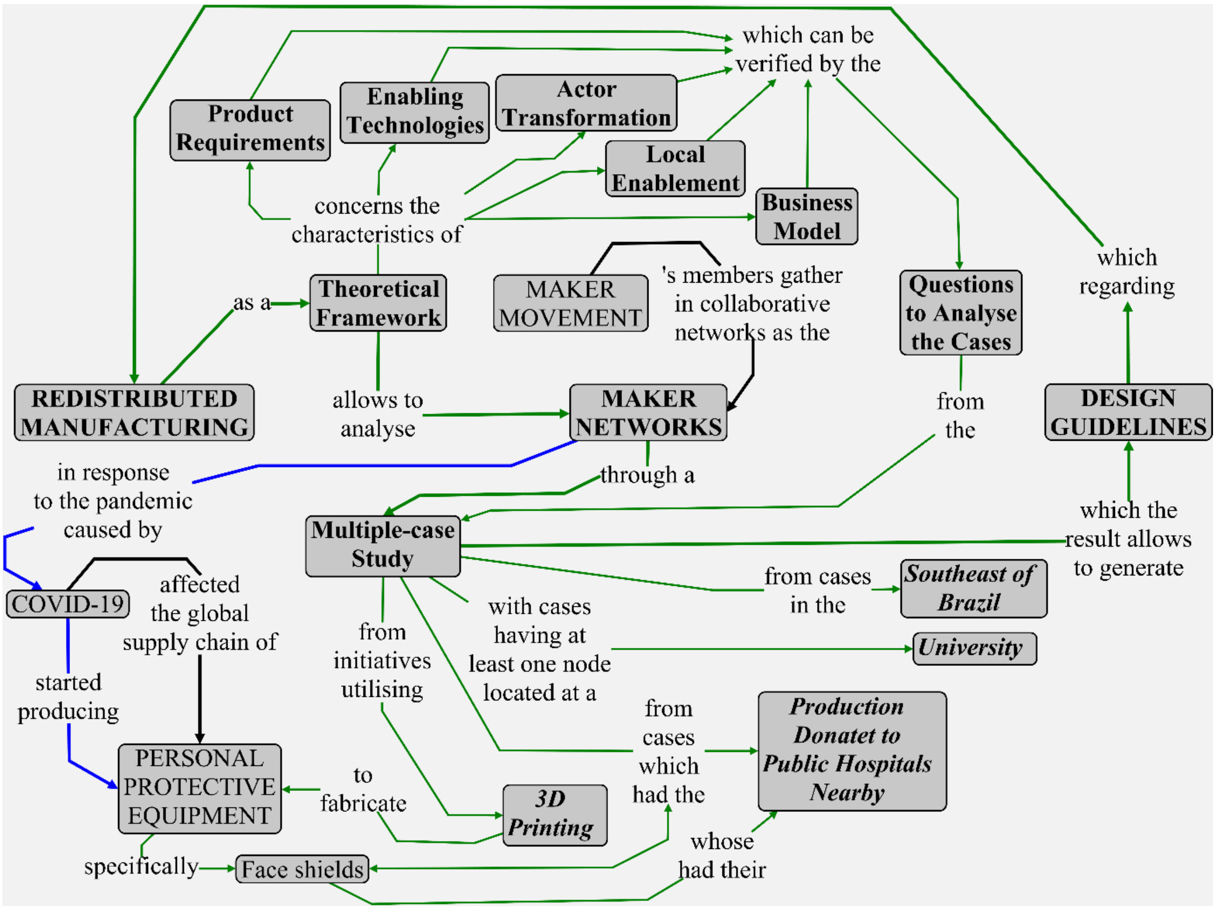
Chapter 4 presents the results, with a detailed description of the initiatives from the Maker Movement implementing RDM. The design proposals stem from that description and are part of the present work's second contribution.

Finally, in Chapters 5 and 6, this work discusses the results considering the theoretical background developed in Chapter 2 and proposes future works, taking this research as a basis. This last step supports the reproduction of the RDM model in future commercial or not-for-profit projects, mainly when they concern initiatives from the Maker Movement.

1.5 THE CONCEPT MAP OF THIS WORK

The last few paragraphs have provided the reader with the overall structure of the present work. To illustrate this structure, the present author created a concept map. See Figure 7. That map will appear in several parts of this dissertation, whenever relevant, to illustrate the relationship of related contents.

Figure 7 – The Concept Map of this work.



Source: Author

2 THEORETICAL BACKGROUND

This chapter provides the theoretical constructions through which the present work encompasses the state-of-the-art literature on Maker Movement and Redistributed Manufacturing. Besides, it also represents this work's theoretical contribution to the academic discussion on the relation of those two areas.

2.1 PERSPECTIVES OF 'MAKER'

Starting the theoretical discussion with the topic of the Maker Movement, this section begins with a historical perspective on this matter in the first subsection. This historical perspective centres on the participant of the Maker Movement – the 'Maker' – the topic of the second subsection.

From this construction, about the individual who participates in the Maker Movement, the other subsections here display a collective perspective, where many individuals form a movement. For this purpose, this work considers cultural, physical and structural perspectives in the Maker Movement.

2.1.1 The History of Makers

Dale Dougherty and Ariane Conrad's words bring a comprehensive perspective to the definition of the Maker Movement's participant: "We Are All Makers" (DOUGHERTY; CONRAD, 2016, p. 9). This sentence is in the literal sense. With that expression, the authors are approaching the distinction between humans and other pre-historic hominids to those closer to a wild ape.

This distinction resides in the ability to make things – therefore creating those things – from what is provided by nature. To taxonomise those hominids, the authors employ the term "*homo faber*" (DOUGHERTY; CONRAD, 2016, p. 9).

Further diving into the maker's historical aspect, the exploration of the term 'homo faber' carried by Vilém Flusser indicates several ways in which the act of making things relates to humankind's ability to build their reality beyond what is available in the remainder of nature:

> This is a functional term since it allows one to introduce the following criterion: Whenever we find any hominid anywhere in whose vicinity there is a working-floor, and whenever it is clear that a hominid has worked in this 'factory', then this hominid should be referred to as *homo faber* (…) (FLUSSER, 1999, p. 43)

Continuing on the same page, Flusser establishes in these subsequent sentences the historiographical panorama through which he advocates one shall observe human societies if trying to understand them:

> Everything, particularly the science, politics, art and religion of the society of the time, can be traced back to factory organization and the manufacture of pots. The same goes for all other periods. If, for example, a shoemaker's workshop from fourteenth-century northern Italy is subjected to close examination, the roots of Humanism, the Reformation and the Renaissance can be understood more thoroughly than by studying the works of art and political, philosophical and theological texts. Because most of these works of art and texts were produced by monks, whereas the big revolutions of the fourteenth and fifteenth centuries originated in workshops and in the tensions contained within them. So, anybody who wants to know about our past should concentrate on excavating the ruins of factories. Anybody who wants to know about our present should concentrate in examining present-day factories critically. And anybody who addresses the issue of our future should raise the question of the factory of the future.

To conclude the historical glance on who can be a Maker, let this text explore the very origin of the word 'make'. The first recorded root word that supposedly, throughout the millennia, gave origin to the verb "to make" is the Indo-European **mag-*, represented in Greek as *mássein*, which is a Greek verbal form for the past (aorist passive) of the verb *magênai*, meaning 'to knead'. Other variations deriving from **mag-* are *mágeiros* and *mageús*, meaning cook and baker, respectively (ONIONS; FRIEDRICHSEN; BURCHFIELD, 1966).

So, yes, the first *makers* whose written language has registered with the same idea carried by the current English language verb 'to make' were food makers.

At this point, the reader may question: Does the history of Makers distinguish from the history of humankind? The most direct answer to the concern of this work is that they are distinguishable, in the sense that although 'we are all makers', not necessarily everyone integrates into or feels belonging to the Maker Movement (ANDERSON, 2012).

Nevertheless, there is still a historical journey ahead to achieve this distinguishability. Consider the link between making and creating when it is more sophisticated than simply building tools and using them in a trial-and-error approach: the historical voyage is getting close to what is known as Design (BUCHANAN, 2009).

This difference from either randomly trying to use tools to build something or using them to copy what is already in nature to building something based on an imaginary idea, an 'image', for that matter, of what one is supposed to build: that is the difference from what happens in the wild ape's brain to the homo faber's mind (FLUSSER, 2011).

Aristotle was a foundational author of the Western culture. He first named these steps between the need for an artefact and its construction, the steps happening inside the mind. Previously, the term *methodos* was already used by Plato, meaning 'way after'. However, in this case, Aristotle is credited for calling the above steps 'method'. That is because he differentiated the methods of Greek Philosophy into three types (BUCHANAN, 2009).

One was Plato's dialectics, the reasoning based on arguments and counter-arguments. Another was Democritus' 'physical way', the atomist principle, where conceptions come from sensations and atomic basics combine to form more complex structures synthesising the material world. The third one, the one of particular interest here, Aristotle claims to be midway from the other two (BUCHANAN, 2009).

Epistemologically speaking, this philosophical method, sitting between the ideals derived from dialects and the materialist true from the physical way, perfectly fits as a philosophic basis for Design, not only as the human endeavour towards materialising something from an idea but also as a field of knowledge and its methods (BUCHANAN, 2009).

Fast forwarding to contemporary times, Design, embodied in the concept of a project to be built or a plan to be followed, becomes an existential need. At the individual or social level, it is a fundamental activity defining how things are and are supposed to be (BOUTINET, 2012).

At the individual level, based on previous experiences, Design allows an individual to consider previous experience to make new decisions, i.e., "prevents the individual from wallowing in the compulsion of repetition, by encouraging them to create something new" (BOUTINET, 2012, p. 380)[6].

---

[6]Free translation from the original: '(…) évitera à l'individu-acteur de se complaire dans la compulsion de repetition, en l'incitant à créer de l'inédit (…)'.

At the social level, Design helps society evolve from a present state to a future one, as “society can reformulate itself by its ability to produce a new order, to generate change and innovation, in short, to lead us to shores so far unknown”. (BOUTINET, 2012, p. 122)[7].

Before finishing this historical perspective, let us first revisit the concept of who has the potential to be a maker, now through the words of a Design author:

> Everyone has a creative nature. Everyone is naturally equipped to receive and assimilate sensory experiences; to think and to feel. (…) It has to be said again and again that everyone is sensitive to musical tones, to colors, to touch and space relationships: that is to say, everyone is able to participate in the entirety of such experiences and everyone can produce non-verbal expression in any medium. Every normally healthy man can articulate the material of the musician, painter, sculptor just as he can articulate language, the verbal material of the speaker. (…) These types of expression are not always synonymous with the "art" of the "professionals" but they are examples of a life governed by inner necessities. (MOHOLY-NAGY, 1947, p. 25)

Further, the author gives us a glimpse of how anyone could start to have ideas, try to design, and *make* things; yet, he adds his commentary on what it would mean for a human being to be deprived of this endeavour:

> People may start with the eternal recurrent psychophysical reaction to their surroundings as well as to the materials of expression, such as color, sound, volume, space. Theoretically, everyone may start out almost as prehistoric man, because even such a start would help him to gain an emotional "literacy," that is, the ability to articulate material stimulated by emotional impulses. This can lead to recreation and enjoyment through the aesthetic appreciation generated by experience and acuity of discrimination. But this is yet rare. Our culture is full of those illiterates who cannot read or write and the others – the illiterates of the emotional life, who live without ever attempting to translate their emotions into meaningful expression. To live without this means emotional starvation just as missing food means starvation of the body. (MOHOLY-NAGY, 1947, p. 25–26)

Through the previous excerpt, we can visualise the link between the idea of the *homo faber*, which, in the sense of building abilities, succeeds the ‘primitive man’, and everyone that wishes to build something departing from an idea, wherever the origin of this idea is. That link is the ability to coordinate the steps necessary to make the whole material into an artefact.

László Moholy-Nagy not only established that link, but he also goes further when stating that the human endeavour of building things is an actual need for our

[7]Idem: ‘(...) la société peut se definir par sa capacité à produire un ordre nouveau, à engendrer le changement et l'innovation, en un mot nous acheminer vers de rivages inconnus de nous jusqu’ici’.

emotional fulfilment since the results of this activity can also be understood as physical expressions of our very emotions (MOHOLY-NAGY, 1947).

Since, through the last excerpt, this text has just positioned the historic journey in the first half of the twentieth century, let us now get into several publications from this time on that helped give birth to the ‘Maker Culture’, the culture where the Maker Movement is inserted. The following paragraphs deal with magazines and other essential publications that derived from and helped shape the Maker Culture before it was even a concept. Those publications do so until the present day. Although the term ‘Maker Culture’ was not yet invented, considering its possible definitions, its concept was already underlying inside its foundational pillars, even as an embryo (ANDERSON, 2012).

If we consider the fields that most contributed to the formation of the Maker Movement, focusing on those enabled by the technological advancements of the twentieth century, two significant fields stand out: electronics and mechanics (DOUGHERTY; CONRAD, 2016).

Both of these fields have a plethora of publications dedicated to different sorts of public, from the absolute layman to senior members of a scientific board in the field (DOUGHERTY; CONRAD, 2016). Nevertheless, to get representative examples of each field, let us use the criteria of being still published and having a broader scope of content – attractive to the layman and the senior scientist simultaneously – for both fields. The criterium of antiquity for mechanics, as this area dates back to long before the twentieth century, and the criterium of a wider spreading around the world for electronics, considering the number of languages and the number of countries it has been published on, so achieving a more diverse public than other publications.

Starting from Electronics, we have the example of Elektor™ magazine. Although it is not the oldest popular publication in the field, it has been translated into the greatest number of languages and published in the greatest number of countries. It has editions with local specificities in more than fifty countries in the five continents and has been published in English, German, Portuguese (European and Brazilian), Spanish, Greek, Dutch, Italian, and Swedish (ELEKTOR INTERNATIONAL MEDIA, 2019).

In their ‘about’ webpage, a statement drives us back to our theme: “Elektor has been a household name in the global world of electronics for more than six decades. With the publication of Elektuur in the Netherlands in 1961, we helped launch and drive the first electronics maker movement”. (ELEKTOR INTERNATIONAL MEDIA, 2019, p. 1).

Now, let us look at the area of Mechanics. Having its first issue in 1902, Popular Mechanics™ stands as the oldest publication on practical mechanics still published in present days. Their self-description on their ‘about’ webpage also contains important concepts further explored in this chapter:

> We bring our audience the latest news on innovations and inventions across the automotive, DIY, science, technology, and outdoor spaces. We also serve our readers with the knowledge they need to get the most out of life, whether that's how to change a tire, how to build a farmhouse table, how to find your lost phone, or how to hike the Appalachian Trail. Popular Mechanics is about wonder, about being curious about the world around you, and it's about getting your hands dirty, too. (HEARST MAGAZINES, 2018, p. 1)

Previously, in the Introduction’s second paragraph, Chapter 1, the present text introduced the idea of a Maker Movement fuelled by DYI initiatives, whether at the individual level or with a knowledge-sharing approach. Therefore, the previous extract makes a direct connection to those concepts. For example, when Popular Mechanics™ mentions ‘outdoor spaces’, in this context, one example of that would be a Maker Fair™ (HONEY; KANTER, 2013). Likewise, for Elektor™, there is a straight connection to the universe of ideas at work in the present research when they mention ‘the first electronics maker movement’.

The present text makes the example of those magazines more tangible by replicating a few pieces. Starting from Elektor™: their first English language issue was published in December 1974. Figure 8 shows the summary of that issue. As seen in their descriptions, its items are detailed sources for the Electronics enthusiast to build the projects listed. Through the pages of that magazine, the reader can find not only the building steps and a suggested design for each project but also a theoretical explanation of the subject, besides the respective electronic components list (ELEKTOR PUBLISHERS LTD., 1974).

Figure 8 – Contents of the first issue of Elektor™ magazine.

contents elektor december 1974 – 7

contents

Source: reproduced with the rightsholder permission from Elektor Publishers Ltd. (1974, p. 7).

Figure 9 shows the example of page 49 in the first issue of Elektor™. The project of a 'flickering flame'. It consists of making a hack[8] with a fluorescent lamp starter to make it into a component of a blinking circuit, like a Christmas tree light string.

Figure 9 – Instructions for making a 'flickering flame'.


flickering flame

elektor december 1974 – 49

flickering flame

The simplest possible flasher device is a bimetal switch. This construction can be found in 'blinker bulbs' and in the starter-switch associated with a fluorescent lamp.
The possibility immediately comes to mind of using a fluorescent-lamp starter as a flasher for Christmas-tree or other decorative lights. If one uses more than one starter in some combination of several lamps or lamp-groups, highly varied and interesting effects can be obtained.

The basic idea is shown in figure 2. The starter is wired in series with the lamp or lamp-string (such as Tree-lights).
When mains voltage is applied across the series combination the inert-gas mixture in the starter becomes conductive and a current-carrying glow-discharge occurs between the electrodes. One of these electrodes is actually a 'bimetal', two thin strips of different metals – having two different thermal expansion coefficients – welded together. Such a bimetal will curl (or uncurl) when it is heated. In the fluorescent-lamp starter the discharge current through the gas provides the heating, and the curling of the bimetal is arranged to cause a short-circuit between the glow-electrodes. This removes the supply of heat, so that the cooling bimetal reopens the circuit a second or two later.
The lamp connected in our arrangement will therefore flash more or less regularly on and off. The current which may be switched by the starter depends on the rating of the lamp for which the manufacturer intended it. The best place to find this rating is the label on the 'ballast' device. Alternatively, assume that if the starter (e.g. Philips type S10, see photo) is intended for fluorescent tubes up to 80 watt rating, that it will safely switch ordinary filament lamps to this amount.
Note that the starter normally becomes 'dormant' when the arc-type gas discharge in the fluorescent tube 'strikes'. This is because the voltage across the steadily burning arc is too low to allow the starter-glow to re-ignite. In our application there is no suah effect, so that the 'starter' will flash its load continuously.
It is however possible to dream up circuits in which more than one starter is combined with a split-up load in a way which makes fuller use of the properties of a given type of device. As an example take figure 3. This circuit will do the wildest things, depending on the individual starters and on the load values.
Suppose that L_2 has the lowest wattage. When the mains is applied it will burn more or less brightly. As soon as one of the starters makes contact, either L_1 or L_3 will come on full and L_2 will go out. When the second starter makes contact all the lamps have the full voltage applied – but almost immediately the first starter will reopen . . .

Figure 1. Photograph of a partly dismantled fluorescent-lamp glow-starter. Note the suppression capacitor.

Figure 2. The simplest possible flasher circuit consists of a single starter wired in series with a filament-lamp load.

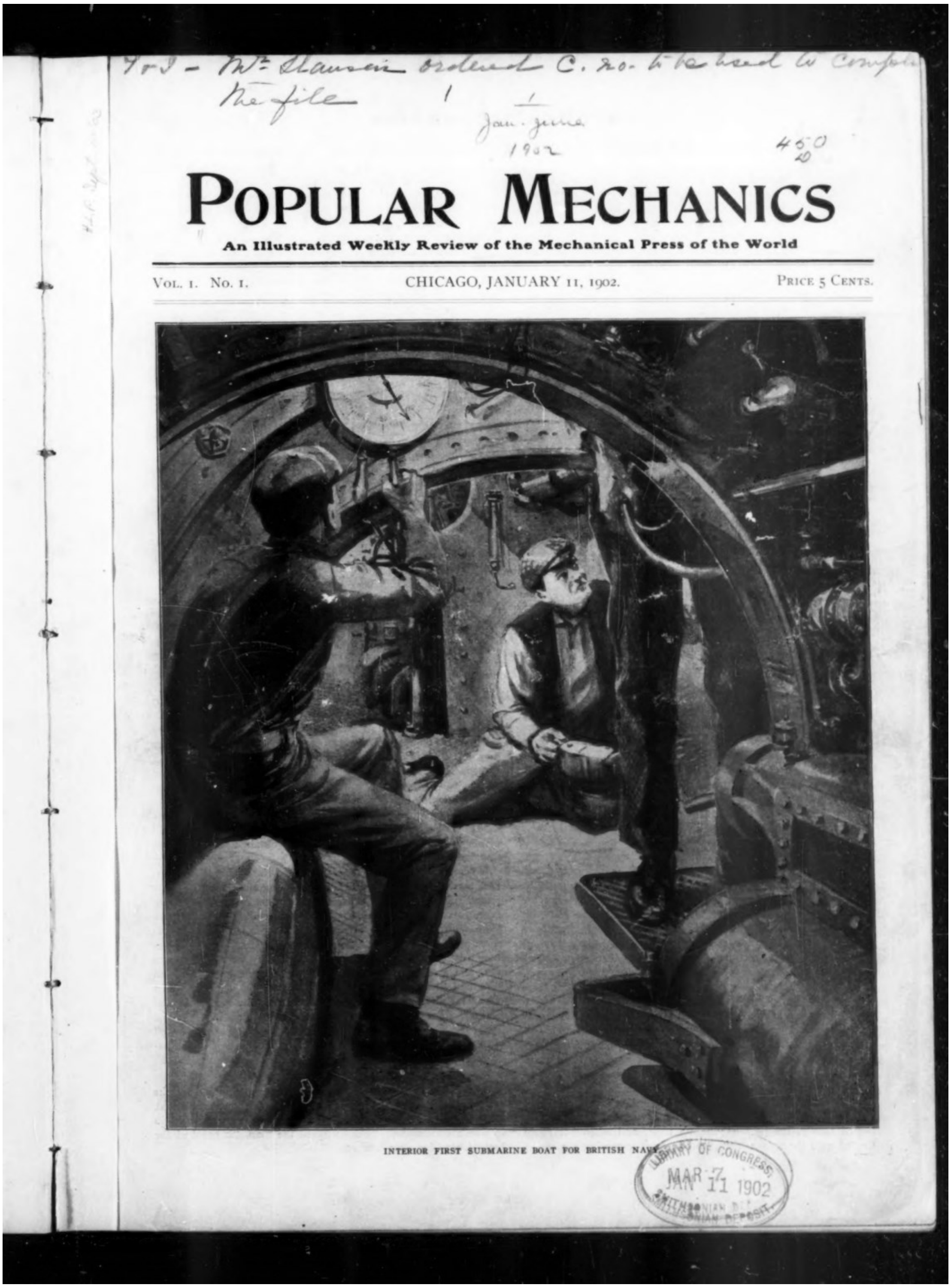
Figure 3. Example of a more complicated arrangement. Two starters and three lamps (or lamp-strings) of unequal wattage will provide a highly variable flickering-effect.

Source: reproduced with the rightsholder permission from Elektor Publishers Ltd. (1974, p. 49).

[8]Hack, in this context, means "a quick and clever solution to a problem" (HACK - COLLINS ONLINE DICTIONARY, 2023).

The same kind of information can be found in Popular Mechanics™ for the field of Mechanics. In its first issue, back in 1902, that magazine already brought to the reader several articles focusing on theory explanation and several others detailing how to build a particular project. Figure 10 and Figure 11 show that.

Figure 10 – Cover of the first issue of Popular Mechanics™.



Source: reproduced from the work under public domain Popular Mechanics Co. (1902).

In the article depicted in Figure 11, we have the explanation of how to and the materials needed to build a 'water motor' powered by running water, which would be helpful in situations when a place lacks a working connection to the electric distribution system (POPULAR MECHANICS CO., 1902, p. 9).

Figure 11 – Instructions to build a 'water motor'.

January 11, 1902. POPULAR MECHANICS 9

HOW TO MAKE A WATER MOTOR.

Will Drive Fan, Generate Electric Light or Run a Sewing Machine.

If you haven't an electric motor in your own house a little mechanical ingenuity, aided by oil cans, a wash basin, a brass tube and other simple paraphernalia may enable you to construct a water motor for yourself. Mr. E. J. Prindle having occasion for a small amount of power in a house where no electricity was to be had, thus succeeded in making a motor of 1/12 horsepower. This was sufficient to run an 8 or 10-inch fan, a small dynamo or other light machinery. Mr. Prindle in the Iron Age tells how the motor was constructed:

Fig. 1.—Motor in Operating Position

Fig 2.—The Wheel

Fig 3.—Motor Inverted.

"The only available water power was that to be found in a fixed wash basin. This resulted in adapting the reaction wheel to a horizontal position to fit the necessity. The wheel consists of a horizontal cylinder on a vertical shaft, having nearly semicircular buckets on its periphery. The water is directed by the nozzle nearly tangential to the upper side of the bucket, and after traversing around the wall of the bucket it leaves in a nearly horizontal line in the opposite direction to that from which it entered. As the water leaves the bucket it drops slightly below the level of the wheel and falls into the basin, from which it passes off through the drain pipe. The wheel and casing are supported on a piece of wood that is 7/8 x 2 inches in section and 18 inches long. At a point 8 1/2 inches from one end a hole 5/8 inch in diameter is bored to allow for the passage of the shaft. Five and one-half inches on each side of the hole for the shaft is a small hole to accommodate a screw threaded rod that is bent at a right angle at the lower end. By turning the bent end of each rod to engage the under side of the top slab of the wash stand and turning the nuts to draw up the rods, the piece of wood is securely clamped to the basin. A bearing is formed for the shaft by screwing to the wood two pieces of 1/4 x 3/4 inch iron that are 1 1/2 inches long. Each piece of iron contains half of a 3/8-inch hole that is occupied by a neck on the shaft. The object in making the bearing in two pieces is to enable it to be placed around the neck of the shaft (this neck being necessary to prevent endwise motion of the shaft) and to allow of adjustment for wear. The shaft is 1/2 inch in diameter and 6 inches long. The lower end is reduced to 1/4 inch in diameter for a distance of 1/2 inch. A neck 3/8 inch in diameter is turned for 1/4 inch, beginning at a point 2 inches from the upper end. The lower end of the shaft is stepped in a stirrup that depends from the under side of the piece of wood. The stirrup is made of 3/4 x 1/4 inch iron, and a piece that is 15 1/2 inches long is required. The feet by which it is attached to the wood are 1/2 inch in length, the vertical arms are 2 1/2 inches inside measurement, and the horizontal cross piece is 9 inches long.

"The wheel, Fig. 2, is built up on a block of wood that is square for convenience. The sides are 4 inches in length, and the thickness is 1 1/2 inches. A 1/2-inch hole is bored exactly in the center and perfectly at right angles to the sides of the block. Two disks of galvanized sheet iron 7 inches in diameter are cut and provided with 1/2-inch holes at the center. These disks are secured with round head screws to the block. A strip of the sheet metal 1 1/2 inches wide and 22 1/2 inches in length is bent into a hoop of the diameter of the disks, and its ends are soldered together. The hoop is then sprung over the disks, and is securely soldered at its edges to the peripheries of the disks. The hoop is now divided into 16 equal spaces by lines running across its face.

"To form the buckets, eight disks 1 1/2 inches in diameter are cut from the sheet iron, and each disk is then cut in half. Strips of iron 1/2 inch wide and 2 3/8 inches long are next soldered to the semicircular edges of the small disks. The buckets are then accurately placed on the lines that have been drawn on the hoop of the wheel and are soldered in place around the outside. A keyway is cut the entire length of the shaft and the wheel is keyed in place.

"To prevent splashing and to support the nozzles, a casing is necessary. This consists simply of a disk 9 inches in diameter having an apron 2 1/2 inches deep that is soldered around the periphery of the disk. The length of the strip that forms the apron is 29 inches. The casing is screwed to the under side of the piece of wood and to the arms of the stirrup. To support the nozzles firmly in the somewhat yielding casing, two pieces of 3-16 inch brass tubing 1 1/2 inches long are soldered into holes in the apron of the casing 3/4 inch below the upper edges, and are set in a line that is tangential to a circle 7 1/2 inches in diameter. The nozzles are taken from zinc oil cans such as may be bought anywhere for from 5 to 10 cents. With a bracket saw the nozzle is cut off to afford an opening of 1/8 inch. The nozzles are carefully soldered in the center of the short tubes. The screw threaded end of the oil can spout is convenient for attaching rubber tubing.

Source: reproduced from the work under public domain Popular Mechanics Co. (1902, p. 9).

Now, heading straight to the third millennium, another magazine deeply related to the Maker Movement is Make:™ magazine, see Figure 12. Make:™ was created to bring a wide variety of DIY projects to the public, not only involving Electronics and Mechanics. The focus was not on specific areas but on dealing with the world around as customisable as possible. Therefore, the magazine brings DIY projects to the public to start from 'zero', from raw materials and projects to modify things to get the desired result. The word they use to describe the latter case is 'hack'[8] (DOUGHERTY; CONRAD, 2016).

> Before *Make:* there wasn't a contemporary magazine that reflected the DIY mindset around technology. Existing technology magazines viewed it in a narrow business-driven sense. They mostly covered the release of new products, but they didn't suggest satisfying projects for readers to do. I wanted the magazine and the projects in *Make:* to include all the technologies in our lives, not simply the newest: the old ones for cooking and woodworking alongside the new ones like 3-D printing and laser-cutting. Before *Make:,* there were DIY magazines for cooks and woodworkers but not for hackers. I set out to create a magazine for people engaged in personalizing, modifying, hacking, and creating, in the broadest possible sense. *Make:* is a bridge between the new world of hackers and the older world of traditional craftspeople, tinkerers, and hobbyists alongside the punks, crafters and DIYers. All these individuals share a DIY mindset, a determination to remake the world and adapt it to their own ideas, with the unstated assumption that this will make the world a better place. The magazine gave them a new name: makers. (DOUGHERTY; CONRAD, 2016, p. 23).

The previous excerpt brings us to two conclusions. One is that the creator of Make:™, Dale Dougherty, was not trying to let the previously existing DIY universe in the past. He wanted to use that, but aggregating various groups around their common ethos of doing things themselves. The other conclusion is finishing this part of the text about magazines, not before giving examples from the Make:™ magazine itself. Following the previous cases, let the first issue of Make:™ serve as an example.

Figure 12 – Cover to Make:™ magazine's first issue (left) & the first page of its list of contents (right).

Source: reproduced with the rightsholder permission from Dougherty; O'Reilly Media (2005).

Figure 13 – First page of instructions for the project '$14 Video Camera Stabilizer'.

PROJECTS: $14 VIDEO CAMERA STABILIZER

www.makezine.com/01/stabilizer

MAKE IT.

BUILD YOUR STABILIZER IN 5 EASY STEPS

START>> Time: 45 min. Complexity: Low

1. MAKE THE HANDLE. This first step is pretty easy. Just attach the T-joint and one end cap to one of the pipes to form a basic handle.

Use the vise for final tightening. Don't use your hands to tighten the T-joint and end cap on the pipe. You'll just hurt yourself and not get it tight enough.

2. DRILL HOLES IN THE END CAPS. Put one of the end caps in the vise as shown. Then drill a ¼" hole in the center of the cap. It doesn't have to be perfectly centered, but the closer the better. You really want to use the vise because you're drilling through a quarter inch of galvanized steel. It's enough to bring weak drills to a dead stop and will definitely do a number on your hand if you just try to hold it. Not to mention it can get hot. Protective eyewear such as safety goggles should ALWAYS be worn when using any power tool. Also, a little bit of machine oil (or even vegetable oil) can make this easier and help preserve your drill bit.

I like using a slow speed because when the bit comes out the other side, it'll jerk from grabbing onto the metal. It's far more pleasant to have a slow jerk than to have the drill suddenly fly out of your hand.

Do this for two end caps.

Do your drilling in an area that's easy to clean up. You'll produce lots of metal shards. And don't use your fingers to wipe away the shards! They'll get in your skin. Use a brush or a vacuum.

Photography by Evan McNary

90 Make: Volume 01

Source: reproduced with the rightsholder permission from Dougherty; O'Reilly Media (2005, p. 90).

Figure 13 shows the project of a US$14.00 camera stabiliser that is supposed to stand up to the functionality of a US$10,000.00 commercial one (DOUGHERTY; O'REILLY MEDIA, 2005). The wish to make affordable things and make things affordable, adds to the ethos of the Maker Movement. That is one of the reasons why hacking things, not only software but hardware too, in the sense of customising them, is a widespread mindset in the Movement (HATCH, 2014).

All the universe generated and reproduced by the magazines, such as those presented above, is also the theme of several books. These books are seminal works, fundamental to those trying to understand the theme (HONEY; KANTER, 2013).

For example, taking the book by Dale Dougherty, which has been cited several times, the reader can find a reasonable explanation about the Maker Movement and Maker Culture, their members – the makers – social aspects of them and the events related to the Movement, and so on (DOUGHERTY; CONRAD, 2016).

Making a backward reference search from Dougherty and Conrad (2016), two more books help shape and give identity to the Maker Movement. Those books are a manifesto by Mark Hatch (HATCH, 2014) and an essay implying that even a new industrial revolution could start within the Maker Movement (ANDERSON, 2012).

In the case of Anderson (2012), the reasoning goes in the way of how things are changing regarding technology, widespread access to it, and new possibilities concerning how digital technology can produce goods and who uses that technology. He advocates the idea that, since any person with an average commercial desktop computer can design everything that comes before the physical building of a product by using that same computer and even free software in many cases, the chances are we face, in the following decades, a considerable shift from a traditional office-and-factory production model to a home-and-community one (ANDERSON, 2012).

Considering the Introduction's content (Chapter 1), the reader can identify a direct connection between what Anderson (2012) says and what the Redistributed Manufacturing model proposes, which this chapter further details.

The Maker Movement Manifesto (HATCH, 2014) is a collection of principles the author identifies as the basic principles of the Maker Movement. Thus, if people follow these principles, they could consider themselves connected to the Maker

Movement. Table 3 contains these principles and their explanation, according to Hatch (2014).

To finish this historic journey about the maker, let us have some educated guesses of a possible future. The present research builds Table 4, based on Anderson (2012), for conciseness, specifically in the part where the author describes several production processes allowed by several technologies and perspective changes. These technologies and perspectives still feed new productive possibilities (MA et al., 2023; MORITA; TSUDA, 2023).

Table 3 – Maker Movement principles.

Principle	Description
Make	Making is fundamental to what it means to be human. We must make, create, and express ourselves to feel whole. There is something unique about making physical things. These things are like little pieces of us and seem to embody portions of our souls.
Share	Sharing what you have made and what you know about making with others is the method by which a maker's feeling of wholeness is achieved. You cannot make and not share.
Give	There are few things more selfless and satisfying than giving away something you have made. The act of making puts a small piece of you in the object. Giving that to someone else is like giving someone a small piece of yourself. Such things are often the most cherished items we possess.
Learn	You must learn to make. You must always seek to learn more about your making. You may become a journeyman or master craftsman, but you will still learn, want to learn, and push yourself to learn new techniques, materials, and processes. Building a lifelong learning path ensures a rich and rewarding making life and, importantly, enables one to share.
Tool Up	You must have access to the right tools for the project at hand. Invest in and develop local access to the tools you need to do the making you want to do. The tools of making have never been cheaper, easier to use, or more powerful.
Play	Be playful with what you are making, and you will be surprised, excited, and proud of what you discover.
Participate	Join the Maker Movement and reach out to those around you who are discovering the joy of making. Hold seminars, parties, events, maker days, fairs, expos, classes, and dinners with and for the other makers in your community.
Support	This is a movement, and it requires emotional, intellectual, financial, political, and institutional support. The best hope for improving the world is us, and we are responsible for making a better future.
Change	Embrace the change that will naturally occur as you go through your maker journey. Since making is fundamental to what it means to be human, you will become a more complete version of you as you make.

Adapted with the rightsholder permission from Hatch (2014, p. 1).

Table 4 – Future possibilities concerning the Maker Movement[9].

Technology/ Perspective change	Explanation/Examples	Production process possibility
'Four desktop factories'	3D Printers, laser cutters, 3D scanner, CNC machines	Subsequent products can be different, have greater design complexity, different products do not require different machinery
Open hardware	Niche consumers consciously help develop a physical product's design before acquiring it.	Feasibility of prosumption[3].
Open innovation	The processes an organisation adopts to implement open development, whether a good, like in open hardware or service. Local Motors serves as an example.	An organisation's innovation process gets contributions from people outside the company.
Open organisation	At least in the beginning, companies have creative development open to the general public, like 3D Robotics.	That is how a company can accommodate the perspective of open innovation intrinsically in its processes in the company organisation.
Crowdfunding	Crowdfunding sites like 'kickstarter.com', 'patreon.com' and 'gofundme.com'	Project financing is from more flexible and accessible sources, with a lower interest than traditional bank loans/lending or even zero interest (grants).
Maker businesses	Hobbies that become businesses and makerspaces serving product development.	Innovation steps happening outside the traditional company environment
Online supply chain	Outsourcing sites like 'mfg.com'	Simplified and cost-saving manufacturing outsourcing from around the world through online transactions
DIY Biology	Unexpensive PCR machines, biosensors and Genetic Engineering technology	Specifically, in the area of medicine, decentralised access to testing and health monitoring

Based on Anderson (2012, p. 73–230).

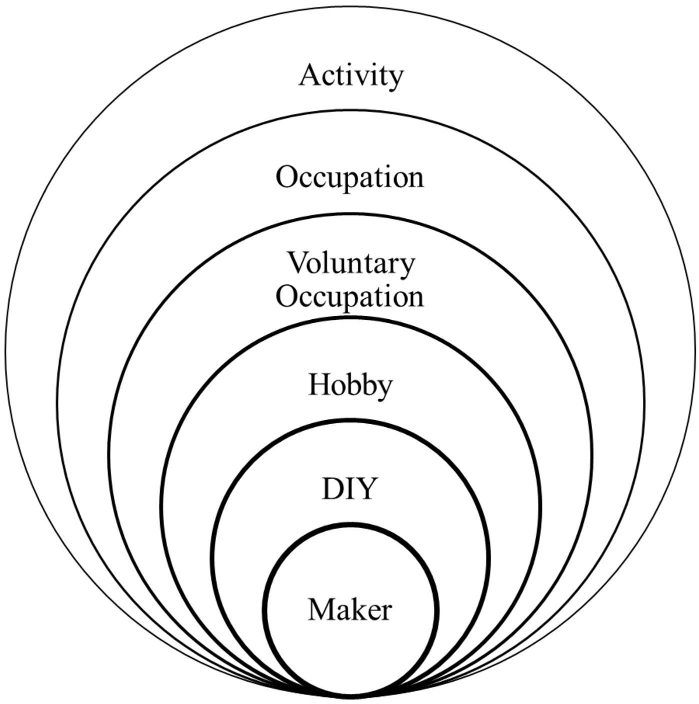
[9]References in Table 4: Local Motors developed niche cars from consumer input (ANDERSON, 2022). Crowdfunding sites let people propose and fund projects (GOFUNDME, 2023; KICKSTARTER PBC, 2023; PATREON, 2023). Outsource means to subcontract work to another organisation (MFG, 2023; OUTSOURCE - COLLINGS ONLINE DICTIONARY, 2023). PCR stands for Polymerase Chain Reaction, a technique to amplify DNA used in disease testing (MADDOCKS; JENKINS, 2017). Biosensor: a sensor that interfaces with biologic phenomena (BIOSENSORS - SCIENCEDIRECT, 2023). Genetic Engineering – direct manipulation of an organism's genes (GENETIC ENGINEERING - SCIENCEDIRECT, 2023).

2.1.2 Who is the Maker?

We have just been through the historical development that builds up to the existence of individuals who self-identify as members of the Maker Movement. Thus, let us explore their existence: Who is the Maker?

First, an ontological perspective locates the Maker in the taxonomy of a human being doing something. 'Doing something' means carrying out an *activity* of any sort. This activity may relate to personal skills and be of some social significance to the individual practising it. That means this person has enrolled in an *occupation*. That occupation may be either a job-related or a voluntary one. If it is voluntary, it may be a *hobby* (AZEVEDO, 2013; DAHLIN; TAYLOR; FICHMAN, 2004; DAILY, 2018; GELBER, 1991). Figure 14 shows these layers to classify the activity of a Maker.

Figure 14 – Layers of a Maker's activity.



Source: Author.

The bridge from the hobbyist to the Maker is the practice of DIY activities. One can fish as a hobby and not be a Maker. However, there is a potential Maker when the reel cranks, and that person tries to figure out how to fix it or even builds the rod themselves. The subtle difference now is if that behaviour is a standard for that person or if it is a rare case (DAILY, 2018; HATCH, 2014).

Let us investigate this subject since the DIY approach is part of the Maker's definition. Following, there is an exploration of literature related to DIY practices.

The studies on DIY activities indicate three main areas where people have used this approach in any part of their lives in recent years. They are DIY science and technology, DIY urbanism, and DIY consumer behaviour (ATKINSON, 2006; KUZNETSOV; PAULOS, 2010; RODGERS et al., 2020). Therefore, this work uses a definition for DIY activities embracing those three perspectives:

> DIY acts as the antithesis of the prescribed design of the mass marketplace – a democratizing agency allowing people, paradoxically, to react against the principles and edicts of design connoisseurship whilst simultaneously enabling the emulation of those above them in social hierarchies. (ATKINSON, 2006, p. 1).

The following definition complements the above one in a more practical sense: "[DIY is] any creation, modification or repair of objects without the aid of paid professionals" (KUZNETSOV; PAULOS, 2010, p. 295).

- **DIY Science and Technology**

In the science and technology branch, the discussion goes towards the possibilities that research and development (R&D) set-ups outside the institutional environment (like universities and private companies) would allow democratised access to R&D (LHOSTE, 2020). Places that embed those set-ups vary in sophistication, from poorly equipped kitchens and garages to highly tooled-up makerspaces and community laboratories (FERRETTI, 2019; TANENBAUM et al., 2013).

Part of the literature inside that ramification concerns the various impacts that DIY R&D may have on society, either positively or negatively. For example, there are concerns that DIY Biology[9] may generate harmful subproducts, like lethal substances and microorganisms, which could facilitate the action of bioterrorists. Conversely, DIY science and technology can generate a greater engagement of society in general around R&D and that can lead to more investments in the sector (SARPONG et al., 2020).

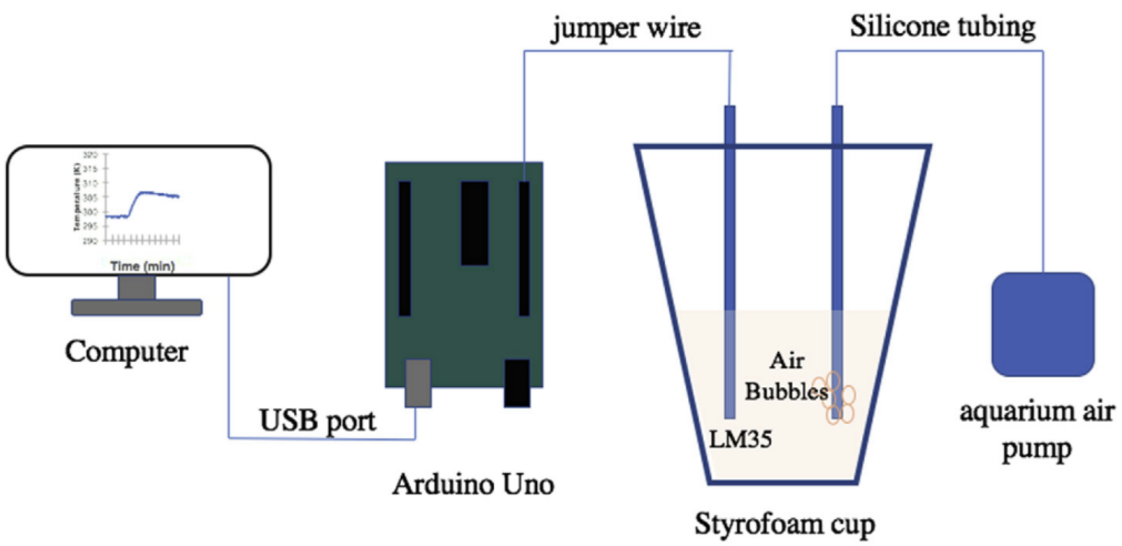
Those considerations on societal impacts help orientate policies concerning DIY science and technology. More specifically, regarding the positive side, it is possible to envision when this subdivision of DIY enables entrepreneurship and helps economic development, especially in developing economies. Therefore, investments in the sector can be aligned accordingly (MEISSNER et al., 2021; WULANDHARI et al., 2021).

DIY entrepreneurship is the DIY basis leading to Maker businesses, in the same sense described in Table 4. It consists of products developed outside traditional company borders by either novice or experienced entrepreneurs (FOX, 2013; REZAEE VESSAL et al., 2021). Let us see three examples in the literature to illustrate this type of DIY activity.

Vallejo, Diaz-Uribe and Fajardo (2020) developed a DIY setup for an introductory chemistry laboratory. Educational institutions can use that setup for teaching chemistry principles. In-home laboratories can use it, too, for recreational purposes.

Their measuring system comprises an ARDUINO™ board that acquires the data from the sensor, a computer to visualise the data, and an LM35 thermal sensor. The sensor is put in a cup of water to sense the temperature. Additionally, they use an aquarium pump and a straw to generate bubbles that take heat from the water (VALLEJO; DIAZ-URIBE; FAJARDO, 2020). See Figure 15.

Figure 15 – DIY entry-level chemistry ‘calorimeter’.



Source: reproduced with the rightsholder permission from Vallejo, Diaz-Uribe and Fajardo (2020, p. 5).

The work of GAVER et al. (2019) has an example of a DIY set-up for nature observation that can be used either for research or as a hobby. The authors build a set-up (Figure 16) that embeds a tiny 5-megapixel camera, a Raspberry Pi™ controller board and batteries. Software coded into the Raspberry Pi™ controls the whole system. It is supposed to automatically identify and capture animals passing in front of the camera. They made ‘My Naturewatch Camera’ to provoke “large-scale engagement with research products by encouraging people to make DIY devices designed to promote engagement with digital making and local wildlife" (GAVER et al., 2019, p. 2).

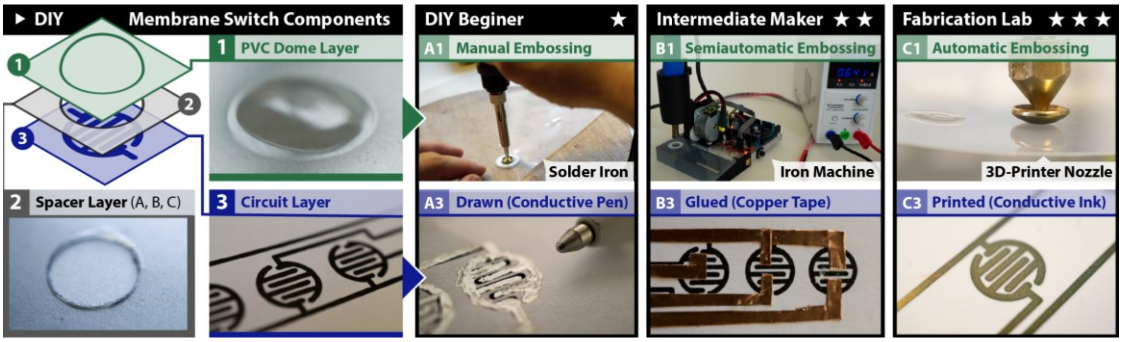
Figure 16 – Typical My Naturewatch Camera housing.

Source: reproduced with the rightsholder permission from Gaver *et al.* (2019, p. 5).

The third case of DIY science and technology consists of a process to make membrane switches. These devices can be used even for professional-grade equipment; thus, this example places the DIY approach vis-à-vis traditional manufacturing techniques in terms of design capability. In "Pushables" (KLAMKA; DACHSELT, 2018, p. 1), the authors create a tactile membrane switch using simple tools and materials, like an upholstery nail attached to a controlled temperature solder iron and a polyvinyl chloride (PVC) film (0.2mm thick), besides a conductive ink pen.

The authors devised this more straightforward approach and established two other ways to build the switch, one more complex than the other but still inside the DIY logic (KLAMKA; DACHSELT, 2018). See Figure 17 for details.

Figure 17 – The ‘Pushables’ approach provides an easy pipeline to fabricate custom membrane dome switches. Our tactile dome switches consist of a 1 PVC dome layer, a 2 spacer layer, and a 3 circuit layer.



Source: reproduced with the rightsholder permission from Klamka and Dachselt (2018, p. 2).

- **DIY Urbanism**

The second branch of DIY is DIY urbanism. It consists of “activities enacted in public space that to some degree attempt to emulate or augment formal municipal designs and infrastructure” (FINN, 2014, p. 382). The objective is to build innovative, ingenious, cost-effective solutions to complex or unaddressed urban problems. These actions are not responses to requests or funded by public art commissions but arise from citizens seeing an unmet need in urban space and responding to it (FINN, 2014; IVESON, 2013). Following there are several examples.

Figure 18 depicts a project called ‘PARK(ing) Day’:

> PARK(ing) Day was created in 2005 by the San Francisco art and design collective Rebar, when members turned a metered municipal parking space into a small urban park for 2 hours (the parking meter’s time limit). The idea quickly went viral and for 2011’s PARK(ing) Day (September 16, see [Figure 18]) activists created 975 temporary pop-up parks in 162 cities in 35 countries on six [sic] continents (FINN, 2014, p. 383).

Figure 18 – Park(ing) Day 2011 in New York City.

Source: reproduced with the rightsholder permission from Finn (2014, p. 384).

Another example of DIY urbanism is the installation of unauthorised street furniture in points lacking them, like a bus stop with no waiting seat. Figure 19 has the example from Steve Rasmussen Cancien, a landscape designer who, in collaboration with low-income communities in Los Angeles and West Oakland, California, has mounted self-fabricated benches and plant vases (FINN, 2014).

Figure 19 – DIY street furniture in south Los Angeles

Source: reproduced with the rightsholder permission from Finn (2014, p. 384).

- **DIY Consumer Behaviour**

The third area where a DIY approach is identifiable is consumer behaviour. Although this tag may not suggest straightforwardly, this is the most commonly known type of DIY activity. The handyperson is in this category. That is the category for the fishers that fix (or even build from scratch) their own rod. People who always try to deal with a broken warranty-outdated home appliance before asking for a professional or head to the store for a new one are also in this category (WILLIAMS, 2004).

‘DIY consumer’ is the name of this branch and resembles people’s relationship with consumer goods. In this case, a more independent and even participative relationship: the idea of the prosumer[3] is at play again. Stephen Fox (2014) differentiates ‘DIY consumer’ into three historical phases. He calls them DIY waves, which relate to the technological level at a certain point in history. The first one, subsistence DIY, is everything predating the First Industrial Revolution. It encompasses anything a person or community makes for themselves, from people building their own houses to subsistence agriculture.

Then, the Industrial DIY came with the advent of machinery from the Industrial Revolutions preceding the Internet. In this phase, people build things depending on industrialised components, like those proposed in DIY magazines like Popular Mechanics™ and Elektor™ (FOX, 2014).

Finally, there is the latest wave. The Internet and digital fabrication equipment like 3D Printers, CNC routers and laser cutters enable that wave. That wave is called simply New Wave DIY or Third Wave DIY. The projects proposed in Make:™ magazine are examples of things built by people in this phase, which is the contemporary phase of DIY (FOX, 2014; MORITA; TSUDA, 2023).

Table 5 shows Fox’s interpretation of the prosumption during those three phases. He bases his analysis on three parameters: Resource-based theory (RBT), Knowledge-based view (KBV), and Transaction-cost Economics (TCE). The explanation for these parameters is the following:

> Within RBT, advantage arises from having resources that are difficult to imitate or substitute… Within KBV, advantage arises most from knowledge because, especially when tacit, knowledge can be the resource that is most difficult to imitate or substitute… Within TCE, advantage arises from determining how best to combine internal resources and external resources (FOX, 2014, p. 19).

Table 5 – Comparison of different types of prosumption.

Type of prosumption	Resource-based Theory (RBT)	Knowledge-based View (KBV)	Transaction-cost Economics (TCE)
First wave	Lack of specialised materials and equipment limits efficiency	Knowledge of only natural materials and handmade tools	Often make only, due to few, if any, purchases in market place
Second wave	Industrial materials and equipment, together with predefinition of design, increase efficiency.	Proprietary knowledge of task specialization, design for assembly, increase production efficiency	Prosumers buy or make according to personal evaluation of opportunity costs.
Third wave	Digitally-driven equipment and tailored materials increase efficiency without reliance on predesign	Continually evolving specialist knowledge through networked read/write of multimedia content	Prosumers buy, make or contribute according to the evaluation of opportunity costs, personal interests, and desire for recognition.

Source: reproduced with the rightsholder permission from Fox (2014, p. 22).

The idea of prosumption brings the matter of how involved in producing a good a consumer would be. The study of Dargahi, Namin and Ketron (2020) analyses this involvement through mathematical modelling, differentiating from the lowest possible, where the consumer buys the final product to the maximum possible, where consumers build the product from source materials – the DIY approach.

There are other possibilities between these extremes: co-creation, coproduction and customisation. The definitions adopted in their work are the following (DARGAHI; NAMIN; KETRON, 2020):

“Co-creation is the joint creation of value by the customer and the firm, through creating an experience environment in which consumers can have active dialogue and co-construct personalized experiences” (p. 3).

“Co-production is the customers’ participation in the production activities and is linked to the firm’s customization capabilities” (p. 3).

“Customization refers to modifying the characteristics of a product/service to make it closer to the preferences/needs of a customer” (p. 3).

The authors find that there are two more prominent consumer segments. One is the consumer who prefers their participation as co-producers of their products. The other is the person with the DIY approach, "likely to do entire tasks themselves (…) without the firm's help" (DARGAHI; NAMIN; KETRON, 2020, p. 8).

In their modelling, they use ideal preference and ideal design parameters associated with the above result. That means that the consumer would be completely satisfied with the outcome of their choice to either co-produce or with the DIY's result. That means that, in the case of DIY, the consumer would have an ideal process to achieve their needs (DARGAHI; NAMIN; KETRON, 2020).

Thence, the authors point to another consumer segment:

> Between those two segments resides a third segment, including all consumers whose ideals are neither close nor far from the firm's standard; these consumers are also DIYers, but choose an efficient but non-ideal design. These consumers cannot justify paying the firm to co-produce, yet they find DIY at their ideal preferences too costly, given their production ability. Thus, they end up choosing to DIY with sub-ideal design. (DARGAHI; NAMIN; KETRON, 2020, p. 8).

- **Defining 'Maker'**

After the exploration of DIY that the reader has just been through, which, as put before, is fundamental to defining the Maker, let us finally get into this matter.

Although this work concerns how Makers may relate to a specific production model (HENNELLY et al., 2019), the definition in use here, especially from now on, comes from an article in the area of Education.

In Martin (2015), the author investigates the influences of the Maker Movement in Education from a detailed exploration of literature on the movement. Hence, his work builds from that literature a definition for the Maker, the same as the present work uses:

"The Maker Movement is a community of hobbyists, tinkerers, engineers, hackers, and artists who creatively design and build projects for both playful and useful ends". (MARTIN, 2015, p. 1).

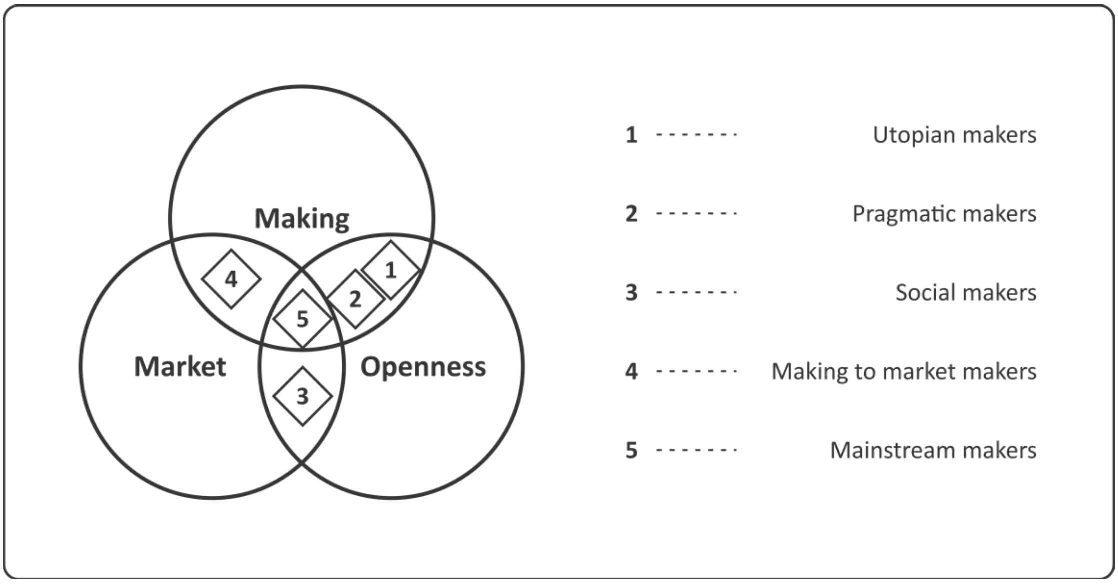
As seen above, we have just addressed two issues at once. The Maker is the individual that feels connected to the Maker Movement. That person may be one of these (or more than one simultaneously): 'hobbyists, tinkerers, engineers, hackers, and artists who creatively design and build projects for both playful and useful ends.' The Maker Movement's definition is the community of that people.

Two examples clarify the type of activities the above definition refers to. First, we can identify the Makers' profile regarding their attitude towards one of the three: market, making and openness, or their intersections (UNTERFRAUNER et al., 2020). The other profiling depends on the Maker's activity: what is the Maker making? (WOLF-POWERS et al., 2017).

Figure 20 has a diagram of the possible Makers' attitudes. They may have a bias for a marketable output of their activity. They can also participate in an open knowledge community where people share and gather information. Alternatively, Makers are just making something out of the individual fulfilment of doing so (UNTERFRAUNER et al., 2020). The following excerpt details the issue corresponding to each Maker type in Figure 20:

> 1. The first type, "utopian makers," perceives maker values as incompatible with market values or disassociates from market values. Makers of this type value openness very highly and show a fascination for technology and the process of "making";
> 2. The second type, "pragmatic makers," analyses this ambiguity and recognizes the opportunity to go beyond the traditional dichotomy between openness and market;
> 3. The third type, "social makers," characterizes makers for whom openness is a key to reduce entry barriers to the market. Many makers of this type identify themselves as part of a community rather than individual makers. Makers of this type often pursue less technical aims and link their activities to education, inclusion, or environmental protection;
> 4. The fourth type, "making to market makers," gathers cases where proprietary ways are favored to commercialize maker products. Attending makerspaces is often linked to the idea of product or career development and to learning and attending university courses;
> 5. The fifth type looks at cases where openness is turned into a competitive advantage, as long as it relies on a strong community. As all three cultural fields with their specific behaviors and attitudes are found here, we tend to call this type "mainstream makers." (UNTERFRAUNER et al., 2020, p. 196).

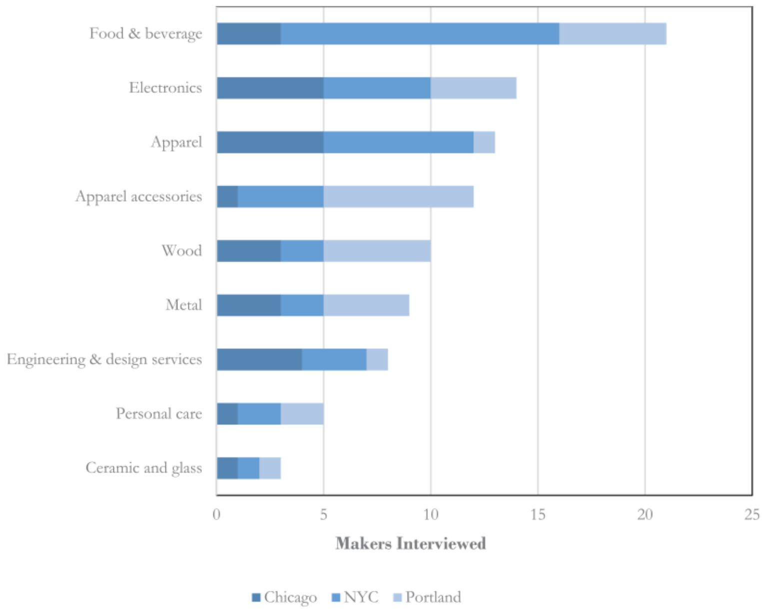
Figure 20 – Maker typology.



Source: reproduced with the rightsholder permission from Unterfrauner *et al.* (2020, p. 196).

The other profiling of Makers has to do with what they are building. This analysis also shows that Makers are not limited to digitally enabled technologies. They can be dealing with even ancient craftsmanship, like woodworking, metal forging, textile fabrication (sewing, knitting, crocheting, embroidery and others), cooking and baking, beverage and liqueur making; in short, almost every hands-on activity (ANDERSON, 2012; HATCH, 2014). Figure 21 depicts the distribution by type of some Makers investigated in three US cities (WOLF-POWERS et al., 2017).

Figure 21 – Variety of maker activities.



Source: reproduced with the rightsholder permission from Wolf-Powers *et al.* (2017, p. 368). Note: NYC = New York City

In the work above, the authors focus on the Maker Movement's influence on the urban economy. They investigated 'maker-entrepreneurs', "makers who were generating revenue from the production and sale of products they had designed" (WOLF-POWERS et al., 2017, p. 367). The axes in Figure 21 represent the segments of the enterprises (ordinates) and the number of interviewees in each segment (abscises). So, even in commercial enterprises, there is a variety of digitally enabled activities, such as Electronics and Engineering and design services, as well as those directly depending on craftsmanship, like Wood and Metal (WOLF-POWERS et al., 2017).

2.1.3 Maker Culture and Maker Movement

In the present subsection, this work differentiates two terms often considered interchangeable. They are, indeed, on some occasions. Therefore, both being and not being equivalent are further explored.

When the terms are exchangeable, they may replace one another without changing the text meaning. See the following example:

> On a physical level, the rise of the maker culture is closely associated with the rise of a totally new entrepreneurial ecosystem… hackerspaces, fab labs, makerspaces, tech-shops, co-working spaces, crowdfunding platforms…
> On a virtual level, sharing and cooperation in the Maker Movement is also facilitated by… internet-based sharing, marketing, distribution, and crowdfunding…
> The makers' culture is experimental and open… collaboration and sharing are so essential to the Makers Movement… collaborations and interactions are the backbone of the maker culture… The maker culture is thus less of a do-it-yourself (DIY) and more a do-it-together culture, merging collaborative play and interactions, often for the sake of shared curiosity. (GIUSTI; ALBERTI; BELFANTI, 2020, p. 2).

The authors of the previous excerpt use the terms modifying 'Maker', either 'Culture' or 'Movement', in sequence. That represents two possibilities (the 'physical level' and the 'virtual level') for describing the characteristics of groups of Makers. That means the authors refer to the same group when using the terms 'Maker Movement' and 'Maker Culture'.

The work of Browder, Aldrich and Bradley (2019) has another example:

> We note the importance of capturing the early history of the movement due to its rapid growth, evolving spaces and business models, and how it may impact the approach individuals and groups take in the development of new products outside traditional, large corporations. The collaborative nature of maker culture means that participants are often eager to share their stories and open to being studied. (BROWDER; ALDRICH; BRADLEY, 2019, p. 466).

Besides sequentially using the terms 'movement' (first line) and 'culture' (fifth line), modified by the term 'maker', without change of context, the previous extract also uses the word 'participants', referring to the Maker Culture.

Considering the dictionary definitions of 'culture', 'movement' and 'participants', the latter word fits better with the second than with the first (STEVENSON, 2010). Thus, considering the context of the passage above, the authors were referring to the Maker Movement but using the expression 'Maker Culture'. Hence, both expressions are equivalent.

If 'movement' substitutes 'culture' in a work, it uses the inverse logic of the last passage.

> (…) millions of citizens are engaging in consumer innovation activities related to products, and that their e ort could be invaluable for the industry… such product hacking activities could be considered partially as related to a broad Maker movement, and they could also be improved by connecting such citizen innovators with existing Maker communities (MENICHINELLI et al., 2017, p. 2).

Again, recurring to the dictionary and the context above, the adjective 'broad' (fourth line) is used instead of the modifier 'broader' (STEVENSON, 2010). Therefore, the authors are not implying a greater group but a more widespread characteristic of that group; i.e., they are using the term 'Maker Movement' instead of 'Maker Culture', with no change in meaning.

Before delving into the specificities of each of these terms, there is a midway in the literature where, during their writing, the authors use these expressions in different contexts, meaning different things, hence not interchangeable. Still, these texts do not specify these terms separately and objectively. The following paragraphs deal with that literature.

For example, when an article has both terms in its keywords, that is evidence that it treats the terms as different expressions. That is the case in Chan and Wu's work

(CHEN; WU, 2017). The authors write the text objectively separating these expressions, like in the following excerpt where they enumerate several works from Chinese scholars dealing with themes related to Makers:

> In recent years, especially in 2016, some Chinese scholars took scientific mapping knowledge to analyze hot spots in domestic maker study, including makerspaces (Xu and Li 2014; Wang 2015; Xu and Lin 2016), maker culture (Song and Wang 2016; Xu and Lin 2016), maker movement (Xu and Li 2014), maker research (Qin and Nie 2016). (CHEN; WU, 2017, p. 2).

They separated 'maker movement' and 'maker culture' (lines 1 and 2) in different areas. Nonetheless, as their work is bibliometric, they did not explore these terms in detail, just in the necessary measure to their objective (CHEN; WU, 2017).

Another example is in Lindtner (2015). Throughout the work, the author uses the terms 'Maker Movement' and 'Maker Culture' but strictly refers to a group of Makers for the former and the culture shared by these people for the latter. In these cases, she is using 'culture' denotatively: "the ideas, customs, and social behaviour of a particular people or society" and "the attitudes and behaviour characteristic of a particular social group" (STEVENSON, 2010, p. 3212).

- **Defining 'Maker Culture'**

Now, let us understand the intricacies of those two terms, starting with Maker Culture. Following, there are several excerpts exploring its characteristics.

Departing from the dictionary definition of culture just presented above, let us investigate the ideas and customs leading to the Maker Culture:

> The maker culture is experimental and open and has an explicit heritage from the hackers…, hacking is 'at once an aesthetic and an ethic' that requires cooperation as much as individual skill and inventiveness. This makes hacking flourish in a molecular state. This has also made it popular to see hacking as a countercultural or anti-consumerist form of hands-on innovation-activism, or quasi-anarchism with the aim of hacking reality itself, in sites such as lifehacker.com, which covers technology as well as social improvements of makers. (VON BUSCH, 2012, p. 59).

Several other texts relate to the Maker and the hacker cultures. Both social phenomena exhibit similar ethos, like openness, hands-on approach and cooperation (ANDERSON, 2012). See the following extract:

> we start connecting both hacker and maker cultures on an attitude, based in solving problems and building things through freedom of action and voluntary mutual assistance, particularly translated in hacking by common values such as a hacker ethic, composed by two normative principles… the act of sharing as a ‘‘powerful positive good’’ coupled with system-cracking as ethically acceptable in the absence of theft, vandalism or breach of confidentiality… If hacker worlds always had a specific mix of ideals of freedom, access, transparency, equal opportunity and social good, which are now possible to detect in the largest part of maker contexts the relation between these two cultures has also more convoluted aspects. (NASCIMENTO; PÓLVORA, 2018, p. 5).

Roedl, Bardzell and Bardzell’s (2015) work shows other examples. The authors explore discourses about the Maker in the literature, intending to understand what this subject poses to studies on Human-Computer Interaction (HCI)[10]:

> Over the last decade, numerous authors have sought to further revise HCI’s conception of the user by stressing the abilities of people to do many things with technology beyond “use,” including building, modifying, maintaining, repairing, reusing, and repurposing. This move from a rhetoric of “users” toward one of “makers,” “crafters,” and “hackers” can be read as the articulation of a new discursive subject and constituency for HCI… research about “maker culture” is frequently framed as a challenge to HCI’s traditional conception of the “user.” This discourse is also often accompanied by claims that the maker, as a specific configuration of a technological subject, is particularly well positioned to bring about increased democracy and empowerment. That is, the argument goes that if HCI acknowledges the DIY movement and begins to design for “makers” instead of “users,” then the field will help to further “empower” and “democratize” society (ROEDL; BARDZELL; BARDZELL, 2015, p. 2).

Getting close to a definition of Maker Culture in use in this work, the following excerpt identifies several defining aspects of it:

> Maker culture focuses on using and learning practical skills and then applying them creatively to different situations. Maker culture draws upon a more participatory approach than traditional learning, encouraging learners to collaboratively engage with others as they learn through the creation of new items. Maker culture draws upon a social constructivist perspective which emphasises the social, cultural, and historical factors of experiences as well as a constructionist view on learning, which examines the tangible items that are created through learners working within their environments. (NIEMEYER; GERBER, 2015, p. 3)

[10]HCI – When a computer intermediates a human activity of any sort (HUMAN COMPUTER INTERACTION - SCIENCEDIRECT, 2023)

Maker culture also represents a social phenomenon, a fundamental dimension for its definition:

> The maker culture is both a symptom and a transformation of the new capitalism that is illuminating the phenomenon of and the increasing importance of digital platforms in the different fields of the society. We can say that this phenomenon is happening on an international scale, but at the same time it has its own particularities that depend on the context in which it is circumscribed, meaning that each national, regional or local maker culture has its contextual specificities. (TABARÉS GUTIÉRREZ, 2018, p. 10)[11].

Deriving from the literature containing the above excerpts on Maker Culture, the present work defines Maker Culture as follows.

Maker Culture is the collection of customs and attitudes of Makers. It is a cultural phenomenon happening amid globalisation, the existence of digital platforms and digital fabrication technologies from the end of the twentieth and beginning of the twenty-first centuries. It converges to and derives from the hacker culture, where knowledge is openly shared, getting things done depends on a hands-on approach, and users are not passive, in the sense that they are makers enabling prosumption as a reality through do-it-yourself and do-it-together practices.

- **Defining 'Maker Movement'**

Towards the other term, Maker Movement, there is an essential transition from the Maker Culture. As previously put, the Maker Movement is a social phenomenon related to the cultural phenomenon called Maker Culture. Take a look at the following extract:

> we can conceive the maker movement as a kind of technological counterculture's manifestation that demands more sustainable, collaborative, transparent, open processes in the production and development of technology, and that, at the same time, result in a greater, more equitable social benefit, fairer and shared. (TABARÉS GUTIÉRREZ, 2018, p. 10)[12].

[11]Free translation from the original: "la cultura maker es a la vez un síntoma y una transformación del nuevo capitalismo que está alumbrando el fenómeno de la globalización y la cada vez mayor importancia de las plataformas digitales en los diferentes ámbitos de la sociedad. Podemos decir que este fenómeno está sucediendo a escala internacional, pero al mismo tiempo dispone de particularidades propias que dependen del contexto donde se circunscribe y que hacen que cada cultura maker nacional, regional o local disponga de especificidades propias de su contexto".

[12]Idem: "podemos concebir el movimiento maker como una especie de manifestación de la contracultura tecnológica que demanda procesos más sostenibles, colaborativos, transparentes, abiertos en la producción y desarrollo de tecnología, y que al mismo tiempo redunden en um beneficio social mayor, más equitativo, justo y compartido".

The previous passage has just made it for us: revealing the relationship between the Maker Movement and the Maker Culture. Now let us get back to defining the Maker Movement and thus searching in the literature about it.

Starting from a broader delineation attached to the attitude related to the Maker Culture, the Maker Movement may be defined as follows:

> The maker movement refers broadly to the growing number of people who are engaged in the creative production of artifacts in their daily lives and who find physical and digital forums to share their processes and products with others. (HALVERSON; SHERIDAN, 2014, p. 496).

The work of Millard et al. (2018) further details how this creative production takes place:

> In principle, today, everybody with Internet access, the right skills and equipment can produce digital content composed of virtual "bits" and make it instantly available across the globe. The same is now happening to the fabrication of physical objects for everyone with access to tools like 3D printers. This inter-changeability of bits and atoms is being called the maker movement, which started as a community-based, socially-driven bottom-up movement but is today also impacting mainstream manufacturing through increased efficiencies, distributed local production and the circular economy. (MILLARD et al., 2018, p. 2).

The last passage uses the concept of 'circular economy'. This expression appears more times ahead in this manuscript. For the pourposes of this work, the definition of circular economy is:

> a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling. (GEISSDOERFER et al., 2017, p. 759).

The subsequent passages deal with who is making and what that person makes inside the Maker Movement:

> the maker movement is driven by makers, who pull these ideas into their communities, adapt them to suit local needs and interests, and literally build out the spaces and activities to engage young makers in active, hands-on learning experiences… maker activities organically invite cross-generational and cross-cultural participation, ranging from parents with expertise in fixing or modifying cars, to grandparents who sew or crochet, to aunts and uncles who carve at home in a woodshop… the maker movement welcomes all types of making. Rather than drawing boundaries around what is and isn't making, makers post and share broad genres of making, spanning cooking, sewing, embroidery, weaving, welding, woodworking, robotics, soldering, printing, painting, and building. (PEPPLER; BENDER, 2013, p. 26–27).

All these activities carried out by these varied people build up to the definition of the Maker Movement below:

> The Maker Movement is a technology-focused do-it-yourself (DIY) movement that emphasizes “learning by doing” and empowers individuals to become makers or creators of physical solutions to local and immediate problems. Individuals are encouraged to “make” or “tinker” using technologies that were once limited to manufacturers but are now becoming more readily available to the average consumer such as mobile technology, cloud-based computing, and 3-dimensional printing. Knowledge of how to make or build is shared through social media, peer-to-peer interactions at community Maker Spaces, or community gatherings called Maker Faires [sic]. (AWORI; LEE, 2017, p. E1).

Considering these last four extracts from the literature and the theoretical development built so far, the present work defines the Maker Movement in the next paragraph.

The Maker Movement is a community of Makers. Its scale varies from local to global. Locally, its members, the Makers, may not necessarily gather in person, but when doing so, they usually do so in shared workshops where various equipment and tools, either crafts-like or digitally enabled, are there to build their own or shared projects. Open forums on the Internet set the link to the global scale, and events set the link to the regional scale. Their projects may have a societal impact by solving a local problem or creating a new product or service.

2.1.4 Makers in the Global South

The literature on Maker Culture also investigates its characteristics in the so-called Global South[13]. Thus far, this work has built upon a literature that, with a few exceptions (LINDTNER, 2015; LUTHRA; MANGLA; YADAV, 2019), is neither specifically worried about cultural contexts nor it specifies a socioeconomic and geographical focus that may differentiate the presence and configuration of the Maker Movement worldwide (CHEN; WU, 2017).

Conversely, the present subsection explores several conceptions of ‘making’ inherent to specific socioeconomic and geographic issues in the Global South to enrich the theoretical discussion about Maker Culture. Those issues are essential to building a global perspective on the Maker Culture, i.e., not attaining just to the mainstream literature (BURTET, 2019; BURTET; KLEIN, 2021).

[13]Global South: “refers broadly to the regions of Latin America, Asia, Africa, and Oceania. It is one of a family of terms, including ‘Third World’ and ‘Periphery,’ that denote regions outside Europe and North America, mostly (though not all) low-income and often politically or culturally marginalized. The use of the phrase Global South marks a shift from a central focus on development or cultural difference toward an emphasis on geopolitical relations of power.” (DADOS; CONNELL, 2012, p. 1).

To introduce the matter, let us take a look at several examples of the three leading countries in this region in terms of population and gross domestic product (GDP)[14]: China, India and Brazil, respectively (WORLD BANK OPEN DATA, 2023). Next, this work brings up several concepts that help understand the context of the examples.

When worried about socioeconomic matters influencing its configuration, the works about the Maker Culture in the countries above usually build upon two concepts. First, many people enrolling in DIY activities in countries like those listed above develop those activities in a materially deprived scenario (PRASETYO, 2017; ZAPATA CAMPOS et al., 2023).

The other is the concept of 'grassroots innovation'. The following definition embraces this phenomenon in its many possible configurations, which vary according to context:

> Grassroots innovation is a diverse set of activities in which networks of neighbors, community groups, and activists work with people to generate bottom-up solutions for sustainable developments; novel solutions that respond to the local situation and the interests and values of the communities involved; and where those communities have control over the process and outcomes (SMITH; STIRLING, 2018, p. 67).

The examples of grassroots innovations explored here belong to the context where activities carried out in materially deprived scenarios generate innovation: "a so-called low-tech approach consisting of improvised or makeshift solutions born from ingenuity and cleverness by knowledge-rich, economically poor people" (CAMPBELL, 2017, p. 32), "innovations for the poor by the poor" (GUPTA, 2012, p. 1).

Each people, and thus language, has its ways of referring to an artefact or attitude that resembles the idea of grassroots innovations (CAMPBELL, 2017). See Table 6 for a list of common terms used to express this idea in some countries, including those of interest here.

[14]GDP: "refers to the total gross value added by all resident producers in the economy. Growth in the economy is measured by the change in GDP at constant price." (THE WORLD BANK GROUP, 2023).

Table 6 – Expressions resembling the idea of grassroots innovation.

Country	Expression
Brazil	Gambiarra
China	自主创新 or zizhu chuangxin
England	hacking
France	Système D.
Germany	Trick 17
India	jugaad
Kenya	jua kali
United States	DIY

Based on Campbell (2017).

With these concepts in mind, the following paragraphs introduce three examples of grassroots innovations in Brazil, India and China, one for each country.

- **Brazilian Example**

The Electronics Technician Hugo Lima developed the project 'Afro Engenharia no Mundo do Cinema' (Afro Engineering in Cinema's World) in the city of Rio de Janeiro, Brazil. The project had two motivations. The first was making filming auxiliary equipment affordable, and the second was making them purposefully not be confused with guns (BURTET; KLEIN, 2021; TINOCO, 2017).

The first objective of Afro Engenharia is similar to that of the project from Make:™ magazine's first issue, described in subsection 2.1.1, Figure 13. It is undoubtedly related to socioeconomic conditions since filming equipment, even when we are not talking about the cameras and other capturing and editing devices themselves, but just peripheric equipment, like camera supports and stabilisers, are not affordable to the lower middle-class individual in Brazil (BURTET, 2019).

Nevertheless, the second motivation is socioeconomic and contextually related to many places in the Rio de Janeiro suburbs. As stated, Hugo Lima built the prototypes of that supportive equipment, like a camera rig – a type of camera holder – purposefully not to be confused with a gun. He does so by using coloured plastic pieces or covering the pieces with fabric. Thus, the equipment built that way, which has some cylindrical projecting parts (likewise a gun), would not be black, as is generally the case for filming appliances and guns (BURTET; KLEIN, 2021).

The stamp of the fabric covering the equipment was in African-culture-related patterns. This necessity of covering or building in colours to make the appliances distinguishable from a firearm does not derive from a random fear that confusion might happen one day by chance. There have been cases reported in the media of that kind of thing happening (BURTET; KLEIN, 2021).

For example, in 2010, a man holding a drill was shot dead because the cops carrying an incursion out at Morro do Andaraí, a favela in Rio de Janeiro, simply confused the drill, a 24 cm model, with a weapon. A similar case happened in 2019 in the Carioca suburb of Taquara. Moreover, in 2018, a man holding a black umbrella was shot at Chapéu-Mangueira, another Carioca favela, because the cops mistook it for a rifle (NOTÍCIA PRETA, 2019).

Hugo Lima says he does not like to call his innovation ‘gambiarra’. Sometimes, the terms in Table 6 have a negative connotation. The difference between the positive and negative overtones resides in the improvisation’s role. It may be an objective per se or supposed to be a temporary solution further substituted for a definitive, more technically and aesthetically improved one (BURTET, 2019; CAMPBELL, 2017; TINOCO, 2017).

- **Indian Example**

Now, heading to India, among the many grassroots innovations found in that country (NIF - INDIA, 2021), there is one that caused great general public recognition, at least if we are to consider the two movies and two documentaries featuring the story of Arunachalam Muruganantham (BHANDARE, 2019; KARKI, 2020), he had given a TED[15] talk (TED CONFERENCES, 2012) and, being one of the 100 most influential people in the world in 2014, as elected by TIME™ magazine (TIME USA, 2014).

Arunachalam’s story began with his intention to provide a better resource to his wife so she could improve the hygienic conditions she had available to manage her periods. He noticed she was using old rags to contain the blood, representing a rather infection-causing and uncomfortable method (GILSON, 2016). This type of

[15]TED: “TED began in 1984 as a conference where Technology, Entertainment and Design converged, but today it spans a multitude of worldwide communities and initiatives exploring everything from science and business to education, arts and global issues.” (TED CONFERENCES, 2022, p. 1).

improvisation with used clothes falls into the category of period poverty (MICHEL et al., 2022).

Arunachalam started making a simple rectangular model sanitary pad from cotton and smooth fabrics he bought in a local store to address the issue. His wife disliked the model, so he kept trying new variants with locally sourced materials. However, each increment would have to wait approximately a month to be tested again by his wife (GILSON, 2016).

Thus, he attempted to circumvent this timing by asking female students from a local university to test his models and give him feedback. Nonetheless, as menstruation is widely seen as a taboo in Indian culture, even between women, let alone for a man to approach the subject with a woman (MICHEL et al., 2022), Arunachalam could not get the students' evaluation.

So, he decided, getting entirely out of the box, to test on himself the models. He built a blood container from a bottle, holding approximately the amount of blood (animal blood) that would fit a uterus. He attached the container's bottom to a flexible tube through a valve. Then, fastened the whole apparatus to his body, with the flexible tubing going to his underwear, which put the tip of the tube in contact with the sanitary toil. He called the system an 'artificial uterus' (GILSON, 2016).

Arunachalam walked and cycled as usual with his artificial uterus tied to his body and intentionally generated a slight pressure with his arms once in a while to simulate a non-continuous flux and one that sometimes grows in volume when the person is in movement, as is the case for some women (MICHEL et al., 2022).

Besides staining some of his clothes and thus negatively calling his community's attention, the setup proved to be efficient and, thus, he could get to a model that was way cheaper and easier to produce than those of traditional brands, therefore much more affordable (GILSON, 2016).

Alongside his testing, he also tried to figure out how to produce the period pads in scale while maintaining its simplicity and price range. That would also require machinery that is cheaper than that used by traditional brands in the industry. Luckily, at that time in life, he had already become an experienced machine operator in a local factory and had dealt with the maintenance of those machines. Hence, he had the knowledge to start building and testing low-cost versions of the machines necessary to scale up the pad production (GILSON, 2016).

During his journey, he received support from government programs to incentivise grassroots innovators and decided never to sell his inventions to the big industry to maintain everything affordable for low-income communities worldwide (GILSON, 2016).

An example of the support was the Fifth National Grassroots Innovation Award from the National Innovation Foundation (NIF) in 2009 and financial aid from the Micro Venture Innovation Fund to disseminate his machines to other Indian states. NIF has also helped him file a patent for his machines to protect them. Regarding the initiative's impact, almost 900 organisations throughout India are using his machines, including many self-supporting women groups (GILSON, 2016; NIF - INDIA, 2009; SHARMA; KUMAR, 2019).

- **Chinese Example**

Most of the works about Chinese grassroots innovation currently deal with agricultural inventions or those that, although not belonging exclusively to agriculture, are set in rural scenarios (LI et al., 2022). The latter case may involve modifying a bicycle. That is because, in rural China, it is a widely used transport (KUMAR et al., 2013). That last cited work lists such bicycle modifications. See Box 1.

Box 1 – Some of the bicycle innovations found in rural China.

Box 1: GRIs with Used Bicycles

Farmers make multi-function farming tools out of used bicycles. Some examples of the innovations include:

- Adapting a bicycle plow for weeding, hoeing, and even for applying fertilizers.
- Converting the bicycle wheels into a power device to draw water from wells.
- Replacing the hoe with the bicycle for sowing carrots and beets (in Sichuan province).
- Modifying the bicycle to make it amphibious.
- Developing a mechanism to give the rider a massage while riding.
- Enabling the power-aided bicycles to convert kinetic energy into electrical energy while going downhill to make cycling uphill much easier.
- Creating battery-powered anti-theft devices and an automatic braking system while tilting for electric bicycles.
- Devising a bicycle breathing-machine which has even saved a 15-year-old village girl's life in Anyang, Henan Province.

Source: reproduced with the rightsholder permission from Kumar *et al.* (2013, p. 115)[16].

[16]GRIs: acronym for grassroots innovations.

Now, let us look at an exclusively agricultural invention as an example of a grassroots innovation in China. When talking about agriculture, we can often almost take the expression ‘grassroots’ by its literal meaning since the novelty can come as a new cultivar. That is the case of farmer Chen Guangxing. His innovation occurred in Yuanluo Town, Baodi County, Tianjin, China. On his farm, he developed a new onion variety named ‘Wu Yeqi’ through selective breeding (ZHANG; MAHADEVIA, 2014).

Compared to traditional varieties of Chinese onion, like ‘Gao Jiaobai’, Wu Yeqi yielded more than double the onions produced per hectare in the first year of trial, 1983. Following the new variety's success, Chen grouped with other local farmers to form the Yuanluo Chinese Onion and Garlic Research Association that same year. Although there was no research on Chinese onion and garlic species in the formal sector, Chen and other growers started the association to gather and share the best practices mutually (ZHANG; MAHADEVIA, 2014).

That association solved various problems the farmers had long been facing. Table 7 shows the problems and the association members’ respective solutions.

Table 7 is built here based on the article of Zhang and Mahadevia (2014). There, the authors explore how science and technology programs and policies from the Chinese government influence grassroots innovations.

Table 7 – Yuanluo farmers' solutions, representing grassroots innovations.

Problem	Solution
Slower than desirable germination rate	Soak the seeds for a day in warm water. Then, wait four to five days to start sowing. Cover the seeds with no more than a finger's width of soil.
Floods caused by the town's low elevation	A technique to manage flood effects in four timely steps: draining the fields, removing residue, redressing the topsoil, and rewatering the fields with adequate water.
Imprecise seeding rate	Count how many seeds are per kilogram and spread them to get one sprout for each cm². Thus, the farmers knew the mass of seeds to spread on each hectare.
Imprecise ditching depth and line spacing	Careful observation led to the best ratio for the ridges' height, which happens to be half the stem's height. In the case of line spacing, onions shall be spaced one and a half times the stem's length.
Difficulties in crop rotation between onions and garlic	Farmers found that by rotating onions with wheat instead of garlic, they could avoid the lack of nutrients in the soil for the next season since garlic and onion are from the same family. They started sowing onion seeds as soon as they harvested the wheat.
The traditional plough damaged some of the onion plants	Although they received the local agriculture bureau's technicians' help, it was only after bringing a plough from another Chinese farming region and with additional Yuanluo association farmers' input that they got to a suitable model.
Lack of honey bees as a consequence of pesticides	As a first solution to enable the production's continuity, the farmers started using flies instead of bees to pollinate the crops. Thus, they placed food leftovers and manure in the fields to attract the flies.

Based on Zhang and Mahadevia (2014, p. 14–15).

Because of the successful solutions provided by the farmer's association, several of these countermeasures received not only recognition from local sectors of the government but also financial prizes from agricultural sections of the local government. Besides, there have been cases of farmers association members invited to participate in governmental sections responsible for overseeing agricultural matters (ZHANG; MAHADEVIA, 2014).

2.1.5 Maker Spaces

This subsection explores the collaborative spaces where Makers develop their activities individually or collectively. Therefore, this part of the text differentiates some of those spaces, pointing out their differences and similarities.

Next, we see that 'Open Workshop' denotes the general concept behind those spaces (LANGE; BÜRKNER, 2018). 'Makerspace' represents a general name for such spaces. However, these spaces receive the names 'Hackerspace', 'Fab Lab' and 'Repair Café' when considering certain specificities (MERSAND, 2021; SOOMRO et al., 2023; SPEKKINK; RÖDL; CHARTER, 2022).

- **Open Workshops**

While there is a considerable proportion of the literature pointing that spaces exhibiting the general idea behind Fab Las, Hackerspaces, Repair Cafés and other similar spaces are to be called Makerspaces (VINCENT, 2023), some works give other names, like 'Open Workshops' (LANGE; BÜRKNER, 2018), 'DIY Labs' (LHOSTE, 2020) and, 'Open Creative Labs' (SCHMIDT; BRINKS, 2017).

Despite this variety of terms, if we are to take the definition of each, there are several elements of these definitions in which the meanings of these terms converge. See the following passages.

> Open creative labs are spatial settings that are open to diverse users… [Users] range from hobbyists, enthusiasts, freelancers, entrepreneurs, makers, hackers, to firms, employees, and startup teams (SCHMIDT; BRINKS, 2017, p. 297).
>
> (…) down-to-earth practices such as tinkering, repairing, and experimenting with everyday materials. They are best represented in open workshops. They combine crafts, tool-sharing, open communication and community building into something that has local and also more general effects. (LANGE; BÜRKNER, 2018)
>
> The term 'DIY labs' refers to a range of spaces where people gather, socialize and share/produce knowledge-by-doing with a variety of tools (LHOSTE, 2020).

We can directly extract the invariant elements – part of every space related here – from the previous three excerpts.

The first element is the openness quality of those spaces, referring to the acceptance of any person seeking to use that space to develop a project, either their own or a shared one. The second is the presence of a variety of tools and equipment. The space may previously determine these devices' diversity, influencing the kind of project usually developed. Otherwise, the inverse may happen; the projects in development will lead to the space acquiring a corresponding set of machinery and utensils. Third, we have an indication of the underlying principle when building something in these spaces, summarised by the idea of DIY practices, as seen in Subsection 2.1.2.

Based on the literature presented thus far, the previous paragraph indicates what this work understands as an Open Workshop.

- **Makerspaces**

Is every Makerspace an Open Workshop? Yes, it is. The opposite does not hold. This work separates these two concepts because the term Open Workshop represents a level up in abstraction from what is a Makerspace.

Both terms encompass well-defined spaces, like Fab Labs, Repair Cafés and Hackerspaces. Nonetheless, the previous definition of an Open Workshop also represents the idea behind a Makerspace. The difference is that Makerspace's definition is more grounded in practical specificities; thus, it is not as general as 'Open Workshop'.

This correlation between these two terms (Makerspaces and Open Workshops) can be verified, for example, in the work of Melo et al. (2023). The authors build a framework to define Makerspaces from interviews applied to university Makerspaces leaders (like managers and coordinators).

The previous three Open Workshops' characteristics of openness, a regular set of tools that allow the users' creativity to be expressed in physical builds, and the development of their own or shared projects are all observed in the interviews from Melos et al. (2023). Nonetheless, their work focuses on the interviewees' perceptions of what a Makerspace would be and in terms of subjective elements of these perceptions (MELO et al., 2023).

Then, heading to a more objective definition, the article of Irie, Hsu and Ching (2019) works with a description that further specifies what kind of tools and equipment one can find in a Makerspace, maintaining the openness and DIY approach characteristics. These devices are those used in robotics, electronics, sewing, woodworking, laser cutting, computer programming, or a combination of these (IRIE; HSU; CHING, 2019).

Makerspaces' role as supportive educational spaces also characterises them (KEUNE; PEPPLER, 2019). That role allows people to learn technical skills and explore new ideas in a creative environment for arts, science and engineering (SHERIDAN et al., 2014). In other words: "Makerspaces are open-access workshops devoted to creative and technical work for individual tinkering, social learning, and group collaboration on innovative and technological projects" (SAORÍN et al., 2017, p. 190).

This environment of a Makerspace, which propitiates innovation and technological project development through various tools, is also said to burgeon entrepreneurship (VAN HOLM, 2017). Several social phenomena enable this in a Makerspace, like socialising with knowledgeable peers and the presence of community-based values such as social support, exploration, transparency and empowerment (HUI; GERBER, 2017).

Another vision contributing to the entrepreneurial development linked to Makerspaces appears in the work of Sheridan and Konopasky (2016). The authors use the idea of resourcefulness to express what a person usually relies on inside a Makerspace:

> individual or communal acts of innovatively drawing on internal sources (e.g., skills, knowledge, confidence) and external sources (e.g., experts, informational texts, community partners) in order to persist in meeting individual or communal needs and wants (SHERIDAN; KONOPASKY, 2016, p. 77).

Further emphasising the communal characteristic of Makerspaces, we can say that they are physical locations where a community of Makers can meet. Thus, in many cases, the configuration of a Makerspace, in terms of planning, function, funding and structure, is organised by the Makers' community using it (WILCZYNSKI, 2015).

In Universities, Makerspaces serve as a place to develop practice-based learning and the development going on in theoretical classes (BARRETT et al., 2015). Through openness, Universities' Makerspaces allow students to develop projects related to classes or even personal in some cases. Because of the collaborative environment, students from different levels and disciplines can cooperate. Employing the tools and equipment, the students have a fast way to prototype and do that in a hands-on DIY or do-it-together fashion (FOREST et al., 2014).

Lastly, as previously pointed out, what makes Makerspaces different from other Open Workshops is the level of specificity in terms of significant use and correspondent tools and equipment found in these spaces. Therefore, a Makerspace that cannot be further specified, i.e., tenting to be more general than a Hackerspace or a Fab Lab, for example, can be referred to as a Makerspace, with no loss in detail (OLIVER, 2016). For instance, a Makespace may not focus so much on software repurposing or coding, like in the case of a Hackerspace, and it may not depend on high-tech devices found in some Fab Labs (OLIVER, 2016). Also, it may not focus on repairing like it is necessarily the case of a Repair Café.

Ending the theoretical discussion regarding Makerspaces, let us build a definition drawing from what has been built so far.

Makerspaces are physical spaces embodying the concept of an Open Workshop: they are open to the general public, they have a variety of tools and equipment relating to the projects in development there, and people are supposed to make things with a DIY or do-it-together approach. These spaces thrive upon a communal sense shared between the participants and the managers of the spaces, which, in some cases, are the same people.

Machinery and utensils found in Makerspaces vary from one to another. If there is a clear focus on software and hardware development and repurposing, that space is a Hackerspace. Then, it will mainly include computers, computer-specialised tool-kits and diagnosing equipment, like oscilloscopes, multimeters, and supplies. If there is a preconceived set of equipment based on a charter, mainly focused on digital fabrication (digital physical tools), like 3D Printers, laser cutters, CNC routers and milling machines, Arduino™ and Raspberry Pi™ boards, and so on, that space can be called a Fab Lab, especially when linked to the Fab Foundation. Suppose a Makerspace dedicates itself to repairing broken domestic appliances; in a way, it can contribute to a circular economy, addressing environmental issues and going against consumerist behaviour. Thus, it may be considered a Repair Café, especially if the space is linked to the Repair Café International Foundation.

If the space has a combination of some of the devices listed above and has no such clear focus, then, as a general case, the space can be called a Makerspace. Makerspaces may have other apparatuses like hand tools for mechanics (screwdrivers, wrenches, plyers, etc.), hand and table electric tools (drills, routers, saws, etc.), hand tools for electronics (soldering irons, desoldering pumps, probes, etc.), chemistry lab utensils and equipment (beakers, tubes, agitators, etc.), and so on. To summarise, Makerspaces are multipurpose, and thus are their set of tools and equipment.

This work builds Table 8 to sum up the topic of Makerspaces. It derives from the definitions of each space, focusing on what more clearly distinguishes each space: the usual kind of project developed in each space and the usual set of tools and equipment found there.

- **Hackerspaces**

Being the oldest of the terms, the origin of the first Hackerspace traces back to the foundation of the first hackers' associations, like Chaos Communications Club (CCC) in Germany, in 1981 (CUNTZ; PEUCKERT, 2023). Although it formed as a virtual group in 1995, some members founded C-base in Berlin, which literature recognises as the first Hackerspace (LINDTNER; HERTZ; DOURISH, 2014).

In his survey of Hackerspaces, Jarkko Moilanen identifies six criteria for identifying a Hackerspace (MOILANEN, 2012). The first is the members owning and running the space with an equity spirit. Second, the space shall not be for profit and should be welcoming to the outside world, at least semi-regularly. Third, people there share equipment and ideas without prejudice. Fourth, having a significant focus on invention and technology. Fifth, having a shared space, like a community centre. Sixth, the presence of a scientific ethos: trial and error and information freely shared.

However, part of the literature concerns situations out of these previous, rather ideal, conditions of a Hackerspace. Situations where some prejudice or lack of equity between participants have prompted people to build other Hackerspaces that specifically go against prejudicial practices. So-called feminist Hackerspaces are examples of these (FOX; ULGADO; ROSNER, 2015).

For example, in some hacker communities, there have been reports of integrants self-identifying as genderqueer, female, transgender or nonbinary undergoing episodes of harassment. Because of that and focusing on the interests of these persons, explicitly feminist Hackerspaces were founded (RICHTERICH, 2022).

Those frequenting a Hackerspace can be called ‘hackers’ despite this word being historically associated, by mistake, with cybercrime (CUNTZ; PEUCKERT, 2023; RICHTERICH, 2022). Another common misleading association with the word is that of a highly tech-skilled male white figure, usually that solitary innovator conquering the electronic frontier (RICHTERICH, 2022).

This conception goes against the very definition of what are supposed to be characteristics of a hacker’s community, like openness, to be integrative, and diversity in participants. Feminist Hackerspaces confronts either negative or biased associations (to masculinism and cybercrime), not by avoiding the term ‘hacker’ but by incorporating new meanings. They do so by not restraining themselves to only tech-centric projects, thus incorporating artistic, activistic and craft practices, usually not considered hacking. Nonetheless, they still vastly promote digital technology “to be discussed, curated, and developed in dialogue with feminist values” (RICHTERICH, 2022, p. 12).

Closing the discussion on this type of space, we can now state that, generally speaking, a Hackerspace is a gathering place for a particular hacker’s community. Although they vary in composition, and this variation has to do with the characteristics of the community supporting and managing them, there is a clear axis of equipment and purpose in these spaces.

They usually centre their activities on repurposing computer hardware and software, aggregating to it other components that may be necessary depending on the project (like Arduino™ boards), some craft tools (like soldering irons and hot glue guns) and some electronic measurement equipment (like oscilloscopes and multimeters).

Regarding the operation model, they are usually not for profit and receptive to outsiders who want to learn from and eventually become part of that hacker’s community. Nevertheless, as Lindtner, Hertz and Dourish (2014) put it, this does not impede Hackerspaces from being nesting places for creating new marketable products and services.

- **Fab Labs**

In the following paragraphs' literature about Fabrication Laboratories (Fab Labs), despite each may add a bit to their concept, there are a few points in which all agree: Their origin, their composition (in terms of equipment), the organisation behind them and, their openness to the public.

Back in 1998, Massachusetts Institute of Technology (MIT) professor Neil Gershenfeld launched a course named *How to Make (Almost) Anything* (BRAVI; MURMURA; SANTOS, 2018). At that time, Neil worked in association with the MIT Media Lab, which, in turn, was founded in 1985 by Professor Nicholas Negroponte (MARAVILHAS; MARTINS, 2019).

Following the success of the classes between the students and a grant from the United States of America's National Science Foundation, Neil, still drawing from the link to Media Lab, founded the Centre of Bits and Atoms in 2001, considered the first Fab Lab (MARAVILHAS; MARTINS, 2019). The Media Lab's Fab Lab program has reached many places worldwide, with various Fab Labs owning at least several of the initially intended equipment.

Then, the Fab Foundation was established in 2009 (THE FAB FOUNDATION, 2023a). Based on existing Fab Labs, they, acting as a not-for-profit organisation, have been helping to maintain cohesion among Fab Labs worldwide (JOHNS; HALL, 2020).

Fab Foundation does that through its *Fab Charter*. Each Lab has a certain level of freedom to determine its type of projects, users and revenue model. However, through the Charter, Fab Foundation members are heavily encouraged to comply with a standard equipment list and to have an open spirit (to every person) (JOHNS; HALL, 2020; WOLF et al., 2014). Fab Foundation does so to make cross-lab project cooperation easier and to maintain the original open model of innovation and development among all Fab Labs (KOHTALA, 2017).

The equipment the Fab Foundation encourages each Fab Lab to acquire is digital fabrication machines, like those described in Introduction's subsection 1.1.1 as 'digital physical tools'. Those include laser cutters, 3D Printers, high-resolution (casting mold-grade) CNC milling machines, large wood routers (large enough for furniture fabrication) and a suite of electronics equipment and components (to allow for in-site prototyping) (BYARD et al., 2019; THE FAB FOUNDATION, 2023b).

Concluding about Fab Labs: they are spaces of the maker community, a type of Makerspace, and considered the most standardised ones (KOHTALA, 2017; SANTOS; MURMURA; BRAVI, 2018). The Fab Foundation promotes this standardisation, and members shall comply with their Fab Charter. So, members shall follow the principia of open innovation and development and, to allow for replicability of projects, also shall comply with the minimum set of digital fabrication tools suggested by the Fab Foundation, like 3D Printers, high-precision milling machines, wood routers and electronic equipment and components available in situ.

- **Repair Cafés**

Repair Cafés sit together with similar initiatives in different places, either physically or virtually based. All of them focus on the idea of repairing day-to-day items that, otherwise, would be much more expensive to fix or would remain broken or thrown away (GHISELLINI; ULGIATI, 2020; SPEKKINK; RÖDL; CHARTER, 2022).

The physical branch includes initiatives like the Fixers Collective in Brooklyn and Fixit Clinics in the San Francisco Bay area, both from the USA and The Restart Project in London, England (VAN DER VELDEN, 2021). iFixit is an example of the virtual branch: a website where visitors can freely access instructions on how to mend many electronic devices (IFIXIT, 2023).

Repair Cafés is the most worldwide spread of those initiatives associated with a physical space (thus, belonging to the physical branch). Literature registers over 2000 Repair Cafés in almost 40 countries as of 2020 (VAN DER VELDEN, 2021).

After having her second child, former Dutch journalist Martine Postma started thinking more about environmental matters impacting the natural resources for future generations. More specifically, the usual life cycle of home appliances, whose destiny was to be thrown away, with no repairing attempt by the owners. That led her, in 2007, to come up with the concept of a place where people with broken items would meet with people with repairing skills who, voluntarily, would help fix the unfunctional object (MADON, 2022).

Imbued with that concept, she wrote a winning project for a Dutch Ministry of Environment selection of initiatives for funding. This fundraising allowed Martine to establish the first Repair Café in 2009 in Amsterdam, Netherlands. Martine started the Repair Café Foundation that year to organise Repair Cafés in the Netherlands while promoting the concept behind them to the general Dutch population (MOALEM; MOSGAARD, 2021).

Following the initiative's success, which spread to other countries, even outside Europe, the Repair Café Foundation changed its name to the Repair Café International Foundation (RCIF) in 2017 (SPEKKINK; RÖDL; CHARTER, 2022).

RCIF is the organisation behind the general similarities found in Repair Cafés worldwide. Their goal is threefold, associated with three issues that Repair Cafés aim to address.

The goals of RCIF are: (i) to (re)introduce the habit of repairing in local communities using possibilities allowed by current technology, (ii) to keep the repairing skills inside that community and freely share them, and (iii) to foster connection in that community by putting together diverse people living near each other, despite the motivation each one has to come to the Repair Café (MOALEM; MOSGAARD, 2021).

All these goals can be linked to all of the following issues Repair Cafés aim to face: (a) to serve as an environmental organisation since Repair Cafés are strongly linked to the rise of environmental challenges and serve as players in the transition to circular economies when supported by local authorities and linked to a network of environmental associations; (b) to represent a way out of the capitalist economy, when a Repair Café is seen as a mode of political participation to allow consumers to break out of the market, repairing instead of buying; and (c) to be a space for the education of the masses, in the sense that Repair Cafés can be linked to the Maker Movement where people create their tools to solve problems posed by manufacturers (MADON, 2022).

The literature above allows asserting what Repair Cafés are. See the following paragraphs.

A Repair Café is a space organised to hold a meeting between people interested in fixing a broken personal item (mainly home appliances and electronic devices) and repair-skilled people who voluntarily repair (or help to repair) these items. This encounter happens under the ethos promoted by the Repair Café International Foundation, comprising values against mainstream consumerist behaviour, environmental awareness and social interaction among the participants.

The setup of a Repair Café will include the tools and equipment necessary to fix the broken objects. The local organisation putting that particular Repair Café forward may own these tools and equipment, or the repairers can bring them. The Repair Café will also include a conviviality space, which may overlap with the place to fix things. That space is supposed to allow social interaction between the participants, including the organisers, thus fostering conviviality in the community.

If a Repair Café does not open regularly in a fixed space, it may happen as an event in a place well known to the local community, like a community hall. That event may or may not have fixed dates.

Table 8 – Makerspaces, Hackerspaces, Fab Labs and Repair Cafés' main characteristics.

				Main supporting literature
Open Workshops	**Makerspaces**: The most general physical realisation of Open Workshops. It thrives on a communal sense shared between the participants, where they develop DIY projects using related machinery and utensils, ranging from crafts-like to digitally enabled ones.			(LANGE; BÜRKNER, 2018; MELO et al., 2023; SAORÍN et al., 2017; VINCENT, 2023)
	Type	**Usual kind of project being developed**	**Predominant tools and equipment**	-
	Hackerspace	Computer hardware and software development and repurposing (hacking).	Computers, microcontroller boards, soldering irons, oscilloscopes and multimeters.	(CUNTZ; PEUCKERT, 2023; LINDTNER; HERTZ; DOURISH, 2014; RICHTERICH, 2022)
	Fab Lab	Prototyping, personal and small batch fabrication and academic projects.	Laser cutters, 3D Printers, CNC milling machines and wood routers.	(KOHTALA, 2017; MARAVILHAS; MARTINS, 2019; THE FAB FOUNDATION, 2023b)
	Repair Café	Repairing of broken domestic appliances.	Mechanical and Electronics tools and equipment.	(MADON, 2022; SPEKKINK; RÖDL; CHARTER, 2022; VAN DER VELDEN, 2021)

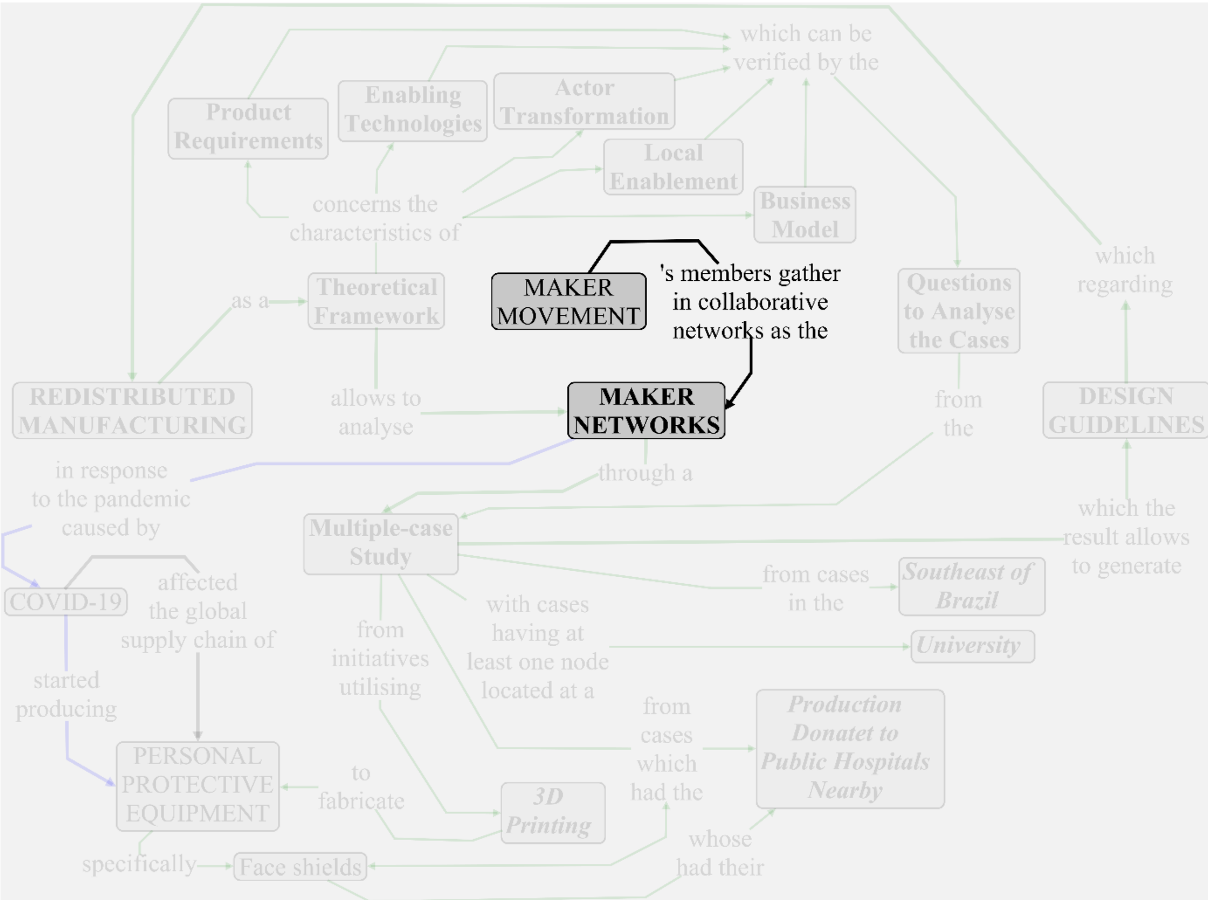
Source: Author.

2.1.6 Maker Networks

Loosely speaking, any group of Makers geographically dispersed, especially with a varied background and linked to different organisations, can be called a Makers' Network. What takes the apostrophe and the 's' from 'Makers' out, transforming the term 'Maker' in the modifier of the noun 'Network', is the focus on the network, which has a clear objective and a varying composition, including organisations as constituents, not just individuals (CAMPOS; CIPOLLA, 2021).

Part of this work's concept map, in Figure 22, marks the centrality of Maker Networks in this research, revealing their collaborative nature.

Figure 22 – Part of this work's concept map solely regarding Maker Networks.



Source: Author.

Thus, let us check several pieces of literature dealing with these concepts. Beginning with the cases when the focus is on the individual of the Maker and a grouping of them: "a maker community describes a broad community built on an individual's ability to be a creator of new technologies and practices, 'a maker'" (ARROYO et al., 2021). In this last passage, the authors refer to the community of makers forming the Corona Virus Makers Network. Although this configures as a Maker Network (without the ‘s’), as we will see further, the previous passage focuses on the individuals’ abilities (the Makers’ abilities).

There will be cases in the literature where authors use the term ‘network’ in the general sense, just meaning a network of people related to the Maker Movement. These pieces of literature attribute no other interpretation to the term ‘network’ than the group of these people together with the structure of their connection. For example, those who go to the same place, those who know others only by the Internet, how they communicate, and so on (GREEN; KIRK, 2018).

One example of this use of the word ‘network’ is in the description of the ‘kiosk culture’ in Ghana, where one can find a

> network of tiny and small-scale makers and entrepreneurs working out of kiosks, sheds, shanties and metal containers, roofed with tarpaulins and corrugated metal sheeting, or temporarily installed under trees, by roadsides, in vacant lots and buildings still under construction, as well as adaptive workspaces housed in more ‘formal’ edifices, that constitute a broad belt of indigenous pan-African innovation. (OSSEO-ASARE; ABBAS, 2021, p. 66).

Another literature branch focuses on organisations and institutions related to the Maker Movement. There are articles dealing with networks formed by makerspaces, like a case from Emilia-Romana, Italy’s region whose capital is Bologna, called Mak-ER network, which “is aimed at connecting local makerspaces, Fab Labs and hackerspaces supporting the innovation capacity of communities, SMEs and professionals” (CATTABRIGA, 2019, p. 86).

Researchers at Indiana University, USA, carried out a similar study. It analyses the role of academic Makerspaces in students’ project development when operating in a network rather than individually, in the same campus or campi. Results indicate an increase in the project’s multidisciplinarity (NAY, 2021).

Likewise, in Catalunya, the public network of makerspaces in Barcelona, Ateneus de Fabricació, may function as a way to empower citizens, especially in the way they come up with innovations concerning local issues and their technological literacy (DIAZ; TOMÀS; LEFEBVRE, 2021).

Regarding the cases of interest to this work, a handful of articles deal with cases where not only the people or the organisations are, separately, the focus of the network but the combination and interconnection of both in several instances of the network. See the following examples.

In Tunis, the capital of Tunisia, the Fab Lab from The National Engineering School of Tunis, FabLab ENIT, had a fundamental role in organising the Tunisian maker community response to the COVID-19 health crisis. FabLab ENIT grouped with "other makers and stakeholders from different fields such as academia, healthcare, private sector, and civil society, to form a national network (in the form of a collective)". (ABBASSI et al., 2022, p. 346).

Before the 2020 pandemic, studies on distributed manufacturing already existed based on the productive capabilities of the Maker Movement dealing with the response to a humanitarian crisis. That is the case of Laura James' work from 2017, where she studied the possibility of using a dispersed network of 3D Printers operated by local makers supported by Field Ready to supply emergency items that otherwise would not reach those in need. Field Ready is an international non-profit and non-governmental organisation seeking to produce non-food essential items locally in distressed areas (JAMES, 2017).

The previous paragraph has another case where the term 'network' refers to the relationship between Makers and institutions. The same holds for the article from Giusti, Alberti and Belfanti (2020), where they study knowledge sharing in open innovation networks:

> Large corporations, SMEs and the entire maker community, collaborate together for innovation in a complex relational network and several other organizations like research centres and universities, take part to open innovation networks too. (GIUSTI; ALBERTI; BELFANTI, 2020, p. 22).

Another example related to the Maker Movement's response to the COVID-19 pandemic, where the term 'network' has the same connotation as above, the article from Kieslinger et al. (2021) study the case of Careables, a project to build tailor-made healthcare solutions. The authors also write about the Open Source Medical Supplies (OSMS), which, likewise Careables, is a virtually-based open hardware community dedicated to medical solutions. In facing the pandemic, both cases helped bring together a "global network of over 70,000 makers, fabricators, community organizers, and medical professionals" (KIESLINGER et al., 2021, p. 3).

A definition, yet closer to the one used in the present work, is in the article from Paul Smith, where he explores ‘Digital Maker Networks’. These networks are “a series of ‘pop up’ manufacturing nodes or ‘maker centres’… [able to] explore the idea of local manufacturing bases connected to a wider network of supporting manufacturers” (SMITH, 2017, p. S2661).

The following paragraph has the definition of a Maker Network in use here. That definition is part of a previously published article by the present author and advisor (CAMPOS; CIPOLLA, 2021).

A Maker Network is

> a group of people and organizations related to the Maker Movement working as a team to produce some good or deliver some service. What connects these actors to the Maker Movement are the tools used, the type of products or services, their relation to the places of production and consumption, how they interact, and the operational model of their collective work. (CAMPOS; CIPOLLA, 2021, p. 210)

Besides, a

> node composing a Maker Network may be a person, a university (or a department), a research institution (or a laboratory), a subnetwork of makers, a makerspace, an organization such as a small company or a non-governmental organization, or even a big company (or a division). (CAMPOS; CIPOLLA, 2021, p. 210).

2.2 MANUFACTURING AND ITS DISTRIBUTION

This section works on how humans have organised themselves to make things, or manufacture them, and the geographical distribution of places associated with that activity, the “working-floor[s]” (FLUSSER, 1999, p. 43).

This part of the work builds on a historical perspective focused on the technological advancements marking each phase of manufacturing’s history and the distribution of goods.

2.2.1 Manufacturing: History and Evolution

Beginning with the etymological origin of ‘manufacture’, the word is borrowed (sixteenth century) either from old French *manufacture*, or (fourteenth century) from old Italian *manifattura*, both derived from Medieval Latin *manūfactūra*, suffixal derivation of *manūfactum*, a compound (univerbation) of two Latin words: *manū*, the singular ablative of *manus* (hand), and *factum*, the substantive use for the neutral past participle of *facere* (to do) (ONIONS; FRIEDRICHSEN; BURCHFIELD, 1966).

So, by considering the literal meaning of 'manufacture' from its origin (put into existence through one's hands) and that the primary body parts humans consciously use to alter the environment are their hands, it is reasonable to look at the most ancient evidence archaeology gives of any hand-modified object humans had ever made. Thus, we can start our evidence-based manufacturing history.

So far, human history (not only manufacturing) has split into two significant segments: everything before the mechanisation of production and everything afterwards. This turning point gave rise to the First Industrial Revolution (SASSANELLI; TAISCH; TERZI, 2023).

Both of these periods have their subdivisions. Commencing with the division of History and Pre-history (ROSER, 2016). The latter refers to everything predating recorded history, based solely on archaeological evidence. History is thus everything happening from the invention of writing until the current reader has just read 'read'.

After the mechanisation of the production of goods, humankind went through at least three phases marked by the technological evolution of the machines associated with that mechanisation: the three industrial revolutions. Nowadays, part of the literature considers that we are going through the fourth one, whose starting date is future historians' job to define. Nonetheless, it is also marked by recent technological evolution (SASSANELLI; TAISCH; TERZI, 2023).

This work deals with a production model born alongside these more recent technologies associated with the Fourth Industrial Revolution (SRAI; HARRINGTON; TIWARI, 2016). Therefore, before getting to this part, which requires more detail, the following paragraphs explore the previous periods in manufacturing history.

- **Down of Manufacturing**

It is noteworthy that, despite all the technological evolution throughout the millennia, the building principles humans have been using to produce their objects are the same ones already identifiable in the Stone Age. The Stone Age began when hominids (e.g., Australopithecus Afarensis) first used stones as cutting tools around 3.4 million years ago (MCPHERRON et al., 2010; ROSER, 2016), representing the first building principle or manufacturing technique (cutting). Simply using stones to break things is not considered since other animals, even a bird species (the Egyptian Vulture), have been observed using rocks with that purpose – and the focus here is human-related (Pre)History (VAN OVERVELD et al., 2022).

Six manufacturing techniques summarise those building principles. Table 9 lists those techniques below.

Table 9 – Manufacturing techniques and when they appeared.

Technique	**Description**	**Time of first evidence**
Cutting	Using a blade-like object to rip surfaces.	3.39 million years ago (ya)
Changing material properties	Using some form of energy or substances to provoke different behaviours in a material.	164 to 72 thousand ya (kya)
Joining	Forcing two separate objects together indefinitely.	72 kya
Coating	Applying a covering substance to a substrate.	32 kya
Moulding and Casting	Forming a shape with a pliable material and then hardening it by applying energy or substances.	29 to 25 kya
Forming	Shaping a pliable material that at NTP retains the shape indefinitely.	11 kya

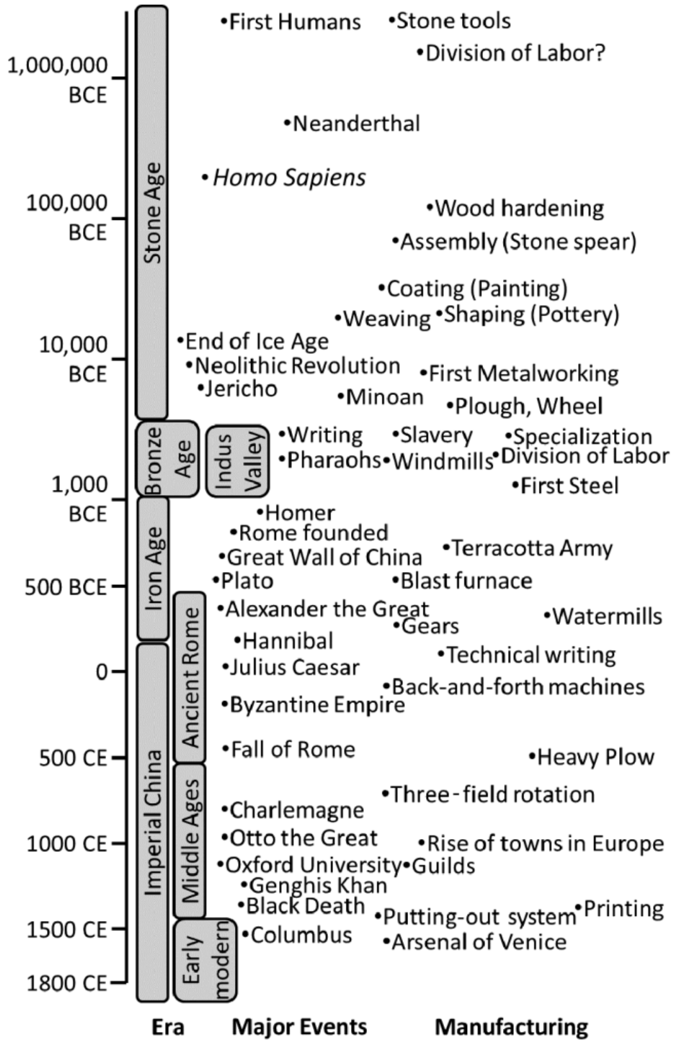
Based on (ROSER, 2016). Note: NTP stands for Normal Temperature and Pressure.

These six principles changed throughout the millennia, giving rise to new technologies and being a base for shaping how humans organised themselves. Figure 23 shows a timeline of the events happening from the dawn of humankind to the end of the Middle Ages and the beginning of the Modern Age. Next, there is a summing up of these events and corresponding technology.

It is possible that before the second technique appeared (see Table 9), labour division was already a thing: differences in stone fragments suggest that Acheulean manufacturing sites had a specific part to build new axes and another to resharpen dull ones. The second technique, changing material properties, is confirmed to have been used 72,000 years ago in South Africa and suspected up to 164,000 years ago, based on silcrete tools. Silcrete is an ore that needs heat treatment before being suitable for shaping (ROSER, 2016).

Then, with the knowledge of heat treatment applied to ochre and plant gum, also at 72,000-years-ago South Africa, Homo Sapiens built composite spears with hardened wood and keen stone heads. The third building principle is joining (ROSER, 2016).

Figure 23 – Timeline of major events and related manufacturing technology: from the dawn of humanity to the beginning of the Modern Age.



Source: reproduced with the rightsholder permission from Roser (2016, p. 391).

Chauvet Cave happened around 30,000 to 32,000 years ago: Humans entered deep into that cave in possession of ochre, charcoal, clay, and a torch, through which they painted numerous depictions of dangerous animals (like cave lions and bears), game animals (like wisents and reindeers), hand imprints, and many other images. The fourth building technique humankind developed is applying a coat to a substrate (coating) (ROSER, 2016).

The first known evidence of the technique of shaping a formless mass of aggregate into an object of use and then putting it into fire to harden it (moulding and casting, the fifth technique) is the Venus of Dolni Vestonice, a female figure made of bones and loess (a type of rock sediment), found in Czech Republic. It dates back around 29,000 to 25,000 years (ROSER, 2016).

The most recent of the techniques is forming. It consists of shaping a piece of pliable material into a desired form. The first known evidence of a formed object dates back almost 11,000 years. It is a pendant made of native copper shaped by hammering (ROSER, 2016).

- **Ancient Manufacturing**

We passed by 3.39 million years and are just at the beginning of the Bronze Age. The Neolithic Revolution brought us the transition from nomadic life to settling farms. Humans have already invented wheels and cities, and ancient societies are starting to form. There is specialised work: farmers and artisans. Before entering the Iron Age, many civilisations with advanced building techniques will form, with different languages (written and spoken) and political arrangements, from those with diametral figures, like the enslaved and the Pharaoh in Egypt, to those that no evidence of centralised power structures has been found so far, like the Harappanian in Indus Valley (ROSER, 2016).

Then, in 1800 BCE, somebody in Anatolia invented the steel, either by accident or design, a league of Iron and Carbon, with controlled amounts of the latter. This technology is considerably cheaper than bronze. It is also much more resistant. In about 800 years, the use of steel will vastly spread to many civilisations, including the already-forming Ancient Greece. That marks the Bronze Age's fall and the Iron Age's beginning (ROSER, 2016).

Through the Iron Age, humanity developed the foundational basis of the occidental and oriental cultures. Constructions from that time still stand today, like the Great Wall of China and The Hephaistos Temple in Greece. During the Iron Age, humans developed fundamental technologies to build those constructions. For example, gears in Greece (270 BCE), Archimedes' worm drive and screw (250 BCE), China's cupola furnaces, able to produce cast iron 1500 years before any other civilisation, and China's weaving machines (looms) (ROSER, 2016).

Iron Age's ending coincides with the beginning of Imperial China. In the Occident, the long-standing Roman Empire lasted until the beginning of the Middle Ages. After the end of the Iron Age, marking the finish of Antiquity, humanity entered Post-classical History. Although this transition took place at different times depending on the region of the world, the average puts it close to the beginning of the Christian Era (ROSER, 2016).

During this latter period, up to the Middle Ages, Imperial China and the Roman Empire were the most influential civilisations in manufacturing technology development. That technology includes, in Imperial China, blast furnaces, water-powered machines (watermills), printing with wood (woodcut), gunpowder, navigation compasses; and, in Roman Empire, advances in construction technology (Roman concrete), advancements in agriculture, like livestock improvement through selective breeding, and food processing advancements, like the operation of bakeries, with many similarities to current ones, including the logistics and the production line (ROSER, 2016).

In 395 CE, the Roman Empire officially split into the Western and Eastern Roman Empires. The first ended in 480 CE, and the latter, known as the Byzantine Empire, ended in 1453. The Western Roman Empire's fall marks the beginning of the Middle Ages, and the Fall of the Byzantine Empire coincides with the transition to the Modern Ages. Since we are discussing advances in science and technology, it is worth mentioning that the first university still operating was founded during the Middle Ages: the University of Bologna, in 1088 (FEINGOLD, 2018; ROSER, 2016).

- **Transition to Modern Manufacturing**

At the end of the Middle Ages, Europe became the World's economic powerhouse. What allowed that was the development of many manufacturing techniques, the foremost being in the fields of agriculture, like the heavy plough and improved horse collars (which enabled a greater yield of their horse-power), labour-saving apparatuses, like the spread of watermills and the Guttenberg print. Other factors include the burgeoning of towns across Europe and the organisation and regulation of production: on the one hand, in artisan guilds – organised groups of artisans that protected themselves from the merchants' power and the competition – and, on the other hand, the cottage industry, also known as *Verlagssystem* or putting-out system, where merchants owned the tools and even the workshops and offered artisan positions in which the merchants had control over the production (ROSER, 2016).

Since the cottage industry is profit-oriented, the accumulation of economic power was intrinsic to the workshop-owner merchant. Conversely, the artisan guilds did not cope with that inclination to amass money. Thus, at the end of the Middle Ages, in the World's central-economic-power Europe, merchants had the economic capability to be ahead of any private investment in manufacturing technology that could improve the means of production's output (ROSER, 2016).

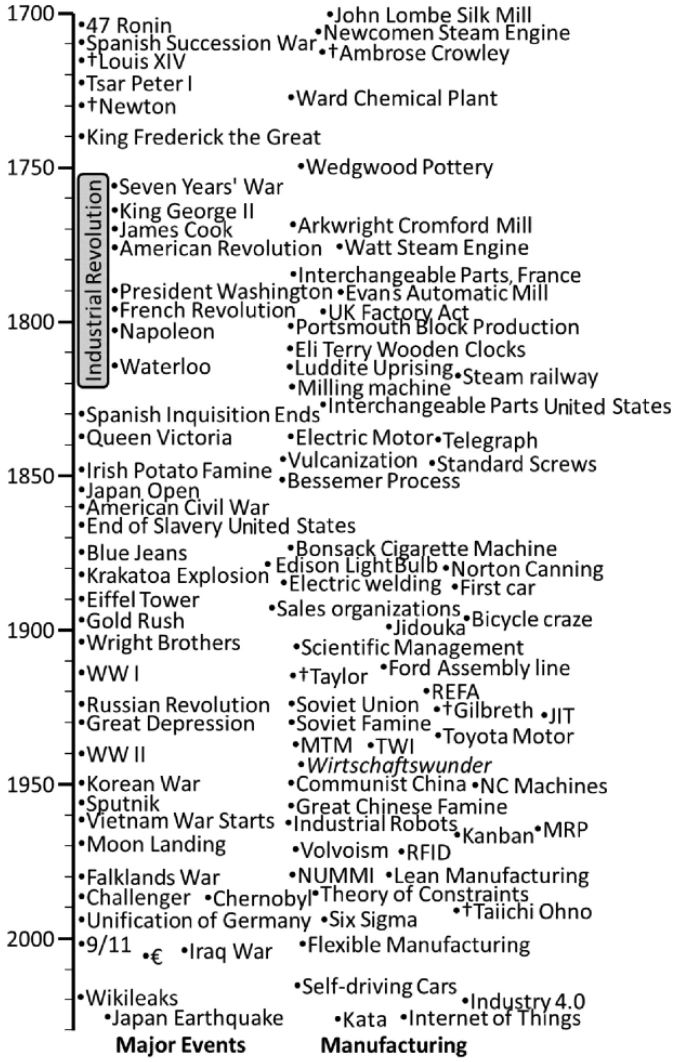
In Europe, the Modern Ages started in the sixteenth century after the end of the Middle Ages. Until the 1750s, there had been many innovations in technology and manufacturing processes, which happened to be the technical basis of the First Industrial Revolution. Figure 24 shows another timeline of events and innovations dating from the Early Modern Age until recently (ROSER, 2016). Next is a description of several innovations just preceding the First Industrial Revolution.

Generally speaking, manufacturing innovations burgeoning between 1500 and 1750 are upgrades in already existing technology and processes. In terms of machinery, most of them were enhancements allowing for the upscaling of the machines. However, a great novelty was the invention of the Steam Engine. Concerning processes, there had been significant advances: the cottage industry developed into the Manufactory, which, with more advanced mechanisation, turned into the Factory system. Several factories applied a proto-scientific approach in production, with at least the experimental validations of processes. Also, several factories reformulated the relationship with their workers, focusing the payments on time worked (instead of pieces produced) and demanding a higher output quality for each production sector (ROSER, 2016).

- **First Industrial Revolution**

The First Industrial Revolution's significant advancements were a continuous bettering of the processes and technologies described above and new inventions and perspectives. A great leap for the industry was the implementation of interchangeability in machines and final products and all the inventions necessary to achieve that, which was also the beginning of the maintenance industry with the production of spare parts. Also, the chemical industry had its first steps (as an actual industrial factory). There is unprecedented knowledge of steel fabrication, with precise carbon content control in the league. The steam-powered locomotives and ships gave base to logistics of that time (ROSER, 2016).

Figure 24 – Timeline of major events and related manufacturing technology: from the Early Modern Age to recent times.



Source: reproduced with the rightsholder permission from Roser (2016, p. 392).

The capitalist bourgeoisie, the working class and their opposing interests regarding working conditions are now a reality. Their struggle (class struggle) defined how work is organised in society. It took decades and decades and uncountable conflicts for minor changes to take effect, like the reduction from an average of 16 hours of work per day in 1810 to 10 hours, only around 1900. The factory owners kept the shorter term because they noticed that the average output increased when an employee worked 8 to 10 hours a day, compared to when the journey was 14 to 18 hours. Actually, before noticing this, factory owners lobbed with the government to maintain the longer journeys and to be able to use law enforcement against those complaining about the issue – which, in turn, is a strong indication that the bourgeoisie sees the workers as just machines made from flash and blood (ROSER, 2016).

Although there is no consensus on the exact time boundaries of the Industrial Revolutions, one criterion widely used is the dominant employment of a specific group of technologies and processes (SASSANELLI; TAISCH; TERZI, 2023).

The focus is on adopting the technology instead of its invention because it usually takes several years, or even decades, to turn an invention into an innovation, especially to apply this innovation in the manufacturing sector. That is the case of electricity, discovered in antiquity and controlled in the 1700s but only coupled to a motor, in substitution of steam power, in 1821 by Michael Faraday. Thus, around 1850, up until 1900, is usually considered the time when electricity became a standard power source for industrial machines. Therefore, the Second Industrial Revolution occurred during this period (ROSER, 2016).

- **Second Industrial Revolution**

In terms of production models, the Second Industrial Revolution solidified the mass production of goods supposed to reach the recently formed consumer market of the working class, with a stratification of the products in terms of quality and, consequently, price. Managers and very well-paid workers could afford products just under the level of luxury (reserved for the ruling classes). In contrast, most workers could buy lower quality but functional goods, significantly improving their living conditions compared to the First Industrial Revolution. Besides, the first ‘industrial empires’ started to form, like Ford and General Motors in the automobile sector, Singer in sewing machines, Siemens and Bosch in varied sectors, Procter & Gamble and Dupont in the chemistry sector (ROSER, 2016).

A cornerstone of the production models came to be during the Second Industrial Revolution: the approach to Scientific Management developed by Frederick Winslow Taylor from the 1880s until the 1910s. During this time, some other names were significant to Management Sciences’ establishment, including Taylor’s colleagues and students, like Morris Llewellyn Cooke and Henry Laurence Gantt. Although these early developments still carried the technocrat thought about the factory worker as a flashy machine, in later developments, the Scientific assessment of management issues evolved to consider the human factor through a positive lens (ROSER, 2016).

During the First and Second World Wars, military interests in being technologically ahead of the enemy, especially regarding the range and precision of bombarding and cryptography, led to the development of increasingly more complex calculators. That happened until the point that if the enemy had a piece of equipment with a minor improvement or change in its operation pattern, a new kind of calculation should be done around the clock to prevent deaths on the battlefield. That was precisely the case with the Nazi's cypher machines (Enigma and Lorenz): with their ability to change the cryptographic scheme even between two sequential messages, The Allies counterparts needed a reprogrammable calculator. That was the birth of the electrical, digital, programmable computer. Although the German Z3 was the first of those computers invented in 1941 (by Konrad Zuse), the Nazi government did not put it in use, for (fortunately) not seeing use for the technology in war. Therefore, the first registered example of a programmable digital computer in use was the Colossus in Britain, developed by Tommy Flowers in 1943, possibly under the supervision of Alain Turing (ROSER, 2016).

- **Third Industrial Revolution**

After World War II, in the late 1940s, industry, including the military, started using computers to solve problems through Numerical Calculus, significantly improving precision. That began the path to computer numerically controlled (CNC) machines that either embed a dedicated computer controlling it, or receive a computer-generated procedure to operate. Another technology derived from using the computer, integrating the mechanical movement of the apparatus, was the invention of robots in the late 1950s. At that time, there were no humanoid robots, just robotic arms used to move heavy objects (ROSER, 2016).

With programmable routines and fast, precise calculations, operations planning also started using computers, programmed based on inputs from the Management

Sciences. In the late 1940s, inventory tracking was their first use. That was the birth of material resources planning (MRP)[17] (ROSER, 2016).

Some scholars consider the Third Industrial Revolution to begin when these computer-based technologies spread significantly, allowing for better planning, control and automation processes. That happened during the 1960s and 1970s, a time with a significant burgeoning of academic programs in these areas, namely Control and Automation Engineering and Industrial Engineering, like the one the present dissertation is linked to, that started in 1967 (PEP, 2023; ROSER, 2016).

The necessity for long-distance communication backed the development of the first electronic systems. Coupling computers with those systems, making possible the transmission and processing of larger amounts and diverse types of information, was just a matter of time. The first electronic mail sent through the USA's Advanced Research Projects Agency Network (ARPANET) occurred in 1971 as a test of the new messaging software written by the computer engineering Ray Tomlinson (THE CENTRE FOR COMPUTING HISTORY, 2023a). USA's Department of Defence developed ARPANET, a precursor computer network to the Internet. Timothy John Berners-Lee published the first ever website in Switzerland on the sixth of August, 1991, at the *Conseil Européen pour la Recherche Nucléaire* (CERN). He coupled the hypertext concept into the Internet (THE CENTRE FOR COMPUTING HISTORY, 2023b).

We will see further that the internet and its related technology are becoming fundamental to production in the current (Fourth) Industrial Revolution.

Management Sciences also evolved after World War II. Based on previous work from Sakichi and Kiichiro Toyoda (father and son, respectively) on more efficient ways to organise factories related to machining and textiles production, Taiichi Ohno developed with great success the idea of Just in Time (JIT) on the factory floor of

[17]This kind of system has been evolving until present days. It passed through integrating management data into the system in the 1980s, the 'M' now standing for 'management' and the acronym in use replaced for MRP II, to avoid confusion. Then, in the 1990s, with other organisational sectors' inputs, that became the ERP, 'E' for enterprise. With 2000's Web 2.0, the system's web integration became the ERP II, with no change in the meaning of the letters. The latest development is ERM, enterprise resource management (ROSER, 2016).

Toyota Motor Company. That led to the development of the Toyota Production System, usually referred to internationally as Lean Manufacturing (ROSER, 2016).

All those advancements from the Third Industrial Revolution until now also evolved by a series of combinations. This evolution consists of three waves concerning the interaction of those advancements. The first wave concerns the previously described automation, which improved productivity, process standardisation, and higher data availability. The second wave came with the Internet and the possibility that companies had to coordinate globally and align operations with external suppliers and customers. In the latest wave, products embody information and communication technology (ICT). Now, goods can incorporate sensors and systems communicating with the Internet, with packets of autonomous behaviours: the Internet of Things (IoT) (SASSANELLI; TAISCH; TERZI, 2023).

- **Industry 4.0**

Together with IoT, other current technologies support the Fourth Industrial Revolution. Some of them are Big Data technologies, those with the capacity to store and process enormous amounts of data and transform them into valuable information; Cloud Computing, allowed by faster telecommunication, is the offering of computing resources on demand via the Internet; Artificial Intelligence (AI), computing systems that mimic and, not yet in every aspect, surpasses the abilities of human intelligence; and Cyber-Physical Systems, enabled by IoT and AI, are systems with increased levels of autonomy, like self-driving cars and autonomous robots, that still are not better than humans in performing intellectual tasks, but indeed are in terms of mechanical force and precision (SASSANELLI; TAISCH; TERZI, 2023).

Literature has associated two terms with these technologies and the consequent new ways the industry is organising itself based on them: ‘smart’ and ‘Industrie 4.0’ (German) or ‘Industry 4.0’, or simply I4.0. Examples of the former are smart cars, smart houses, smart factories, and others. I4.0 is similar to a rebranding that experts in the field made to the previous expression, ‘Fourth Industrial Revolution’. Thus, concerning the First, Second, and Third Industrial Revolutions, I1.0, I2.0, and I3.0 are also used nowadays (SASSANELLI; TAISCH; TERZI, 2023).

CNCs have also evolved to allow for much less interaction with humans. In many cases, before the machines and after them, there is just the client and the operator, respectively. Of particular interest in this work is a technology that allows this possibility on the side of the factory: 3D printing.

Between customer and operator, there is a computer running software, many times open-source, that reads a 3D file, many times freely acquired in the internet, the internet itself, the factory's or printing farm's computer (see Subsection 1.1.1) – a printing server – that queues the printing list sending the current file to the next available 3D Printer, which prints, layer by layer, the plastic or metallic piece. The operator is usually the same person who checks the computer and takes the finished piece off from the printing bed (KEUNE; PEPPLER, 2019).

Regarding production models, four economic tendencies have been a reality for ten to twenty years and shall probably remain in the industry. One is the passage to servitisation, where goods are no longer the main character but physical media to deliver a service. An example is car sharing, where a person does not mind possessing a car but getting from one place to another, with more privacy and comfort than public transportation would allow, paying more than in public transportation but considerably less than the cost of owning a car (ROSER, 2016).

Two other coupled tendencies are the realisation of prosumption and mass customisation. For prosumption, the reader may refer to subsection 1.1.3. Mass customisation, in I4.0's context, allows for the maximum possible flexibility of the final product corresponding to a specific client's requirements without losing the price range associated with mass production. Usually, this means mass producing whatever will not be in direct contact with the customer and manufacturing the product's parts they will interact with on a smaller scale – so the consumer has a greater chance to purchase an exclusive product. Options when buying a car illustrate this: the chassis and motor tend to come from mass production, identical in various models. However, the client may choose everything else that comes over the chassis, such as the type of seats, the air-conditioning, the rear camera system, the sensors, the wheels and tires, and the steering system and wheel (ROSER, 2016).

Another tendency is the digitalisation[18] of production and operations. For instance, in 3D Printing, everything happening before the machine builds the good, except for the material inputs, is made digitally, like the design, the physical simulations, the purchase, and the queuing; if there are a lot of different products to print (SASSANELLI; TAISCH; TERZI, 2023).

We finally got to the current days in the present text regarding technology development and its implications in manufacturing. Thus, we can finish by pointing out where the manufacturing is heading based on discussions in recent literature.

Substituting human labour for machine-based work is a global trend observed since I1.0. Although it has a positive side, how positive it can be has a limit, determined by politics. By definition, Politics is how a society organises itself. Therefore, if a society's political structure does not have a way to deal with the loss of jobs to machines, especially when this substitution reaches the level of intellectual jobs, like designing, what has already been observed, and machines can operate even services, like self-driving cars, then, there is a considerable risk of collapse (ROSER, 2016).

The collapse is a direct consequence of having a job be the unique form of income and society doing nothing to compensate for the loss of most jobs for machines. After that, there is no more money to buy things, no more consumer market. There is even the chance that machines, after what is known as the *singularity* – when they acquire some conscience coupled with higher intellectual capability than human beings – decide to get rid of us altogether, as we serve no more than giving orders (ROSER, 2016).

Indeed, this is a possible future, each time more accurate and less science-fiction. Moreover, as stated before, getting there or not depends on how society will organise from now on; it depends on politics (not politicians; after all, there is still hope). In manufacturing studies, academics have considered the dissociation between humans and production, provoked by the current way automation, mass production and

[18]Digitisation vs digitalisation: the former usually means to turn a once analogic entity into its digital counterpart, like scanning a document and obtaining a Portable Document Format (PDF) file from that. The latter term commonly means the move from analogic-based processes to their digital counterparts, for example, searching in that old metal file cabinet with hundreds of archives and documents, is a hugely time-consuming activity, whereas the 'find' tool in a digital file simply does not exit out of the digital world, and makes that process as quick as the computer is (STEVENSON, 2010).

logistics are linked to each other in the manufacturing systems (IVANOV, 2023; ROSER, 2016).

- **Manufacturing the Future**

Scholars are discussing how to reconnect humans and manufacturing in future steps from now on, steps happening even after the ongoing I4.0 transformation of industry. Ergo, this future transformation has been called Industry 5.0, the Fifth Industrial Revolution, I5.0 (IVANOV, 2023).

In the same way as in previous Industrial Revolutions, current technology will not necessarily be substituted, but evolutions of it will be employed with a different approach. The main distinction is the integration of human and environmental factors in the new ways of implementing the technology in the industry (ORDIERES-MERÉ; GUTIERREZ; VILLALBA-DÍEZ, 2023).

There is a variety of definitions in the literature about I5.0. A good source for them is the work of Maddikunta et al. (2022). All in all, the definitions revolve around the same base of concepts concerning the presence of humans in factories that are supposed to use technology considering the well-being of the workforce, the environment and society.

The following definition coalesces all of that:

> Industry 5.0 provides a vision of industry that aims beyond efficiency and productivity as the sole goals, and reinforces the role and the contribution of industry to society. It places the well-being of the worker at the centre of the production process, and uses new technologies to provide prosperity beyond jobs and growth while respecting the production limits of the planet (GAGNIDZE, 2023, p. 2280).

Other works also go in the direction of this definition but, at the same time, make a clear distinction from I4.0, precisely concerning the shift in focus from a 'technocentric' I4.0 to a 'humancentric' I5.0 (IVANOV, 2023; TÓTH et al., 2023; XU et al., 2021).

The idea is to "put humans back into the loop" (LONGO; PADOVANO; UMBRELLO, 2020, p. 3). Because of that, scholars are discussing how to design the so-called Cyber-Physical Production Systems (CPPS) in a human-centric way, which is supposed to address several issues, like issues related to human values. For example, new ethical issues may arise from the workplace interaction between humans and robots. One of the current propositions is the use of Value Sensitive Design (VSD) because it motivates designers to come up with flexible and malleable technology architectures, allowing post-deployment augmentations that may be necessary when new human values concerns emerge (LONGO; PADOVANO; UMBRELLO, 2020).

At this time, there are two significant visions about what is supposed to be seen in I5.0. One of them is 'human-robot coworking', where, whenever possible, humans and robots work together. The other vision concerns the 'bioeconomy', signifying an intelligent use of biological resources to achieve a realistic balance between industry and ecological matters. These are not concurrent visions; both are expected to be part of the industry's operation (DEMIR; DÖVEN; SEZEN, 2019).

I5.0's time is supposed to occur when the industry accomplishes three prerequisites: intelligent systems, intelligent devices and intelligent automation. They are all merged into the physical world in cooperation with human intelligence – configuring a synergy between humans and autonomous machines (NAHAVANDI, 2019).

The realisation of this scenario shall also count with an overall flexibility to circumvent unforeseen situations, so humans still have control over what is going on. Thus, the concept of 'orthogonal safe exits.' The concept of orthogonality in use here relates to the concept of an independent entity. Thus, it is expected that, for safety reasons, future systems also have a built-in way to consider the need for either acceleration or deceleration of production and even an escape from the digital networks altogether. That needs to be independent of the digital networks, like a safety switch in an industrial machine is independent of other machine's commands, that either puts it in a safety mode or, in the worst case, completely halts the machine (IVANOV, 2023; ÖZDEMIR; HEKIM, 2018).

Having laid down the historical perspective on manufacturing and several of the forms it took along the time, since the dawn of humanity, to current visions on the possible future, this work can now head to a more specific way to organise production. That involves organising the production in a distributed way. That is the subject of the following subsection.

2.2.2 Distributed Manufacturing Processes

The literal interpretation of the term already makes it possible to have a good grasp on the meaning of ‘distributed manufacturing’. It is a manufacturing process that comprises various simpler manufacturing nodes contributing to the whole manufactured yield (SRAI et al., 2016).

The manufacturing nodes are geographically separated. They often represent companies that specialise in a specific part of the assembly. In situations like these, to determine the optimal production chain, the company responsible for the whole product utilises a so-called distributed manufacturing system (DMS) (ZHANG et al., 2022).

DMS consists of a manufacturing planning and scheduling algorithm accounting for the location of the whole supply chain involved in assembling the product and the final customer (ZHANG et al., 2022). Thus, the supply chain tends to be closer to the consumer, and the production process to be demand-prompted (GUPTA et al., 2023).

Scholars consider DMS an innovative way to plan production since its developments and implementations reside in the context of I4.0. Technologies used to implement DMS include big data to inform the algorithm, blockchain to maintain communications inside the supply chain safe, IoT to generate machine data that builds up to the big data, and AI to help process and identify patterns in the data (RAMAKURTHI et al., 2022).

The scenario above concerns a planned situation with enough time and effort to implement DMS features into the manufacturing processes. Conversely, there are situations where this is not possible. However, distributed manufacturing is feasible and becomes the primary way to provide a specific product, for example, in humanitarian emergencies and disasters, where, besides all the direct impacts of diseases, conflicts or tragedies, the supply chain of many fundamental goods gets disrupted – including the very ones necessary to amend the situation (LIU et al., 2023).

In such emergencies, people trying to help, and even physicians, may benefit from the current widespread availability of open-source hardware (OSH) designs. Departing from a model freely acquirable on the internet, these people can use their local resources to build that model. Even if a modification is necessary to the model, it is much easier and cheaper than in a commercial model. For example, a commercial model of medical equipment may be unavailable due to a supply chain shortage or disruption (BOW et al., 2022).

Distributed manufacturing also includes cases where various actors use local resources to build a device or equipment. Furthermore, a 3D Printer can build many such open-source models; thus, it may become the leading manufacturing resource (WITTBRODT et al., 2013). In LIU et al. (2023), for example, the authors developed an open-source model for a tourniquet testing system with many 3D-printed parts. The model uses an Arduino board as the controller for the electronics running an open-source code provided by the researchers. It is easily replicable, works as well as a commercial model and is way cheaper – from dozens of dollars for the open-source model to hundreds of dollars for the commercial ones (LIU et al., 2023).

Recalling section 2.1, we know that this open-source approach is at the core of the Maker Movement. Although using open-source files and a 3D Printer to manufacture more accessible devices could solely mean a niche-kind initiative, the articles above show that this is not the case precisely because this manufacturing possibility is increasingly considered the best alternative in many emergencies. People found this method fast and reliable when other alternatives were either impossible (for supply chain reasons) or unreliable. For example, when somebody tries to build a makeshift with spare materials that can achieve neither the reproducibility of 3D Printers nor the precision of the final piece (BOW et al., 2022; WITTBRODT et al., 2013).

That means that, in many cases, the people taking part in initiatives to help during an emergency are Makers. They and organisations related to the Maker Movement, like Makerspaces, are those that, at any given time, own 3D Printers and the expertise to operate them (AWORI; LEE, 2017; MILLARD et al., 2018).

Still, people can benefit from open-source designs not only in case of emergency. People often use these designs as a substitute for off-the-shelf products because of the final object’s reliability and lower price range. That is the case of the model developed by So, Reeves and Pearce (2023). The authors designed a walker to help people with locomotion disabilities using wood rods and 3D-printed parts. Broom handles were the source for the linking rods, the joints are the printed parts, and the set is put together with screws (SO; REEVES; PEARCE, 2023).

Now, recurring to the history of manufacturing, one could say that it has already incorporated a distributed model. That person would be correct: artisans' manufacturing indeed adopted a distributed model: they sourced the materials locally and produced the same product other artisans would produce elsewhere, although with local characteristics, either because of that artisan's specific abilities or because they were designing something to the local market attaining to its specific demands (SRAI et al., 2016).

That is one of two reasons why some scholars refer to the current wave of manufacturing distribution as Redistributed Manufacturing (RDM). The other one is the fact that, contrary to a tendency for centralisation observed since I1.0, which searched for the cheapest place to build a large-scale factory, many nouveau enterprises build on a demand for reshoring the production – that is, to bring the production closer to the consumer once again – in a kind of re-industrialisation of areas that, before impacts of a globalised economy, had its local economy deeply related to industries located there (SRAI et al., 2016; SRAI; HARRINGTON; TIWARI, 2016).

2.2.3 Redistributed Manufacturing

The work of Ouyang, Yuan and Wang (2019) further explores the specificities of a Distributed Manufacturing (DM) model that allows its classification as RDM:

> DM becomes RdM when a DM system can respond to ecological needs to redistribute the manufacturing location, scale, standards, value, risks and responsibilities of distributed sites or agents (OUYANG; YUAN; WANG, 2019, p. 77).

Freeman and Mcmahon (2020) also contribute with distinctions between DM and RDM:

> Distributed manufacturing refers to the geographical distribution of the production of one organization, or the distribution of manufacturing within a dispersed production network of autonomous agents. Distributed manufacturing differs from RDM in that there are no assumptions about production being close to customers or happening in smaller production units, or in using new production technologies (FREEMAN; MCMAHON, 2020, p. 452).

- **RDM Characteristics**

If we look at the emergence of the term in the literature, RDM's first appearance was in the report from a workshop held by the United Kingdom's (UK) Engineering and Physical Sciences Research Council (EPSRC) in 2013, about the importance of novel approaches to restructuring UK manufacturing capabilities. The motivation for the workshop was the UK government's worries about being less dependent on global supply chains and maintaining the UK's positioning as a leading nation in the world of manufacturing (PEARSON; NOBLE; HAWKINS, 2013).

In that report, RDM encompasses the effect novel business models and technologies would have on production's scale and location (PEARSON; NOBLE; HAWKINS, 2013).

Since that report, a handful of definitions have emerged in the literature. Next, those definitions further explore the axes of scale and location.

In the axis of location, the definitions usually go with the word 'localisation' (of the production). That is because the authors refer to when the production designers intentionally plan the production's site to be closer to the consumer, so it has a territorial dimension (CHIARINI; GRANDO; BELVEDERE, 2023; FREEMAN; MCMAHON; GODFREY, 2017; PHILLIPS et al., 2022).

This territoriality builds upon the two sides of the supply chain: it aggregates locally-sourced materials on the side of the suppliers and, on the side of the client, it considers local tendencies and consumer preferences, even allowing for prosumption (PEI et al., 2019; PHILLIPS et al., 2022; TURNER et al., 2019).

The other axis, scale, is linked to the location axis. They are linked in the sense that, considering current technology, production and logistic constraints, the type of production's scale suitable to this level of localisation is generally small-scale manufacturing (CHANDIMA RATNAYAKE, 2019; CHIARINI; GRANDO; BELVEDERE, 2023; SINCLAIR et al., 2018).

Some definitions also include the type of current technologies RDM benefits from (KUMAR et al., 2020). For example, they indicate that RDM is "empowered by Industry 4.0 toolset offerings through advanced ICT, such as the internet of things, and manufacturing technologies, such as additive manufacturing" (HADDAD; SALONITIS; EMMANOUILIDIS, 2021, p. 1011)[19].

[19]ICT stands for Information and Communications Technology (STEVENSON, 2010).

- **RDM Technology**

Additive Manufacturing (AM) refers to 3D-Printing (SRAI; HARRINGTON; TIWARI, 2016). Several works use an RDM definition that already takes into account the area of application of 3D-Pinting, like in healthcare: "RDM of bioprinting refers to decentralised business models that place bioprinters in local hospitals or third party centres" (LI; FAULKNER; MEDCALF, 2020, p. 1017). Bioprinting, in turn, has a variety of forms, from direct printing using cellular material to build tissues to more 'simpler' cases, where 3D Printing technology is employed to build customised pills with the necessary accuracy and reproducibility that medicine manufacturing requires (YANG et al., 2023).

Nowadays, the most accessible 3D Printing technology is Fused Deposition Modelling (FDM). Building things by FDM is a type of additive manufacturing. It consists of extruding a fused polymer layer-by-layer to form a shape constituted by the sum of all the layers (GAO et al., 2015). Extrusion is the process of expelling material through a nozzle. It is the same process used in a dried pasta machine to make spaghetti (or another variant) or in cake-making when decorating the cake with a piping bag. Food technology also uses 3D Printing, especially in research, and many processes derive from those just described (SHARMA et al., 2024).

The final product of an FDM 3D Printer is a solid object since the polymer solidifies in normal temperature and pressure (NTP) conditions (NGO et al., 2018). Likewise, most of the cases studied in this work used FDM 3D Printing as the enabling technology of their RDM model.

- **RDM: Current Definition**

Academic exploration of RDM began in the Global North, and few articles have dealt with it in the South. An example of the latter is the work of Luthra, Mangla, and Yadav (2019), where the authors investigate the causes of RDM not being developed in India. Considering the current literature, the present research is the only one to investigate RDM cases in Brazil as of 2023. The results of this investigation have already been published (CAMPOS; CIPOLLA, 2021), and that publication is seminal for this dissertation.

All in all, the present work uses the following RDM definition:

> the ability to personalise product manufacturing at multiple scales and locations, be it at the point of consumption, sale, or within production sites that exploit local resources, this is exemplified by enhanced user participation across product design, fabrication and supply, and typically enabled by digitalisation and new production technologies (SRAI et al., 2016, p. 6932–6933).

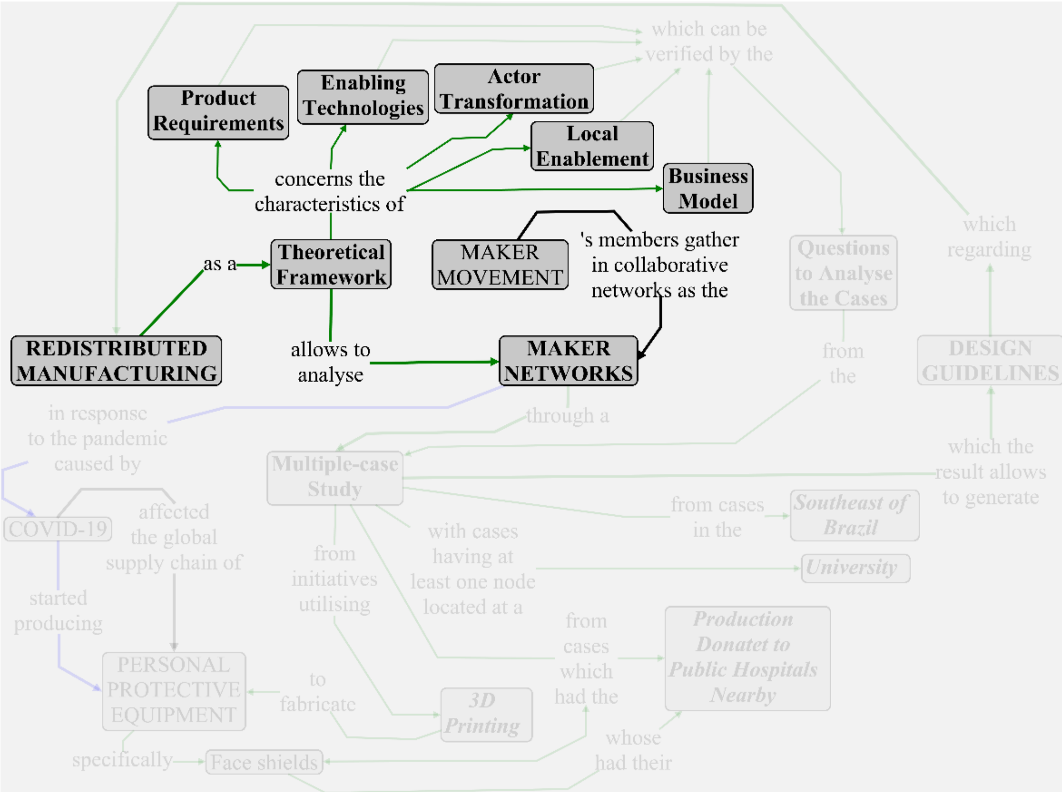
Finishing this chapter, we further explore the relationship between Redistributed Manufacturing and the Maker Movement in the next section. It finishes with the theoretical background on the core issue giving base to this work: the relationship between a model of production of goods, which is deeply related to its geographical dispersion, Redistributed Manufacturing, and the Maker Movement (HENNELLY et al., 2019).

2.3 RDM AND MAKER MOVEMENT: INTERCONNECTION

Deriving from everything built so far on RDM and the Maker Movement, it would not be a far-fetched supposition that the Movement's members, Makers – people prone to know how to operate a 3D Printer – would be the ones found taking part in an RDM initiative, where 3D Printers are the primary technology at the production point in play. As we will see next, beyond this more-than-reasonable supposition, some literature is already exploring scenarios where this is the case before, during and after 2020's main peeks of the SARS-CoV-2 pandemic.

The following subsections will guide the reader to the structure of RDM this work takes as its theoretic framework. This work's concept map also summarises this framework. See Figure 25 below.

Figure 25 – Summarised version of the RDM model in this work’s concept map.



Source: Author.

2.3.1 Works Before, During and in the Aftermath of the Pandemic

- **Before 2020**

In Chapter 1, this work stated that a theoretical development was already in course before the pandemic, and there was a fundamental article for the present work. That article investigated how Makerspaces could participate in RDM and was published in 2019, somewhat before the pandemic (HENNELLY et al., 2019). Let us now understand how they contributed to the academic discussion on the Maker Movement, RDM and their relationship.

In that paper, the authors departed from investigating the literature with terms related to RDM and Makerspaces. Using visualisation and text processing techniques over the literature they found, they built a theoretical framework for investigating several Makerspaces cases to understand their RDM characteristics (HENNELLY et al., 2019).

Nevertheless, the authors did not develop their model solely based on physical spaces (Makerspaces) elements but on RDM and Maker Movement’s overall features.

Thus, this framework is of particular value to grasp RDM characteristics related to initiatives from the Maker Movement, not only for Makerspaces. Table 10 is their first theoretical result: it has the axes (set implementation characteristics) they used to study several cases and subcategories of these axes, all supported by the literature they reviewed (right column).

Table 10 – Key RDM implementation characteristics.

Implementation Characteristics	**Subcategories**	**Supporting Literature**
Product/Service Requirements	Proximity	Anderson (2012)
	Customisation	Eyers and Potter (2015)
	Real-time	Mikkola and Skjøtt-Larsen (2004)
	Innovation	Coronado et al. (2004)
	Environment/CE	Barrett et al. (2015)
	Digital	
	User participation	
Enabling Technologies	Capability	Telenko et al. (2016)
	Maturity	Emelogu et al. (2016)
	Capacity	Rogers, Braziotis and Pawar (2017)
	3D Printing	Wagner and Walton (2016)
	Big Data	Thomas (2016)
	IT H&S	Liu et al. (2014) and WEF (2015)
Business Model	RDM Prod. D&M	Rogers, Braziotis and Pawar (2017)
	RDM cost model	Srai et al. (2016)
	Product ownership/IP	Brennan et al. (2015)
	Alternative finance	Kühnle (2010)
	Commercialisation	De Ugarte, Artiba and Pellerin (2009)
Local Enablement	Institutional support	Laplume, Anzalone and Pearce (2016)
	Local networks	Holmström et al. (2016)
	Social/Communities	Srai et al. (2016)
	Rebalancing	Tatham, Loy and Peretti (2015)
	Research	Prendeville et al. (2016)
	Students/Experts	Rauch et al. (2015)
	Schools/Libraries/Labs	Levy et al. (2016)
Actor Transformation	Culture	Romero-Torres and Vieira (2016)
	Leaders	Fawcett and Waller (2014)
	Education	Leonardi (2012)
	Multidisciplinary	Sheridan et al. (2014)
	Communication	

Adapted with the rightsholder permission from Hennelly et al. (2019, p. 543). Notes: CE = Circular Economy; H&S = Hardware and Software; WEF = World Economic Forum; Prod. D&M = Product design and materials; IP = Intellectual Property.

In Hennelly et al. (2019), there is a definition for each of the sets of implementation characteristics. The following paragraphs enumerate them.

Product Requirements:

> RDM requires the manufacturing of products in which the customer is much more involved and participative in their development. Users are assumed in RDM to be strong co-creators in the design and production process, this leads to unprecedented levels of co-creation and personalization (HENNELLY et al., 2019, p. 542).

Enabling Technologies:

> Rapid advances in digital design and fabrication technologies are creating radical new possibilities for innovations in production and consumption (…). The variety of materials and complexity of fabrication expands and knowledge systems and digital interfaces are easing user engagement (HENNELLY et al., 2019, p. 542).

Actor Transformation:

> (…) requires a transformative culture change in existing supply chain governance. Current models of centralization and hierarchical management of actors (i.e., suppliers) need to be reconfigured towards greater actor decentralization and innovation driven supply chain design. (HENNELLY et al., 2019, p. 543).

Local Enablement:

> In this RDM production model paradigm, we might envisage factories in local communities, meeting the needs for employment and wealth generation (…). Small-scale local manufacturing means that a high level of customization of products is possible – with autonomous systems able to anticipate needs as much as respond to them – and create direct relationships between customer and factory. In the context of the importance of sustainability and limited resources, localization means far less need for costly international supply chains, low-energy use and carbon footprint, and more reliance on domestic materials that come from recycling processes or are grown or produced in the community. (HENNELLY et al., 2019, p. 543).

Business Model:

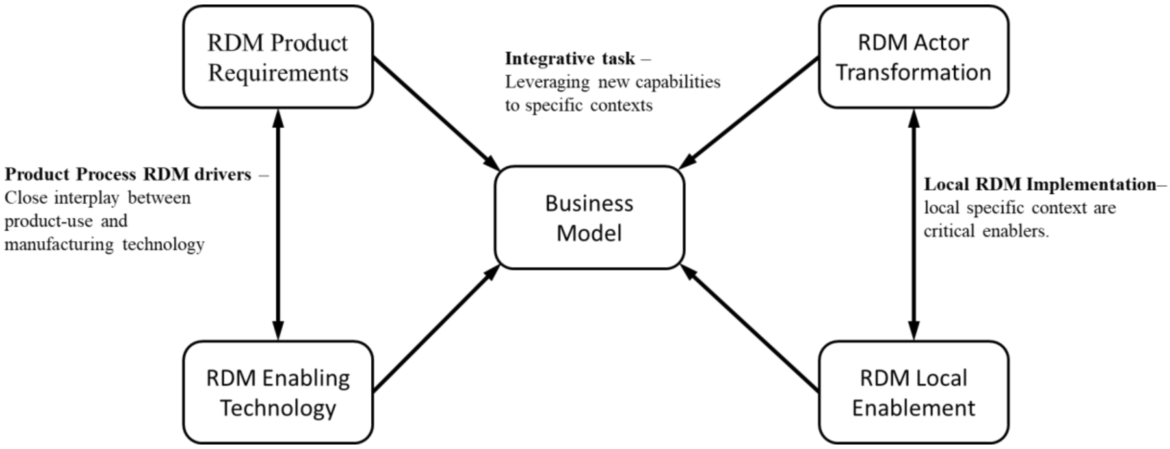
> The different business models link the unique contexts and enablers for a given sector and/or region for effective implementation. Processes and supply chain activity need to be organized to create and sustain value in the supply chain. Theoretically the business model implies that local material resources are used locally to locally produce goods for local consumption and disposal. The production activity is supported by a global flow of non-material resources such as capital, technical expertise, patents, data analytics and business planning. The flow of both material and non-material resources is managed locally by either the global firm or local organization (HENNELLY et al., 2019, p. 543–544).

All those characteristics are supposed to work in harmony in an RDM model, and they have a structure where not only do they interconnect, but also, the Business Model links all of them together since it represents the fundaments upon which an

RDM-Maker initiative would work (HENNELLY et al., 2019). Figure 26 shows this structure.

Observe that the sets of characteristics connect in pairs. The Product Requirements have to do with the available Enabling Technology to build them, which also holds the other way around. The same is true for the pair Actor Transformation and Local Enablement since only the local possibilities can transform the people participating in an initiative; likewise, the local enablement a place has to offer to an initiative depends on the people related to that place, which are taking part in the initiative (HENNELLY et al., 2019).

Figure 26 – Implementation characteristics structure in an RDM-Maker initiative.



Source: reproduced with the rightsholder permission from Campos and Cipolla (2021, p. 211). Originally adapted with the rightsholder permission from Hennelly et al. (2019, p. 544)

Considering the definitions above and the subtopics in Table 10, the present work builds its first theoretical derivation to analyse initiatives from the Maker Movement through the lenses of the RDM model. That result is a set of questions organised as a table (Table 13). Since this research uses those questions to verify the RDM characteristics of a studied case, it represents a method for obtaining a result; thus, it is part of the methodology of the present work, Chapter 3.

Table 10 explains each of those characteristics (subcategories). That explanation comes from the literature supporting it. Because these subcategories are part of Table 13, their explanation also appears in the methodology (Section 3.3) since they are fundamental to interpreting the set of questions.

- **During 2020’s Pandemic**

Indeed, the present work could be cited as partially developed amid the pandemic. Besides this trivial example, another work that explores possibilities regarding 3D Printing and RDM, developed during the pandemic, is the article of Robinson et al. (2021).

In that article, the authors explore how changing several 3D Printing parameters could lead to an open-source production process suitable for RDM, using as input material a metallic league of Copper, Tungsten and Silver, capable of eliminating the SARS-CoV-2 by contact. They obtained a porous material which achieved 100% virus inactivation in five hours. Although they say further studies can improve the time for inactivation, the final result is suitable for production under an RDM model and can reduce surface contamination (ROBINSON et al., 2021).

- **A Work on the Aftermath**

Now, looking for a work that evaluates the use of 3D Printing and RDM after 2020, a good example is the article from Phillips et al. (2022). Their article tries to understand how RDM could improve the reconfiguration of global value chains so that local production can be more resilient against global disruptive events. They develop a work focusing on the healthcare industry. They conclude that implementing additive manufacturing under the RDM model, at least in healthcare cases, can lead to a more resilient local economy. (PHILLIPS et al., 2022).

Overall, we have gone through all the theories and theoretical discussions that give basis to the present work. Therefore, we can now proceed to the chapter detailing the methods that led to this work’s results, considering all that theory.

3 METHODOLOGY

The following sections describe the path taken to build this work. It starts with how this author digs the scientific literature, giving a base to this manuscript. Then, there is a section on how the cases were selected and analysed according to case study research. After that, this work dedicates a section to the case analysis questions. Finally, in the last section, the reader finds a clarification on how to provide design proposals from the studied cases.

3.1 LITERATURE REVIEW

Many studies deal with possible ways to conduct a systematic review (TRANFIELD; DENYER; SMART, 2003).

Some of them are somewhat rigid in their structure, not allowing for any deviation cover to cover. These methods seek to improve the integrity of the whole research while at the same time being especially fit for pre-designed investigations (THOMÉ; SCAVARDA; SCAVARDA, 2016; TRANFIELD; DENYER; SMART, 2003).

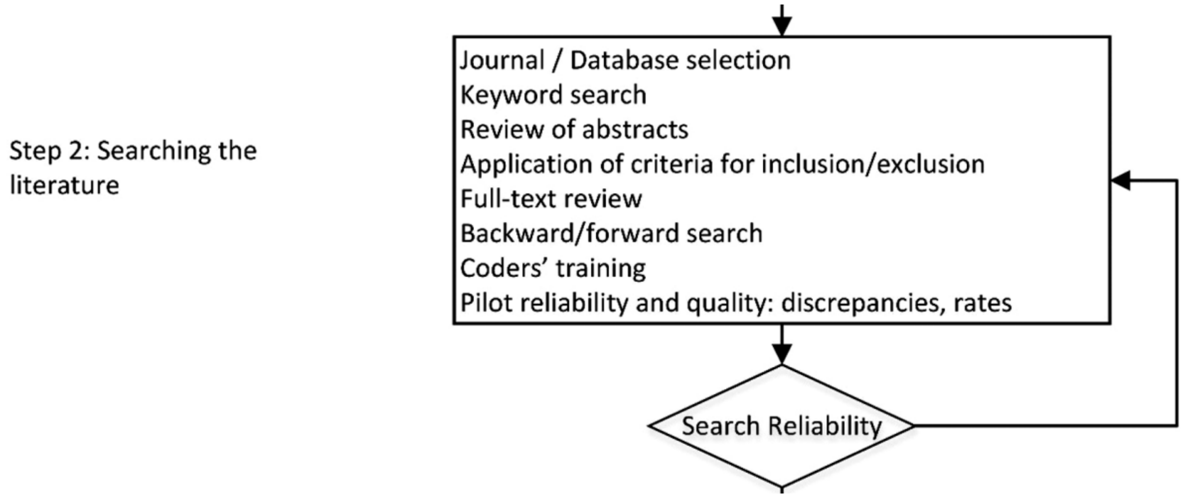
Considering the need for a flexible yet reproducible and reliable method, the present author followed Thomé, Scavarda and Scavarda (2016).

Those authors have a detailed description of systematic literature reviews. Nevertheless, considering the scope of the literature review carried out here and the extent of the overall results from searching knowledge databases, the directives sufficing these criteria are just those relative to the second step proposed by them: "Searching the literature" (THOMÉ; SCAVARDA; SCAVARDA, 2016, p. 410).

Using their own words: "This step-by-step approach is a guideline. Some LR techniques embrace all steps while others will fit in some but not all steps." (THOMÉ; SCAVARDA; SCAVARDA, 2016, p. 409)[20].

[20]LR – Literature review.

Figure 27 – Step-by-step for searching the literature.



Source: adapted with the rightsholder permission from Thomé, Scavarda and Scavarda (2016, p. 410).

Next, we see the details about the literature search in the present work, according to the subitems necessary for that search in the order shown in Figure 27 (Journal / Database selection to Full-text review). Table 11 sums up the whole process, described below.

This research conducted two separate searches in the primary databases in this work, Scopus™ and Web of Science™. One was about RDM, and the other was about the Maker Movement. The decision to conduct the searches separately was due to the few works returning from a composed search. Although the number of works returning in a search is considerably higher nowadays, less than ten articles appeared from a combined search in 2019. In both cases, a search on Google Scholar with the same sentence returned some more results, not showing in Scopus and Web of Science at that time, see Table 11.

To find works related to RDM, the sentence used was: "redist* manuf*" OR "manuf* redist*" OR "redist* of the manuf*" OR "manuf* proc* redist*" OR "re-dist* manuf*" OR "manuf* re-dist*" OR "re-dist* of the manuf*" OR "manuf* proc* re-dist*".

This search returned 31 works from Web of Science™ and 18 from Scopus™. From the total 49 works, 16 were duplicates. Thus, the present researcher read through the remaining 33 works without a previous title, keywords, or abstract exclusion.

Table 11 – Selection of works for reviewing the literature carried out in 2019.

Scopus + Web of Science	**Subject**	
	Redistributed Manufacturing	**Maker Culture/Maker Movement**
Search sentence	"redist* manuf*" OR "manuf* redist*" OR "redist* of the manuf*" OR "manuf* proc* redist*" OR "re-dist* manuf*" OR "manuf* re-dist*" OR "re-dist* of the manuf*" OR "manuf* proc* re-dist*"	"maker movement" OR "maker culture" OR "DIY culture" OR "DIY movement" OR "do-it-yourself culture" OR "do-it-yourself movement" OR "do it yourself culture" OR "do it yourself movement"
Results	Scopus: 18 / Web of Science: 31.	Scopus: 307 / Web of Science: 417.
Duplicates	16.	210.
Inspection by Title, Abstract & Keywords	The remaining 33 papers have been read.	("networks", "literature", "maker movement", "maker culture", "economic development", "entrepreneurship", "supply chain"): 21.
Google Scholar	Pearson et al., 2013.	Kohtala and Bosqué (2014); Wolf et al. (2014); Wolf and Troxler (2016); Menichinelli et al. (2017), Yang and Jiang (2019); Manzini (2012); Zhang et al. (2020).

Source: reproduced with the rightsholder permission from Campos and Cipolla (2021, p. 212).

For retrieving studies about the Maker Movement, the search sentence was: "maker movement" OR "maker culture" OR "DIY culture" OR "DIY movement" OR "do-it-yourself culture" OR "do-it-yourself movement" OR "do it yourself culture" OR "do it yourself movement".

It returned 307 results from Scopus™ and 417 results from Web of Science™. From that total of 724 works, 210 were duplicates. Hence, the individual 514 works passed by the inclusion/exclusion process over the titles, keywords and abstracts. The inclusion criterion was a work containing either of the expressions: "networks", "literature", "maker movement", "maker culture", "economic development", "entrepreneurship", and "supply chain". The exclusion criteria were a work not dealing with one of these themes or not containing these expressions. That led to the final 21 works to consider.

The present researcher took a similar approach to the one described above to gather relevant and recently published peer-reviewed works up to 2023.

The database used this time was Scopus. The relevance criterion was the number of citations. This research applied that criterion to every theme explored in Chapter 2, except for RDM. Again, in this latter case, the number of new works in the database was insufficient to require previous analysis before reading all available works.

This effort aimed to enrich the theoretical background and bring up-to-date literature on the subtopics related to RDM and the Maker Movement analysed in Chapter 2. Thus, the present researcher chose an average limitation of ten works for each subtopic since it is sufficient to give examples of the topic. This limitation is justified since the intention is not to promote a methodologically-oriented literature review, as would be the case of a systematic literature review (THOMÉ; SCAVARDA; SCAVARDA, 2016). Instead, it aims to give an overall literature-baked basis for exploring more details of the central theme.

The selection described above applies to the works used in Chapter 2 to describe Distributed Manufacture; Industry 5.0; Grassroots Innovations in Brazil, China and India; Makerspaces and their variations; DIY; Hobbies; Maker Culture; Maker Movement and Maker Networks.

The exception was the search for works dealing with the history of manufacturing. The present author chose the most cited book on that subject in the Scopus database (ROSER, 2016). Also, the simultaneously most recent and cited work in that same citation database (SASSANELLI; TAISCH; TERZI, 2023). That could guarantee both reliability and currentness – thus, the present author adjusted the search parameter to show only the works from 2023 on, and in decreasing order of citations – so it is just a matter of choosing the first on the list discussing the theme of interest.

The limitation in ten works for most of the topics in Chapter 2 has a similar division as described above. First, the most historically cited study was chosen. Then, five of the most cited in the last five years. The remaining were chosen from the most recently published, starting from the most cited ones. The most recent work, independent of citation count, was chosen if there were fewer than ten articles, even with no current citations.

For RDM, the Maker Movement and the Maker Culture, this new search used the same sentence as in Table 11. For every other topic, another search parameter changed: the engine should now look solely at the titles of the works. That is because the intention is to deal with studies containing definitions of the investigated topic.

The only part of the literature used here that the present author did not obtain by the methods described so far are books or papers previously known by the present author, including those recommended by the examining committee at the Pre-defence.

That includes works on the History of Design (BUCHANAN, 2009; MOHOLY-NAGY, 1947), Anthropology of Design (BOUTINET, 2012) and Philosophy of Design (FLUSSER, 1999, 2011). It also includes dictionaries of the English Language (STEVENSON, 2010) and the English Language's Etymology (ONIONS; FRIEDRICHSEN; BURCHFIELD, 1966).

Once the methods for developing the theoretical background of the present work are clear, we can now proceed to understand how this work applied these methods to study the reality to which it refers. As put in the introduction, this work analyses several initiatives from the Maker Movement through the lenses of RDM. These initiatives are the investigated cases, and the next section explains how this work investigated cases through the lenses of a specific theoretical background.

3.2 CASE STUDY

The procedure to build knowledge from the investigated cases in this work followed the path in the book by Robert Kuo-zuir Yin (YIN, 2018). The work of Kathleen Marie Eisenhardt (EISENHARDT, 1989) also informs this work.

A case study may have six phases: planning the research, designing it, preparing data collection, collecting data, analysing data, and finally, reporting (YIN, 2018). Reporting consists of composing works like the present one, and in the book of Yin (2018), it does not constitute a research method per se.

3.2.1 Planning the Case Study

In stepping towards case study research, there are four criteria to verify before designing the investigation (YIN, 2018):

a) checking if that is the preferred method;
b) understanding the definition of a case study inquiry;
c) addressing traditional concerns about case study research; and

d) deciding, based on the other three criteria, if the research will indeed follow a case study approach.

Regarding the first and second criteria, suppose the intention here is to investigate initiatives from the Maker Movement, using their description through the RDM theoretical framework because they seem to coincide with previous RDM scenarios described in the literature. Thus, it makes sense that this investigation depends on the context of that specific initiative. That strongly suggests the use of case study research (YIN, 2018).

Following this logic, we can state that any result of this investigation "benefits from the prior development of theoretical propositions to guide design, data collection, and analysis" (YIN, 2018, p. 46).

Regarding the third criterion, this work follows a clear methodological path, which makes it reproducible research based on falsifiable hypotheses (YIN, 2018).

The fourth criterion applies to the present work as follows.

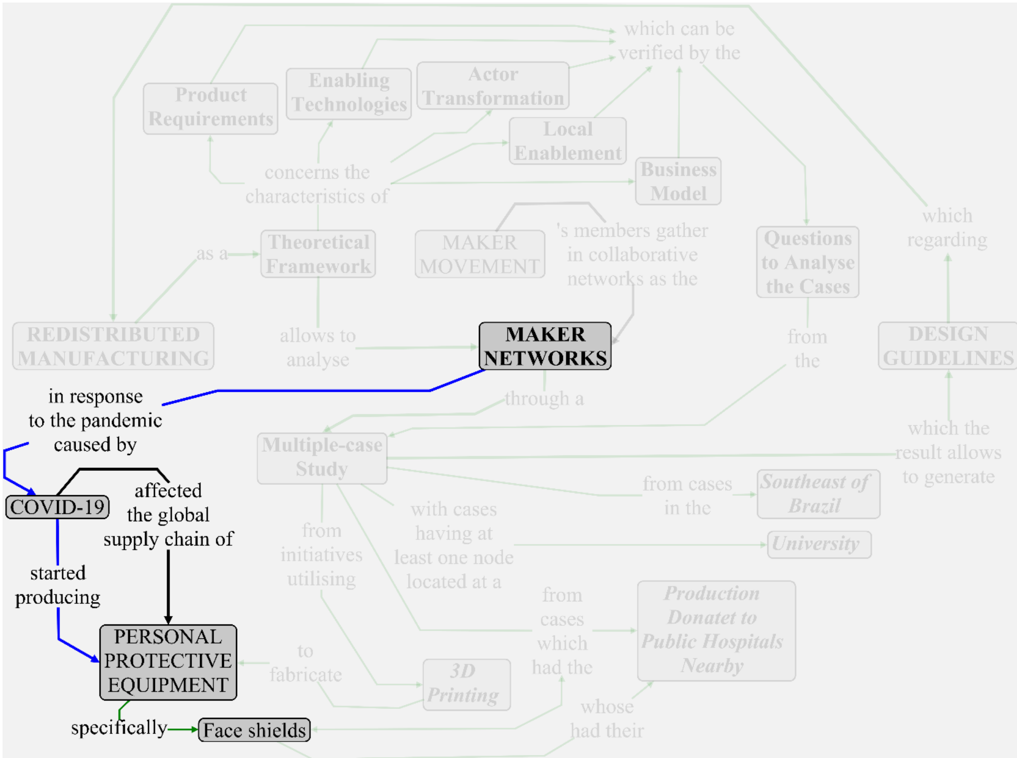
The present author is a member of the Design for Social Innovation and Sustainability Network (DESIS Network) Laboratory in Rio de Janeiro (RIO DESIS LAB, 2020). That laboratory contributed as a productive node to the SOS 3D COVID19 network, one of the cases investigated in this work. By coming into contact with actors involved in this process and contrasting the situation with the theoretical framework explored in the study, that initiative looked similar to RDM cases described in the literature. Hence, the present author searched for similar collaborative networks (MANZINI, 2012). The present author chose these other initiatives as the other cases to study.

3.2.2 Designing the Case Study

The first step in designing case study research is to define the case(s) to study (YIN, 2018). This work relies on theoretical sampling to select cases, considering that this research utilises pattern-matching as an analytic technique. 'Sampling' means the selection of cases and not the process of verifying a variable in many samples in survey research, which has the same name (YIN, 2018). It is theoretical because it depends on previous theories to guide this selection. Pattern-matching refers to select cases with possible similarities to cases studied in the literature (EISENHARDT, 1989; YIN, 2018), as shown in subsection 3.2.5.

Besides, this work also used several criteria for selecting the cases, representing part of this work's limitations. The following paragraphs describe these criteria and their application in case selection. Again, the concept map of this work helps summarise the cases' selection. First, in Figure 28, what started the search for the Maker Networks.

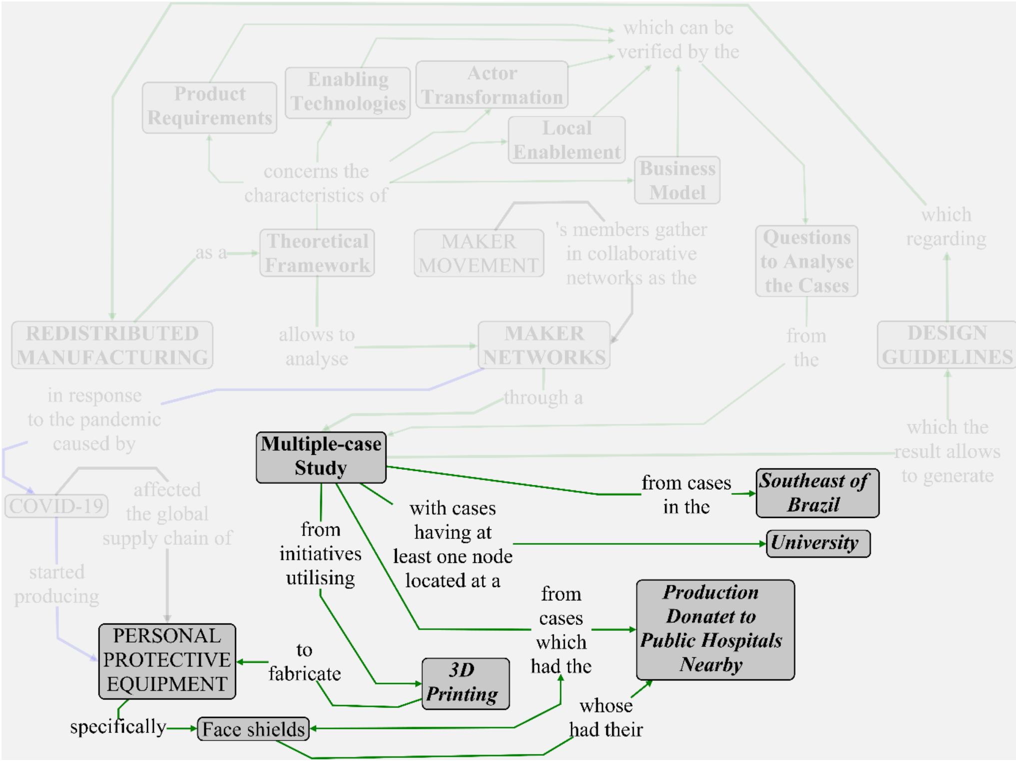
Figure 28 – The part of this work's concept map showing the beginning of the whole case selection.



Source: Author.

Then, further selection criteria were adopted, as described in the following paragraphs. Figure 29 shows the part of the concept map regarding this process.

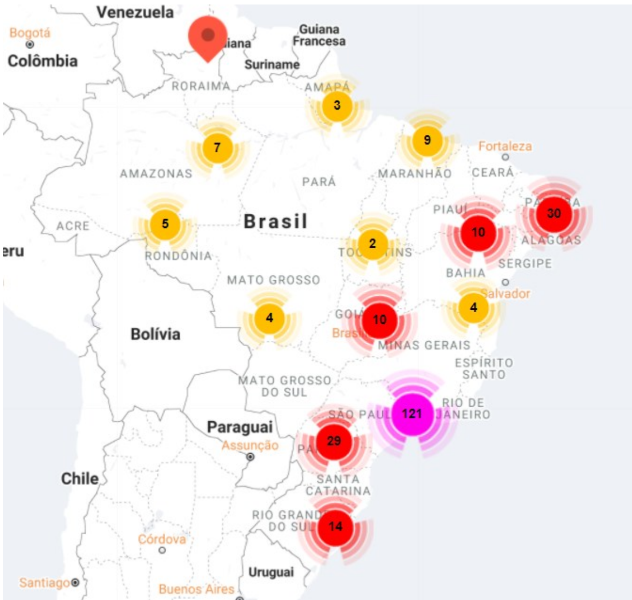
Figure 29 – The part of the concept map regarding the selection criteria.



Source: Author.

The Maker Networks were selected in a website containing a map of initiatives operating in Brazil (OLABI, 2020). That website was part of ‘ProtegeBR’, an initiative integrating the Olabi, a not-for-profit organisation to “democratise technology” (OLABI, 2022, p. 1). Figure 30 shows that map.

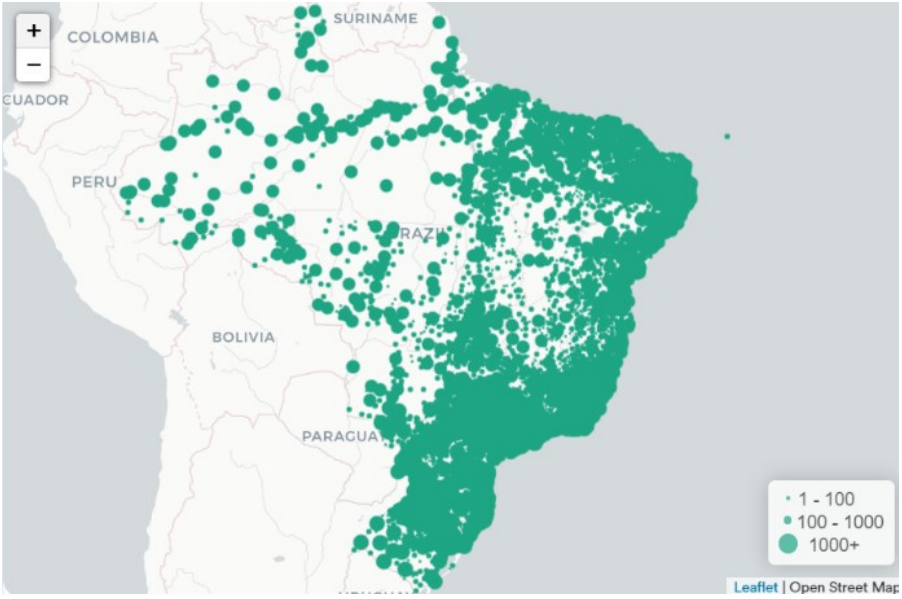
Figure 30 – Map of initiatives in Brazil related to the Maker Movement actively helping society during the COVID-19 pandemic in 2020.



Source: reproduced from the Creative Commons content Olabi (2020).

The Brazilian region with the most initiatives also displayed the most COVID-19 cases in 2020: The Southeast Region (MINISTÉRIO DA SAÚDE, 2020). Thus, one of the selection criteria was the initiative being located in that region, which implies a more significant impact of the initiative. See Figure 31 below.

Figure 31 – Map of COVID-19 cases in Brazilian population per municipality in May 2020.



Source: reproduced from the Creative Commons content Ministério Da Saúde (2020).

The definition of a Maker Network, in Chapter 2, encompasses a diversity of node types: universities (or departments), research institutes, individuals, makerspaces and companies (or divisions). Thus, another criterium was searching for cases with a comparable diversity of nodes.

The first case considered for this study was SOS 3D COVID19, and it had university departments as nodes. Hence, the research kept this as a criterion for other cases. There was an unpredictable exception, however. Rio Hacker Maker Space (RHMS), previously a SOS 3D COVID19's subnetwork, split from their parent network during the research. Thus, it became a separate case to be studied.

The other two criteria were the initiatives to use 3D Printing technology in their production process and donating the output of that production to nearby public hospitals.

By adopting all the above criteria, this research selected five cases of Maker Networks operating in the Southeastern region of Brazil to study, considering a theoretical framework based on previous works on RDM.

The second step when designing a case study research is developing “theory, propositions, and related issues to guide the anticipated case study and generalise its findings” (YIN, 2018, p. 58). The result of that process here is what the reader could appreciate in Chapter 2, where this work developed theory, propositions and related issues regarding the studied cases.

When discussing research results, researchers generalise the findings in the context of case study research. It is called analytic generalisation (YIN, 2018), which means building a theory-backed qualitative interpretation of the results on which to base future studies. This work develops this generalisation in Chapter 5.

The third step when designing a case study is to identify the case study design. Case studies may have the following divisions: multiple- or single-case, holistic or embedded studies (YIN, 2018).

The present research develops a holistic multiple-case study. The research takes each of the cases as a whole. Although the analysis of the results incorporates insights deriving from differences in the cases, this research gives no specific attention to any of the cases’ characteristics in a way that would justify a separate analysis of that characteristic (an analytical subunit, for that matter).

Another classification in case study research has to do with the kind of investigation: it may describe the case(s), it may explore characteristics of the case(s), or it may explain something about the case(s) (YIN, 2018).

The present research adopts a descriptive approach. It intends to describe if and how the studied cases implement the RDM characteristics derived from the literature.

The fourth and final step to properly design a case study is to “[t]est the design against four criteria for maintaining the quality of a case study” (YIN, 2018, p. 58). These criteria are the following:

a) internal validity (only for explanatory studies);
b) construct validity;
c) external validity; and
d) reliability.

Regarding the present research, these validity checks go as follows.

This is a descriptive holistic multiple-case study (now the reader knows the name and surname). As such, it does not require internal validity verification concerning the possible causes for the characteristics of a case to be what they are and how they behave (YIN, 2018).

The construction validity of this work can be verified in Chapter 2. It defines the subject matters and related terms, such as RDM, Maker Movement, Maker Networks, and Makerspaces. It also builds a clear path for why and how this work came to be, departing from previous works in literature. Specifically, it has a clear theoretical connection to a previous case study interested in analysing RDM characteristics of Makerspaces (HENNELLY et al., 2019), which may also represent a node of a Maker Network.

The external validity of the present work can be ultimately verified in Chapter 5 and Chapter 6, where this work analyses the obtained results and identifies possible future works, respectively. Nonetheless, the way this manuscript structures its motivation (Subsection 1.1.4), its objectives (Section 1.2), and the way it states the contributions of this work (Section 1.4) already indicates the possibility for future works to use the present research as a basis for further investigations of its subject matters.

The present case study is reliable because it clearly states how the research obtained the information to build it. Also, it describes the contexts in which the present research took place. Thus, it is possible to follow the same theoretical path and steps in the methodology to analyse Maker Networks from the perspective of RDM.

3.2.3 Preparing the Data Collection

This step of case study research has two divisions: on the one hand, it focuses on the researcher. On the other hand, it focuses on the research.

Regarding researchers, they can follow general pieces of advice for conducting case study research found in Yin (2018).

Some situations can exemplify the use of these pieces of advice in the present research. See the following paragraphs.

Regarding ‘building the research upon good research questions’ (YIN, 2018, p. 120), in Chapter 1, specifically in theoretical motivation (Subsection 1.1.4) and in objectives (Section 1.2), although not formulated as direct questions, that part of the text guides this research the same way good research questions would.

Concerning ‘seeing unexpected situations as opportunities’ (YIN, 2018, p. 120), RHMS’s separation from SOS 3D COVID was unexpected since the present author was not close to those composing that subnetwork. Thus, the unexpectedness. Nonetheless, RHMS were not excluded from the research cases since it was a network itself, but a different approach to getting information from them was necessary (CAMPOS; CIPOLLA, 2021).

Regarding ‘getting a firm grasp on the subject matters’ (YIN, 2018, p. 120), the theoretical discussion in Chapter 2 stems from a literature review and was written even after the practical phase of the research ended. That allowed the present author to expand the understanding of the Maker Movement and RDM nuances. That helps enrich the theoretical background per se and contributes to the discussion of the results in Chapter 5 and the proposition of future works in Chapter 6.

Regarding the research itself, the researcher defines the case study protocol in this stage (EISENHARDT, 1989; YIN, 2018).

The complexity of that protocol varies according to the complexity of the research. Nevertheless, all case study protocols shall comprise four sections. Yin enumerates them (YIN, 2018):

a) section A: an overview of the study;
b) section B: the logistical part of the protocol;
c) section C: the questions to guide the line of inquiry and
d) section D: an outline of the research report.

Table 12 below displays the research protocol for the present case study. That table also informs the chapters of this dissertation with the highest correlation to the protocol directives in each section.

Table 12 – Case study protocol for investigating Maker Networks in the present research.

Section	Directives	Related Chapters
A	This is a descriptive holistic multiple-case study. It observes Maker Networks helping public hospitals with donations of PPE. The PPE's manufacturing is such that its description follows the RDM model. The central theoretical development supporting the framework used here comes from Hennelly et al. (2019). The present work develops related theoretical discussions in Chapter 2. This manuscript is a dissertation with a correspondent structure to inform expert audiences on its theme and related ones.	Chapter 1, Chapter 2 and Chapter 3
B	The present research could obtain data from websites and social networks regularly maintained by the Networks, with publicly available information. The exception was RHMS, in which the present work embeds interview data previously published.	Chapter 3
C	This research focuses on the RDM characteristics of the cases. Therefore, it uses questions about the Product Requirements, the Enabling Technologies, the Actor Transformation, the Local Enablement and the Business Models identified in the cases. The investigation looked at publications on the cases' websites and social networks about production output, donations to hospitals, formularies, partnerships, people contributing and other issues. Those publications were generally texts and videos.	Chapter 2 and Chapter 3
D	The outline of the present research can be inferred from the summary of this dissertation. The introduction in Chapter 1 also serves as a more detailed outline.	Chapter 1

Source: Author.

After this preparation, the researcher can head to the data collection step (YIN, 2018), the subject of the following subsection.

3.2.4 Collecting Cases' Data

Two sets of information must be clear to the researcher in this phase. The first are the types of data sources used in case studies. The second contains four principles of data collection, which intend to improve the construct validity and reliability of that research. These principles are (YIN, 2018):

a) using multiple sources of evidence;

b) creating a case study database;

c) maintaining a chain of evidence; and

d) exercising care when sourcing data from social media.

The present research sourced data from the websites and social networks of the Maker Networks. The types of evidence obtained were documents, archival records, and physical artefacts.

The documents were mainly online formularies that helped the initiatives to organise their logistics.

The archival records were the many reports about the face shield donations, the announcements of partnerships, and posts about testing a possible product to print, like design variations of the face shield or other products that could also be 3D-printed.

The physical artefacts were observed through videos available online. For example, if a Network reported operating with dozens of 3D Printers in parallel, a video showing their set-up could confirm or disprove that. In this example, the 3D Printers are a 'technological device or tool' (YIN, 2018).

Thus, the first principle holds for this research.

The second principle is attained twofold. Copies of the main sites and social networks were downloaded to guarantee the future retrievability of the information provided, even if the sites went down or the posts were excluded. The present researcher only reproduces the information contained there. The other way to achieve the second principle relates to the nature of this research. Since it is descriptive, the results represent a database with information regarding the cases explored.

The detailing in the present methodology represents the effort to attain the third principle. The idea is that the reader can understand each of the steps taken by the present researcher. From envisioning the research gap in exploring RDM in Maker Networks until the description of the cases, allowing the verification of the RDM characteristics. That latter step led to the synthesis of the design proposals.

The fourth principle represents much to this work since its primary sources are the internet. Nonetheless, attaining it was straightforward because the information of interest was the same that would be obtained from a survey questionnaire or a structured interview: questions concerning the information already available on the websites and social networks would be asked in a possible survey or interview. Another piece of evidence is that the numbers displayed by the Networks in their social media, concerning their production capacity and capability, corresponded to their size and complexity.

3.2.5 Analysing Cases' Data

That is the step that finally leads to the results of a case study. Once the researchers had collected data, analysing this data in the light of a theoretical framework is necessary to build some knowledge from the cases. Thus fulfilling the primary endeavour of a research (YIN, 2018).

Before getting into any specific analytic strategy, the researcher may have done something with an imbued analytic potential during the collecting phase since patterns may naturally arise from them, depending on the nature of the collected data (YIN, 2018).

The present study utilises two analytic strategies simultaneously to get to the findings. One is relying on theoretical propositions, and the other is developing the cases' descriptions. Both are implemented through the analytic technique called pattern-matching, which consists of comparing an empirically based pattern – that is, one based on the findings from the case study – with a predicted one (or with several alternative predictions, including rivals) made before data collection.

The theoretical propositions supporting the patterns to observe derive from the part of the theory concerning the relationship between the Maker Movement and Redistributed Manufacturing (RDM). More specifically, they stem from the characteristics an initiative from the Maker Movement shall exhibit according to the RDM model. Those characteristics belong to the following sets: Product Requirements, Enabling Technologies, Actors Transformation, Local Enablement and Business Model.

The descriptive framework for the Maker Networks with RDM model parameters derives from detailing each of these previous groups of characteristics. The parameters are a collection of characteristics described in Section 2.3, Table 10. As stated in that part of Chapter 2, the present researcher developed a set of questions in the form of a table to access these characteristics. Those questions are the main subject of the following subsection.

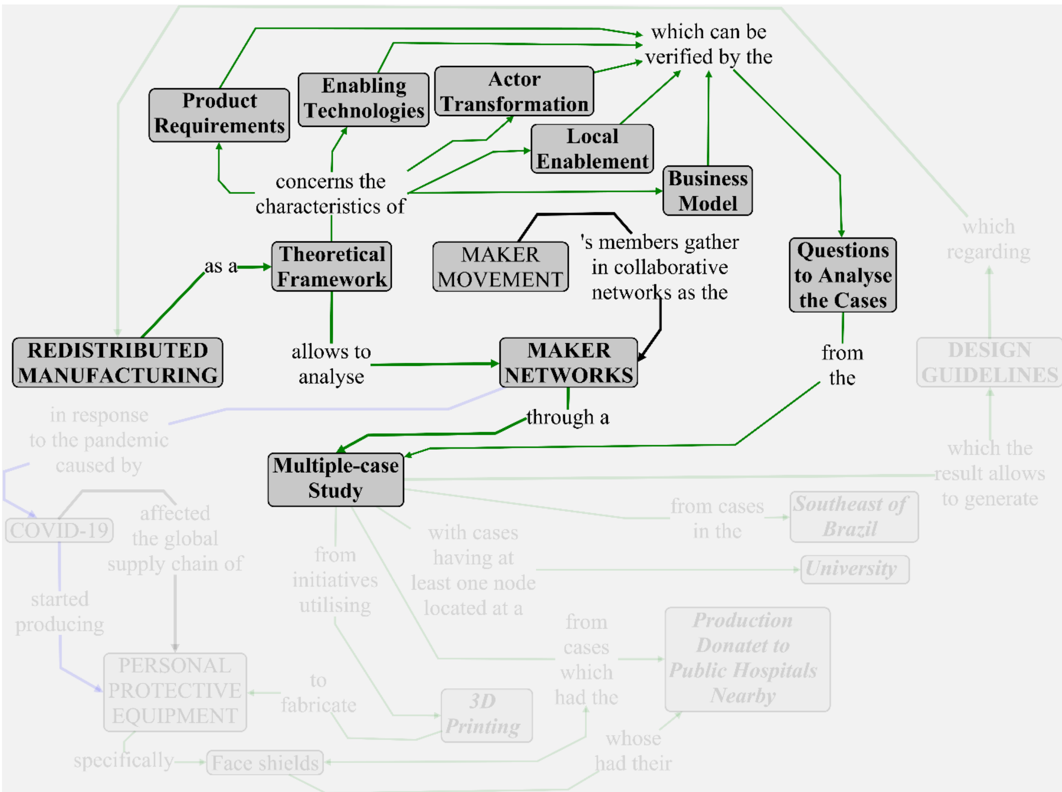
Using such a set of questions is a way to implement the pattern-matching analytic technique described above. That is one of two analytic techniques developed in the present research. The other is a cross-case synthesis, considering differences and similarities when contrasting the cases' answers.

3.3 QUESTIONS TO ANALYSE RDM-MAKER NETWORKS

This subsection finally presents the analytic tool. It is the set of questions found in Table 13. After that table, the subsequent paragraphs explain each question and what they intend to assess. Once again, the questions in Table 13 derive from the characteristics of an RDM-Maker Movement initiative – as built by Hennelly et al. (2019) – presented in this work in Table 10. Many of those are polar questions: it suffices to know whether a case did or did not have a specific characteristic to compare to the theory's predictions.

Once more, the concept map sums up the use of these questions in the present research. See Figure 32 below.

Figure 32 – The use of the questions to analyse the cases represented in this work's concept map.



Source: Author.

Table 13 – Questions to analyse RDM-Maker Networks.

Dimension	Question
Product Requirements	Proximity (Where was the equipment delivered?)
Product Requirements	Customisation (Has any modification been made to the model?)
Product Requirements	Real-time (Time from prototype until first batch?)
Product Requirements	Innovation (Was any adaptation made on or with any tool or equipment?)
Product Requirements	Environment/Circular economy [ECE1] (Has tool sharing been observed in any node?)
Product Requirements	Environment/Circular economy [ECE2] (Have nodes themselves repaired any tool?)
Product Requirements	Environment/Circular economy [ECE3] (Did the network use recyclable materials?)
Product Requirements	Digital [1] (How did the network get the files?)
Product Requirements	Digital [2] (Who projected the files?)
Product Requirements	User-participation (How did healthcare professionals contribute?)
Business Model	RDM product design and materials [1] (What was the product's composition?)
Business Model	RDM product design and materials [2] (What were the main manufacturing requirements?)
Business Model	RDM cost model (How is it being financed?)
Business Model	Commercialisation (Were products sold, rented or donated?)
Business Model	Product ownership/IP (Had the files any cost?)
Business Model	Alternative finance (Did the network use any alternative finance model?)
Actor Transformation	Culture (Do nodes identify with maker culture/movement?)
Actor Transformation	Leader (Are any members leading a project?)
Actor Transformation	Education (Does any network actor provide a course?)
Actor Transformation	Multidisciplinary (Are projects multidisciplinary?)
Actor Transformation	Communication (How are PPE requests made?)
Enabling Technologies	Capacity (What was the daily output volume? [units/day])
Enabling Technologies	Maturity (How were the machine operators skilled?)
Enabling Technologies	Capability (Did the network exchange knowledge through digital media?)
Enabling Technologies	3DP [Tools] (What were the tools used?)
Local Enablement	Institutional support (Did the network receive institutional support?)
Local Enablement	Local networks (Do nodes participate in any local network?)
Local Enablement	Social/Communities (Have any nodes contributed to a social project?)
Local Enablement	Research (Does any node develop an R&D project?)
Local Enablement	Students/Experts (Are there specialists in the network?)
Local Enablement	Schools/Libraries/Labs (Network or any member contributes to some of these?)

Adapted with the rightsholder permission from Campos and Cipolla (2021, p. 213).

Following the order in Table 13:

a) let us begin with the Product Requirements:

- **Proximity** tries to assess if the products reach the users closer to the vicinity of the production site. For example, if nearby hospitals are those receiving the face shields,
- **Customisation** investigates if the Maker Network attempted a modification of their own to any of the products' models,
- **Real-time** tries to understand if the time to deliver the product, counting from the start of the production, is compatible with an RDM model, a considerably shorter time, compared to a centralised model,
- **Innovation** tries to understand if there were some novelty in the fabrication process. This question concerns the tools or equipment used and how to employ them,
- **Environment/Circular economy (ECE): [ECE1], [ECE2], and [ECE3]** evaluate if the Maker Network has environmental concerns that may fit a circular economic perspective,
- **[ECE1]** is about using resources in production economically, regarding tool sharing by participants, instead of tools that would be exclusive to a person, thus out of use most of the time. A shared computer may be an example,
- **[ECE2]** checks if any of the Network's participants contributed with their expertise to repair a tool or equipment instead of depending on costly external services and resources,
- **[ECE3]** identifies if the Network attained at least the first level of environmental-friendly use of materials. At a higher level, recycled materials are input materials for several processes. In this case, the idea is that, if nothing else, the final product could be recycled. For example, can a face shield, with no more use, be recycled?
- **Digital [1] and [2]** try to assess the digitalisation characteristic from the RDM model, inferring from the production process. The first wishes to know the medium through which the Network obtained the digital file of the 3D model. For example, the Network may have obtained it in a virtual database of models, like in Thingiverse™ (MAKERBOT INDUSTRIES, 2023). The

second is a verification of the expertise in modelling within the Network: was somebody from the Network that designed the model, or was it outsourced?

- **User participation** refers to prosumption. The primary end users of the face shields are healthcare professionals. Thus, an example of user participation is their input in the production process, like suggesting modifications in the model and ultimately approving it for larger-scale production;

b) Now, let us explore the Enabling Technologies of the Networks:

- **Capacity** refers to the production capacity of a case, indicated as an average to a defined time interval. This study considered how many face shields a Network produced daily on average,
- **Maturity** indicates the level of knowledge in operating the production equipment that the individuals responsible for that task had,
- **Capability** concerns the digital readiness of the people and processes involved in the production. It is another way to verify RMD's digitalisation,
- **3DP [Tools]** inquires about the tools used in production;

c) Actor Transformation is the next set of characteristics:

- **Culture** wants to know if the individuals in the Network identify themselves with the Maker Culture or feel that they belong to the Maker Movement. The idea is to verify a common mindset shared by these individuals,
- **Leader** tries to identify if there is a confirmed leadership mindset in at least one of the participants. The verification does not derive from the initiative itself – the idea is to verify if there is some leadership activity – besides the Maker Network,
- **Education** checks if the Network represents a transformation for their integrants or other people regarding educational efforts. For example, a fast course on how to use a 3D printer represents an affirmative answer,
- **Multidisciplinary** is about the nature of the projects developed within the Network regarding the multiplicity of expertise involved when the case's members possess diverse professional backgrounds, which corresponds to an affirmative answer,

- **Communication** tries to access how the Network managed to get the requests from the hospitals. If the initiatives organised the requesting process with a digital tool, this is yet another way to verify the digitalisation characteristic of RDM;

d) Next, we take a look at the <u>Local Enablement</u> characteristics' set:

- **Institutional Support** checks if the Network was supported financially or with some infrastructure by any public or private institution. In general, as the cases comprised universities, the answer will be affirmative. However, in some cases, they may have received support from other institutions too,
- **Local Networks** tries to identify if the Network has a relationship with any other local network. Any network fits, not only Maker Networks,
- **Social/Communities** wants to identify if there is any social inclination within the Network that may benefit local society in some way,
- **Research** identifies whether nodes integrating the Network carry out Research and Development activities locally,
- **Students/Experts** tries to access the local availability of skilled professionals by looking to the individuals integrating the cases,
- **School/Libraries/Labs** checks if any of the Networks' nodes, be an individual or an organisation, has a direct relationship to a local educational or research institution or if any of them has a direct relationship to a local library. As the cases have universities' departments as nodes, the answer will be affirmative;

e) Finally, we verify the Maker Networks' <u>Business Model</u>:

- **RDM product design and materials [1] and [2]** try to understand what the organisational model (business model) implemented in the Networks designated for the product they were manufacturing in terms of [1] source materials inferred from the products, and [2] what were the necessary characteristics in the final product that implied a correspondent manufacturing requirement. The input and output materials are identical since the cases do not use chemical reactions,
- **RDM cost model** assesses what a business model is supposed to exhibit in terms of financial support to cover their costs,

- **Commercialisation** identifies if a Maker Network charged any cost to deliver the face shields. If so, were they sold or rented? If not, were they donated?
- **Product Ownership/IP** tries to understand if any intellectual property issues related to the product may have required a purchase to obtain the model. For example, some 3D-model archives require a payment or subscription to access a model,
- **Alternative Finance** concerns the possible non-traditional financing models in use by a Network. Traditional financing models are bank loans, mortgages and grants. Alternative finance comprises models like crowdfunding and microfinance.

The following section explains how to grasp the design proposals, which finishes the methods adopted in the present work to get to the results departing from the theoretical background.

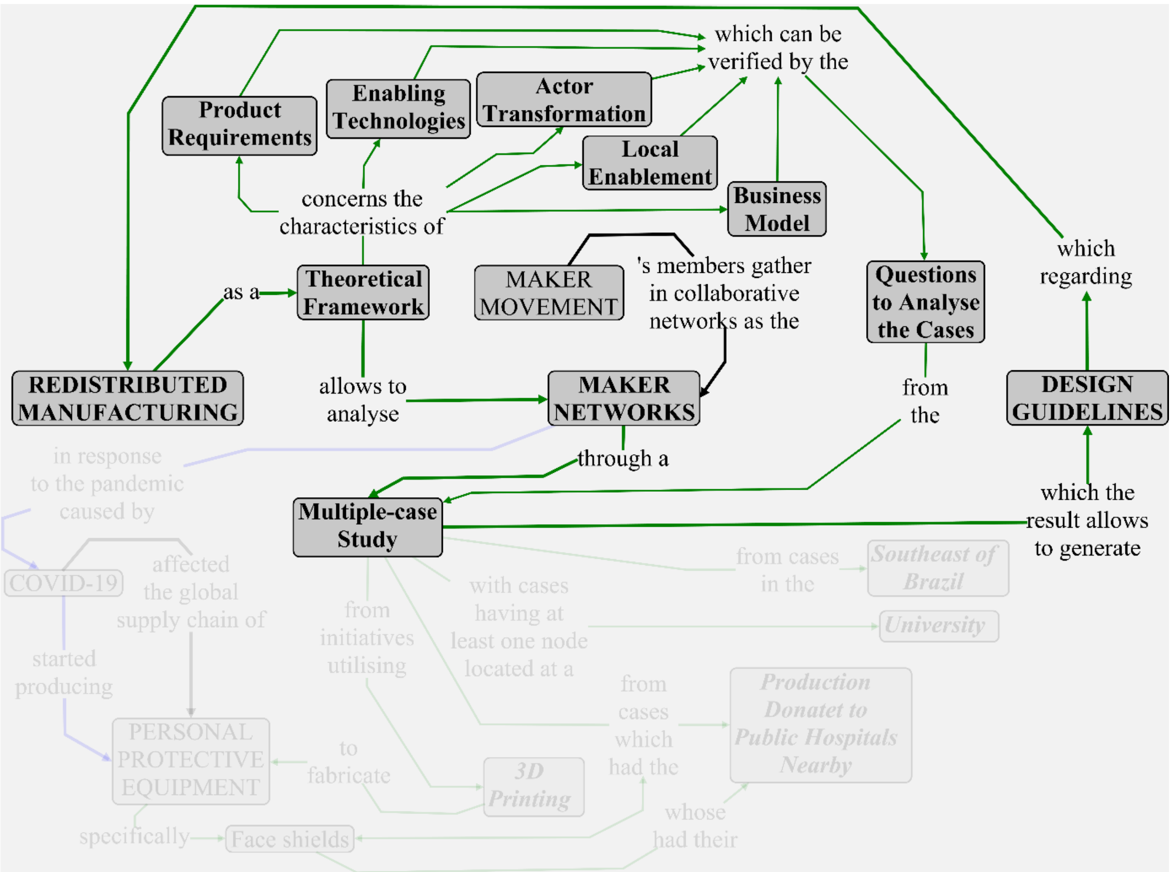
3.4 DEFINING THE DESIGN PROPOSALS

The steps to build the proposals for designing RDM-Maker Networks comprise identifying how the cases implement RDM. That demands describing the cases in three ways:

a) the first is to build their description according to the selection criteria only;
b) the second is creating tables based on the answers to the questions in Table 13 to analyse the cases' RDM features; and
c) the third is building a Maker Networks' description that helps point out their differences. That description derives from how the RDM features manifest in each case.

Figure 33 below depicts how obtaining the design proposals from the studied cases fits the present work.

Figure 33 – From where the design proposals come, as represented in this work's concept map.



Source: Author.

The design proposals are operative principles that enable a Maker Network to function in an RDM logic. Thus, as part of the results, the present study proposes these proposals to orientate future works.

The differences and similarities found across the Maker Networks, considering the tables representing their RDM characteristics and each Network's specificity, support the derivation of the design proposals.

Therefore, this research also builds Table 19 to summarise the line of evidence observed to generate each guideline.

Now, we can head to the results obtained from the processes described so far. That is the subject of the next chapter.

4 RESULTS

This chapter displays the findings from the case study research described in Chapter 3. The following sections contain, in that order, the description of the Maker Networks considering the selection criteria, the RDM features of those Networks presented in five tables, the particularities of each Network, and, finally, the design proposals and a table demonstrating the line of evidence for each of them.

The following results are present in Campos and Cipolla (2021). They are further explored and detailed in the subsequent sections.

4.1 MAKER NETWORKS: DESCRIPTION

This section presents the description of the analysed cases according to the criteria used to select them. The primary function of this part is to identify the cases and to make their similarities evident. Recalling from subsection 3.2.2, the selection criteria included:

a) the location of the Networks,
b) where the researcher found the evidence;
c) having a university-related node;
d) the main products they were fabricating; and
e) the types of nodes included.

Brasil Contra o Vírus [Brazil Against the Virus] (BCV). The Network headquarters and nodes could be found in the metropolitan region of São Paulo (city). Their website contained updated information about them and was the primary data source to evaluate this Maker Network (BRASIL CONTRA O VIRUS, 2020). The node related to a university was the University of Campinas' Biofabrication Institute (Biofabris). Face Shields and Continuous Positive Air Pressure Non-Invasive Ventilators (CPAPNIV) were the main products this Network delivered to the hospitals. Nodes included in this Network: individual Makers, a shared workshop, universities' departments, and research institutions.

Makers Contra a Covid-19 [Makers Against Covid-19] (MCC). The Network headquarters and nodes could be found in São Paulo (city). Their website contained updated information about them, and from there came most of the data to evaluate this Maker Network (MAKERS CONTRA A COVID-19, 2020). The node related to a university was located in the University of São Paulo (USP). Face shields were the products this Network delivered to the hospitals. Nodes included in this Network: individual Makers and Makerspaces.

Rio Hacker Maker Space (RHMS). The Network headquarters and nodes could be found in the city of Rio de Janeiro. Their website contained updated information about them and was the primary data source to evaluate this Maker Network (RHMS, 2020). The nodes related to a university were departments from the Federal University of Rio de Janeiro (UFRJ) and the Pontifical Catholic University of Rio de Janeiro (PUC-Rio). Face shields were the products this Network delivered to the hospitals. Nodes included in this Network: individual Makers.

SOS 3D COVID19 (SOS). The Network headquarters and nodes could be found in the city of Rio de Janeiro. Their website contained updated information about them and was the primary data source to evaluate this Maker Network (SOS 3D COVID19, 2020). The nodes related to a university were departments at UFRJ and PUC-Rio. Face shields and protective goggles were the main products this Network delivered to the hospitals. Nodes included in this Network: individual Makers and university departments.

Trem Maker [Maker Train] (TM). The Network headquarters and nodes could be found in Belo Horizonte. Their website contained updated information about them and was the primary data source to evaluate this Maker Network (TREM MAKER, 2020). The node related to a university was located at the Federal University of Minas Gerais (UFMG). Face shields were the products this Network delivered to the hospitals. Nodes included in this Network: individual Makers and Makerspaces.

4.2 MAKER NETWORKS: RDM FEATURES

The present section displays the tables built by answering the questions from Table 13. In that table, the reader can see five subsets of questions, each corresponding to a subset of RDM features in Table 10, from Product Requirements to Business Model. The following tables also go along this logic. Each table corresponds to the answers to each subset of questions from Table 13 when using it to analyse the cases.

During the analysis of the Maker Networks, several particularities of each case became evident. Also called the cases' specificities, the presence of an asterisk (*) in the following tables indicates that the case's answer has something beyond the others regarding the corresponding RDM feature. Section 4.3 details the cases' specificities, whose primary function is making the cases' differences evident.

4.2.1 Product Requirements

Table 14 – RDM-Maker Networks' Product Requirements.

Case	Proximity	Customisation	Real-time	Innovation	ECE1	ECE2	ECE3	Digital [1/2]	User-participation
BCV	Face Shield: collected at Leroy Merlin® – Tietê by representatives from São Paulo (city) hospitals. CPAPNIV: collected in production nodes and delivered throughout Brazil by Instituto Motirõ.	Face shield: Yes, following physicians' recommendation. CPAPNIV: Yes, see Favero (2020).	Approx. one week.	Face shield: Yes, following physicians' recommen-dation.	Yes.	Yes.	Yes.	Face shields: BCV design team. CPAPNIV: see Favero (2020).	Face Shield: inputs on design and prototype approval. CPAPNIV: prototype approval.
MCC	Logistics and distribution team delivered to public hospitals in the metropolitan region of São Paulo (city).	No.	Approx. one week.	Yes. On the digital model.	Yes.	N/A.	Yes.	Based on Prusa files, see Prusa Research (2020).	Prototype test and approval.
RHMS	Delivered by each individual member at the National Institute of Traumatology and Orthopaedics (INTO) and Hospital Municipal Evandro Freire.	No.	Approx. one week.	No.	Yes.	Yes.	Yes.	WhatsApp® group [Prusa files], see Prusa Research (2020).	Prototype test and approval.
SOS	Representatives from hospitals in the Rio metropolitan area collected them at PUC-Rio.	No.	Approx. one week.	Yes, heat gun to finish parts. *	Yes.	Yes.	Yes.	Face Shield: see Prusa Research (2020). Protective Goggle: see VIVALAB (2020).	Prototype test and approval.
TM	Logistics and distribution team delivered to hospitals in several cities from Minas Gerais state.	No.	Approx. one week.	No.	Yes.	Yes.	Yes.	Face Shield: see Prusa Research (2020).	Prototype test and approval.

Source: reproduced with the rightsholder permission from Campos and Cipolla (2021, p. 222).

4.2.2 Enabling Technology

Table 15 – RDM-Maker Networks' Enabling Technology.

Case	Capacity [units/day]	Maturity	Capability	Tools
BCV	Face Shield – 100 to 150 (3DP); 150 to 200 (Cutters). CPAPNIV – Approx. 60 to 70. *	Advanced.	Yes. *	3DP, Cutters and vat polymerisation 3DP (SLA and DLP).
MCC	Approx. 60 to 70.	Advanced.	Yes.	3DP and Laser Cutters.
RHMS	Approx. 35.	Advanced.	Yes.	3DP and Cutters.
SOS	Approx. 400 Face Shields and 65 Protective Goggles.	Advanced.	Yes.	3DP and Cutters.
TM	Approx. 400.	Advanced.	Yes.	3DP and Cutter.

Source: reproduced with the rightsholder permission from Campos and Cipolla (2021, p. 222). Notes: SLA – Stereolithography. DLP – Digital Light Processing. Otherwise specified, 3DP alone stands for FDM 3D Printing. Cutter(s) stands for cutting equipment, like laser and vinyl cutters.

4.2.3 Actor Transformation

Table 16 – RDM-Maker Networks' Actor Transformation.

Case	Culture	Leader	Education	Multidisciplinary	Communication
BCV	Yes. *	Yes. *	Yes.	Yes.	Online Google® Forms™.
MCC	Yes. *	Yes.	Yes.	Yes.	Online Google® Forms™.
RHMS	Yes. *	Yes.	Yes.	Yes.	Acquainted health staff.
SOS	Yes.	Yes.	Yes.	Yes.	Online Google® Forms™.
TM	Yes. *	Yes.	Yes.	Yes.	Online Google® Forms™.

Source: reproduced with the rightsholder permission from Campos and Cipolla (2021, p. 223).

4.2.4 Local Enablement

Table 17 – RDM-Maker Networks' Local Enablement.

Case	Institutional support	Local networks	Social/Communities	Research	Students/Experts	Schools/Librarie s/Labs
BCV	Yes. *	Yes.	Yes.	Yes.	Yes.	Yes.
MCC	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
RHMS	No, only individuals.	Yes.	Yes.	Yes.	Yes.	Yes. *
SOS	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
TM	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.

Source: reproduced with the rightsholder permission from Campos and Cipolla (2021, p. 223).

4.2.5 Business Model

Table 18 – RDM-Maker Networks' Business Model.

Case	RDM product design and materials [1]	RDM product design and materials [2]	RDM cost model	Commer-cialisation	Product ownership /IP	Alterna-tive finance
BCV	Face Shield – 3DP: PETG/ABS/PLA/PET/PVC/PVA; Cutters: PET/PETG/PVC/PVA. CPAPNIV – Charlotte valve: PA12 (Nylon 12); Mask: see SUBEA (2018).	Face Shield – The materials and the design, as oriented by physicians. CPAP NIV – Charlotte valve made with free porous process to avoid contamina-tion.	Institutional support and donations.	Donated.	No.	Yes. "Vaqui-nha online", see Vakinha (2020).
MCC	ABS/PLA/PETG.	ANVISA - RDC Nº 356, see ANVISA (2020).	Institutional support and donations.	Donated. *	No.	Yes. "Vaqui-nha online", see Vakinha (2020).
RHMS	PLA, acetate, PVC, rubber band. *	Comfort.	Own money and individuals' donations.	Donated.	No.	No.
SOS	ABS/PLA/PETG	3DP parameters, shield composition and thickness.	Institutional support and donations.	Donated.	No.	No.
TM	ABS/PLA/PETG.	ANVISA - RDC Nº 356, see ANVISA (2020).	Institutional support.	Mainly donated. *	No.	No.

Source: reproduced with the rightsholder permission from Campos and Cipolla (2021, p. 215).

4.3 RDM-MAKER NETWORKS: SPECIFICITIES

The peculiarities of each case help differentiate one from another. For each Maker Network, its specificities' description follow the same order they appear, marked by an asterisk (*), in the tables representing their RDM features, Table 14 to Table 18. In those tables, the asterisk-marked answers symbolise specific information about the corresponding RDM characteristic, which, in turn, helps tell each case apart:

a) **Brasil Contra o Vírus (BCV)**:

- from the characteristic of 'Capacity' (Table 15): the Network acquired a substantial production capacity when Leroy Merlin® provided its Bricolab™ shared workshop in the Tietê region, São Paulo (city). Thus, it became their headquarters.
- from the characteristic of 'Capability' (Table 15): Their members used Telegram® groups to exchange information with specialised professionals regarding eight different areas: 'Biomedical Engineering and Health', 'Hospitals and Public Managers', Information Technology ('IT'), 'Legislation', 'Machining and Production', 'Modelling', 'Printing and Prototyping', and 'Production Supplies.'
- from the characteristic of 'Culture' (Table 16): On the Network's website, there was a manifesto regarding the importance of open-source software (BRASIL CONTRA O VIRUS, 2020).
- from the characteristic of 'Leader' (Table 16): The Biomedical Engineer who idealised the Network, Thabata Ganga, developed and led several maker projects (BRASIL CONTRA O VIRUS, 2020).
- from the characteristic of 'Institutional Support' (Table 17): Two institutions purveyed adequate 3D Printing technology to fabricate Charlotte valves: Biofabris from the University of Campinas (UNICAMP), Institute for Technological Research (IPT), and Centre of Information Technology Renato Archer.

b) **Makers Contra a Covid-19 (MCC)**:

- from the characteristic of ‘Culture’ (Table 16): The Network’s members praised for autonomous behaviour devoid of hierarchy. They championed the Brazilian Universal Healthcare System (SUS) as “the unique form of reassuring the population survival” (MAKERS CONTRA A COVID-19, 2020).
- from the characteristic of ‘Commercialisation’ (Table 18): MCC’s first 3D model’s name is ‘VIVA SUS V1’. Other of their 3D models have the engraving ‘NOT FOR SALE.’

c) **Rio Hacker Maker Space (RHMS)**:

- from the characteristic of ‘Culture’ (Table 16): In the interview given to the authors of Campos and Cipolla (2021), one of the members declared to understand the Maker Movement related to open innovation processes.
- from the characteristic of ‘Schools/Libraries/Labs’ (Table 17): RHMS offered classes and organised dissemination activities in a public school in Del Castilho, a Rio de Janeiro neighbourhood. The interviewee mentioned above delivered some lectures in that school.
- from the characteristic of ‘RDM product design and materials [1]’ (Table 18): A Network member created a fresh face shield model based on PVC pipes as another option to the 3D-printed model.

d) **SOS 3D COVID19 (SOS)**:

- from the characteristic of ‘Innovation’ (Table 14): They employed a heat gun to smooth the surface of 3D-printed parts to give them an unruffled finish.

e) **Trem Maker (TM)**:

- from the characteristic of ‘Culture’ (Table 16): Their self-description is “makers and enthusiasts believing in the potential of Maker Culture and the importance of creative economy to the economic growth of Minas Gerais state” (TREM MAKER, 2020). Daniel Lopes is the member who started the project. He is the founder of 3DLabs, a 3DP company.

- from the characteristic of ‘Commercialisation’ (Table 18): This is the only Network that fabricated a face shield for selling.

4.4 DESIGN PROPOSALS FOR RDM-MAKER NETWORKS

Finally, the analysis developed so far leads to the Design Proposals this research provides for future works. The Proposals also comprise five divisions, corresponding to the five axes of categories used for analysing the cases, from Product Requirements to Business Models. Here, the approach to identifying the proposals is naming them according to the core idea behind them:

a) Proposals concerning the Product Requirements.

- **Coordinating node.** The Maker Networks with a coordinating node used that node to guarantee a regular quantity and final product characteristics output. All the Network’s nodes should reproduce the model approved by the Network’s coordinating node.
- **User participation.** Since the beginning, healthcare professionals’ inputs helped the Networks to rapidly validate, or even create, the PPE digital models. That enabled the initial product batches to be ready in approximately a week.
- **Open-source.** Departing from open-source models was an essential approach to effect a quick response to the demand for PPE.

b) Guideline concerning the Enabling Technologies.

- **Node diversity.** The idea is that nodes with different capabilities, in terms of the enabling technology associated with them, allow for a diversified output. The representative case is BCV. Other Networks, although manufacturing products besides face shields, were not seen using complex technologies like those available at research institutions. In BCV, they used digital light projection (DLP) and stereolithography (SLA) 3D Printers to fabricate CPAPNIVs.

c) Proposals concerning the Actor Transformation.

- **Cultural aspect.** Encouraging the Networks' nodes to collaborate in a network. Four of the five Maker Networks had assertions on their websites regarding the Maker Movement's essential part in overcoming circumstances like the COVID-19 pandemic.
- **Online processes.** From the five cases, four Maker Networks employed online Google Forms™ to process the requests for PPE. This approach also comprised digitally storing the hospitals' information, thus providing a straightforward way to request donations.
- **Multidisciplinary.** The variety of professionals and their ability to deal with inputs from one another represents a multidisciplinary capability. That characteristic of a Network indicates its know-how in managing complex problems.
- **Networked activities.** As captured by an interview with an RHMS member on a previous work (CAMPOS; CIPOLLA, 2021):

> The importance of makers in society is to be able to bring innovation and collaboratively contribute to research. So, not only I contribute here in Brazil, but I can receive contributions from other countries (...). This was made very clear with these models of Face shields (CAMPOS; CIPOLLA, 2021, p. 217).

Networks' members may already include expert individuals, like designers, engineers, makers, and researchers, among many others. Still, the evidence indicates that the networked collaborative approach motivated those individuals to keep participating and helping the initiatives.

d) Proposals concerning the Local Enablement.

- **Institutional support.** When Leroy Merlin® made their shared workshop available to BCV, or when SOS had access to a prototyping lab at PUC-Rio, the Networks integrating such resources grew even in terms of audience. Manly, they grew in output volume and logistic capability.
- **Actors and the community.** All the networks had at least one node participating in a social project. That goes from the RHMS member interviewed in Campos and Cipolla (2021), who gave some lectures in a local

public school, to a university department through its extension programs, like Rio DESIS Lab (RIO DESIS LAB, 2020).

e) Proposals concerning the Business Model.

- **Crowdfunding.** Two sources of funds were essential to the Networks' expansion: institutional support and donations via crowdfunding. The latter has been deemed a fundamental source of financing for individual projects, start-ups, and even a new kind of philanthropy (ZHANG et al., 2020).
- **Confirmation of previous proposals.** As stated in Chapter 2, the Business Model is the integrative set of characteristics from the RDM-Maker Network model. Thus, it shall confirm the preceding proposals. That includes institutional support, open development, and user participation.

4.4.1 Design Proposals in a Nutshell

Table 19 shows each guideline's origin, considering the cases' descriptions, RDM features and specificities. That table works as a condensed presentation of the proposals, a straightforward way to consult them.

Table 19 – RDM-Maker Networks Design Proposals.

Group	Design guideline	Evidence
Product requirements.	*Coordinating node.*	Table 14 (Proximity) and Specificities: Except for RHMS, initiatives had a central node as a logistics centre and headquarters.
	User participation.	Table 14 (User participation): Maker Networks had input from health staff in their designs.
	Open-source.	Table 14 (Digital [1/2]) and Specificities: Maker Networks used open-source models.
Enabling technologies.	*Node diversity.*	Table 15 (Capacity; Tools), Specificities and Description: The Maker Network showing the greater variety of nodes had access to more advanced machines, better exemplified by the case of BCV.
Actor transformation.	*Cultural aspect.*	Table 16 (Culture) and Specificities: Webpages or WhatsApp™ groups with messages about the importance of makers' collaboration in fighting the pandemic.
	Online Processes.	Table 16 (Communication): Except for RHMS, cases used Google Forms™ to process demand.
	Multidisciplinary.	Table 16 (Multidisciplinary): Maker Networks include professionals developing multidisciplinary projects.
	Networked activities.	Table 16 (Local networks) and the section of the RHMS member's interview – transcribed in Campos and Cipolla (2021).
Local enablement.	*Institutional support.*	Table 17 (Institutional support) and Specificities: Except for RHMS, cases received institutional support, better exemplified by SOS and BCV.
	Actors and the community.	Table 17 (Social/Communities) and Specificities: Cases had members participating in some social projects, better exemplified by SOS and RHMS.
Business model.	*Crowdfunding.*	Table 18 (RDM cost model; Alternative finance), better exemplified by BCV and MCC cases. Besides, all the initiatives could count on individuals' donations.
	Confirmation of previous proposals.	Table 18: The columns of RDM product design and materials [1/2] confirm Product Requirements and Enabling Technologies-derived proposals. The remaining characteristics relate to members' interaction with society. As the networks depended on donations and donated their production, it possibly allowed members to feel part of a collective effort (Actor Transformation-related proposals). Besides, institutional support and alternative finance confirm the relationship between the Maker Network and the people and institutions existing at the Network's location (Local Enablement-derived proposals).

Adapted with the rightsholder permission from Campos and Cipolla (2021, p. 218).

4.4.2 The Purpose of the Design Proposals

The proposals developed here intend to inform new designs concerning RDM-Maker Networks. There are four types of initiatives where these design proposals can be applied.

- **Similar Initiatives**

The most immediate possibility is if a future Maker Network would like to learn from previous experience. The proposals would serve the people involved as advice on how past similar Networks used 3D-printing technology to manufacture a considerable amount of goods, even in harsh situations like a pandemic.

A future context to that would not necessarily be an emergency scenario. The RDM production model also serves as an alternative model to mass manufacturing. Thus, niche applications, like prototyping and customised goods, would also be a context for a Maker Network to contribute.

- **Maker Businesses**

Embedding the RDM model, the proposals can also inform future commercial enterprises originating in the Maker Movement. The proposals bring structural and logistics advice to entrepreneur makers, like what the proposals of 'Coordinating node', 'Node diversity', and 'Networked activities' imply.

Besides, initial support for businesses is usually a cornerstone to success. The proposals of 'Institutional Support' and 'Crowdfunding' advice on that topic.

- **Maker Education**

There are many applications of making to support education. Notwithstanding, to incorporate real-world application of maker practices themselves in the curricula, beyond supporting the teaching of a specific subject, initiatives like the RDM-Maker Networks serve as examples.

For example, if a student questions: what for, in the real world, are those maker practices? The proposals developed here would demonstrate how maker initiatives may function in the real world.

Since RDM is a production model, as part of the future workforce, those inside the educational system nowadays will probably occupy jobs related to that model. Thus, educating them about this is a reasonable topic for their curricula.

- **Related Research**

Future research concerning the subject matters of the present work may use the proposals in several ways, depending on the methodology adopted. For example:

a) in future case studies, it may guide the choice of case types to study;
b) in surveys, it may serve as a basis to define what to investigate; or
c) in literature reviews, it may guide the comparison between the works retrieved.

All in all, the proposals also represent a theoretical framework. They derive neither from only observing cases, as would a grounded theory research do, nor from only observing the theory, as in a literature review. Conversely, the design proposals developed here depended on both finding a theoretical framework to observe the cases, repurposing it, and adapting it through that observation.

5 DISCUSSION

This chapter displays interpretations of the findings based on reflections oriented by the theoretical background. The following subsections agree with the topics developed in Chapter 2, with the titles here reflecting the discussion's core point.

5.1 MAKERS' PERSPECTIVE

The present section interprets the findings based on the part of the theory devoted to the Makers and perspectives related to them.

5.1.1 Keeping History Alive

'Keeping history alive' is another way to say 'heading to the future but not forgetting the past'. RDM-Maker Networks are a promising configuration for people and organisations to build what part of the literature identifies as possible developments for the Maker Movement.

Some Maker Networks had Open Workshops, like the shared workshop Bricolab™ in BCV. Many of the individual Makers contributing to the Networks were doing it from their homes, like the RHMS member interviewed in Campos and Cipolla (2021).

Either way, these places can be seen as the "working-floor[s]" (FLUSSER, 1999, p. 43) of the Makers. These people, in turn, are a relatively recent kind of "homo-faber" (DOUGHERTY; CONRAD, 2016, p. 9).

Recalling Table 4, in Subsection 2.1.1, the reader can find several RDM characteristics observed in the cases. That includes one of the 'four desktop factories' (the 3D Printer), an open-source approach, and crowdfunding supporting the initiatives.

5.1.2 Bottom-Up Initiatives

Departing from the theoretical discussion on 'Who is the Maker?' (Subsection 2.1.2), we may better understand the individuals taking part in initiatives like Maker Networks studied here.

They share characteristics from two types of DIY: DIY science and technology and DIY consumer behaviour.

Regarding the first type, despite universities integrating the Networks, the initiative to start the Networks did not begin at the University in four cases. The exception is SOS, which began as an initiative from people related to the PUC-Rio's Department of Arts & Design. Thus, the other four cases correspond to an initial DIY endeavour independent from traditional R&D institutions, corresponding to the definition of DIY science and technology.

In terms of consumer behaviour, all the networks contacted some health professionals, mainly physicians and nurses, who, considering the situation of the PPE shortage, started giving inputs on the production of the equipment they used.

The Makers participating in the studied cases are inclined towards the intersection of the 'open' and 'making' profiles. Between market, making, openness, and their intersections (UNTERFRAUNER et al., 2020), we can see that "pragmatic makers" is the correct classification for the individuals collaborating with the Maker Networks (UNTERFRAUNER et al., 2020, p. 196). See Figure 20.

5.1.3 Do-It-Together Approach

Let us identify aspects of the Maker Culture and the Maker Movement in the cases studied, departing from the definitions of these terms in Subsection 2.1.3.

The shortage of PPE from global supply chains woke the attitude of many Makers worldwide (KIESLINGER et al., 2021), like those participating in the cases described here. They contributed with their hands-on approach and used 3D Printing technology to face the challenge of supplying PPE for the hospitals. The PPE's digital models and know-how in fabricating them were openly available online. Imbued with a do-it-together approach, even amid the pandemic, the Maker Networks could count on the inputs of the people using the PPE, healthcare professionals, manly physicians and nurses. Therefore, they are the prosumers participating in the Networks.

Shared workshops were essential as productive nodes of the Networks. Despite the sanitary restrictions demanded because of the pandemic (ABBASSI et al., 2022), these were the in-person places where the local Makers gathered. Undoubtedly, with care, the initiatives' social networks displayed photos and texts about participants responsible for the production working in an alternation scheme, thus not overcrowding the space.

Undoubtedly, the activities developed by Maker Networks generated a significant societal impact by offering an alternative to the global supply chain of PPE, which the pandemic caused a disruption (PHILLIPS et al., 2022).

5.1.4 This is 'Brasil'

In Portuguese, including in Brazilian Portuguese, Brazil is written 'Brasil'. In this subsection, the discussion concerns the cases studied as Maker Networks in the Brazilian context.

A member of RHMS built a face shield model based on PVC pipes and rubber bands. The present author participated for several months in a WhatsApp® group related to that initiative, where the member responsible for the model shared instructions to build a face shield. Recalling Table 6 in Subsection 2.1.4, this DIY makeshift can be called a 'gambiarra' here in Brazil (CAMPBELL, 2017).

That kind of gambiarra is associated with a positive connotation, a beneficial outcome of improvising with a DIY approach. As pointed out in Subsection 2.1.4, the focus is not on making this a permanent solution but on providing something that can address an issue with available resources.

The same holds for SOS: Members of that Maker Network smoothed the surface of 3D-printed products by applying hot air over them with a hand-held heat gun. Indeed, it does not account for an industrial standardised process for finishing thermoplastic material, which usually involves an oven with controlled temperature and airflow. Nonetheless, the heat-gun process works out for processing at least a part of the whole production or at least in the prototyping phase.

The matter of how grassroots innovations, specifically in materially deprived scenarios, should be faced as a positive or negative phenomenon touches on an ethical matter. If this type of inventiveness is harnessed, in part, from material deprivation, we shall ask ourselves how we are facing its existence. The point is not that those innovations are unnecessary: by definition, they come to mend a gap generated by the lack of material conditions. The problem resides in saying that we want them to be part of our world as a given. Because of their contextual definition (poverty, sometimes misery), that means saying we expect poverty and misery to remain a reality, as if they were a given, instead of what they are: a political and socioeconomic generated condition. Therefore, it must be clear that, while poverty exists, researchers, policymakers, decision-makers, and the like shall embrace grassroots innovation linked to lack of material conditions, trying to learn from and (possibly) boost its problem-solving capabilities while at the same time, recognising that, in the long run (shortest as possible), the socioeconomic paradigms which set this context, shall be transcended.

5.1.5 Productive Nodes

Recalling Table 8 in Subsection 2.1.5 and all the theories behind that table, we can classify the Makerspaces associated with the Maker Networks studies in this work.

BCV used Leroy Merlin®'s Bricolab™ as its headquarters and productive node. That shared workshop is a Makerspace of the more general type (not a Fab Lab, Repair Café, or Hackspace). It has various tools with varied possibilities, not focusing on anything that would imply the other specific types of Makerspaces.

MCC used a Makerspace called 'Casa de Makers' as a productive node (MAKERS CONTRA A COVID-19, 2020). That Makerspace is also of the more general type for the same reasons above.

RHMS had a meeting centre before the pandemic that, based on the content of their site, can be understood as a Hackerspace. It focuses on hardware and software development and repurposing (RHMS, 2020). In this case, the individual makers taking part in the Network printed the face shields in their houses.

As a manufacturing node, SOS had a prototyping laboratory from PUC-Rio's Department of Arts & Design. For the same reason of general purposefulness, that laboratory can be called a Makerspace, oriented to attend the University's members (BARRETT et al., 2015).

TM also had a general-purpose Makerspace, the FAZ Makerspace (TREM MAKER, 2020).

In Hennelly et al. (2019), the authors developed a theoretical framework, which the present work uses to build its own. There, the researchers used their framework to assess the RDM characteristics of Makerspaces. They did so to verify Makerspaces' productive capability to participate in an RDM model as a productive node.

RDM presupposes a non-centralised model. The Maker Networks proved to be realisations of that concept, and their primary productive nodes were individual Makers and Makerspaces.

Indeed, compared to what the traditional global supply chain can offer, RDM could not compete in volume and cost (SRAI; HARRINGTON; TIWARI, 2016). However, the pandemic brought the disruption of those same supply chains. Thus, RDM could show its potential through the Maker Networks.

A possible analytic generalisation (YIN, 2018) is that RDM-Maker Networks have great potential to help by manufacturing products with local resources when a disruption of that product's usual supply chain occurs. That may include emergencies such as disasters, wars, and diseases (BOW et al., 2022; LIU et al., 2023; WITTBRODT et al., 2013).

5.1.6 Initiatives

The Maker Networks studied here are a tiny fraction of many Maker Movement-related initiatives worldwide that responded to the pandemics, manufacturing necessary items with local resources (KIESLINGER et al., 2021).

The initiatives studied here resemble, in part, the Tunisian collectives from the Maker Movement organised by FabLab ENIT comprising makers and stakeholders from different fields (ABBASSI et al., 2022), as described in Subsection 2.1.6.

They also resemble the dispersed networks of 3D Printers operated by local makers with the support of Field Ready, which would supply emergency items that would not find their way to those in need otherwise (JAMES, 2017).

The cases studied here are also similar to those described in Smith (2017), where a series of 'pop-up' nodes are connected in a network, exploring the idea of local manufacturing.

Therefore, the Maker Networks are not restricted to Brazil and its contexts. Thus, they can represent crucial initiatives to help society in emergencies, especially when operating with RDM characteristics in other contexts.

5.2 MANUFACTURING'S PERSPECTIVE

This section brings interpretations from the findings based on the part of the theory dedicated to Manufacturing and the ways to distribute it.

5.2.1 Steps Towards the Future

As stated in Subsection 2.2.1, the transformation from I3.0 to I4.0 is still happening. There is still debate in the literature on when I4.0 started (SASSANELLI; TAISCH; TERZI, 2023).

Because manufacturing is still moving towards a well-established Industry 4.0, we can say that RDM-Maker Networks is a phenomenon observed during this transition. Since many of the technologies RDM may utilise, like Big Data, IoT and 3D Printing, are also part of the I4.0's portfolio, we can also say that RDM is part of that transition (SRAI et al., 2016; SRAI; HARRINGTON; TIWARI, 2016).

For example, an RDM-Maker Network may comprise minor 'smart factories' versions. Thus, the idea of a 'smart factory' becomes partially real by turning a production node with 3D Printers into a 'printing farm' with automated tasks, like the Makerspaces in the cases studied here (KEUNE; PEPPLER, 2019; SASSANELLI; TAISCH; TERZI, 2023).

Also, this production scheme was another way the Networks could attain the pandemic's constraints, like the sanitary restrictions (ABBASSI et al., 2022). That configuration allows much fewer human interactions in producing and delivering goods (SASSANELLI; TAISCH; TERZI, 2023).

Another thing in common between RDM and I4.0 is the idea of prosumption and mass customisation (SASSANELLI; TAISCH; TERZI, 2023; SRAI; HARRINGTON; TIWARI, 2016). Regarding prosumption in the Networks studied in this work, previous passages have already addressed the fact that health professionals occupied this position.

Regarding mass customisation, 3D Printers represent that possibility. It is possible because it depends on what that equipment will print after its current object. Concerning the studied cases, the 3D Printers replicated a file over and over again.

However, 3D Printing would allow a custom adjustment for every professional wearing a face shield if necessary.

Finally, the present research also observed the digitalisation characteristic from I4.0 in the studied cases. Again, because of the pandemic's sanitary restrictions, the Networks tried to deal digitally with the most steps they could. A clarifying example is the Telegram® groups from BCV to take care of various steps other than the physical production itself. Without the restrictions, those groups could be in-person meetings depending on physical infrastructure.

5.2.2 Spread and Reduce

The Maker Networks of this study belong to the branch of distributed manufacturing relating to dispersing the production of goods in response to an emergency (LIU et al., 2023), as described in Subsection 2.2.2.

Although not as fast as a disaster that happens in a matter of minutes, like the breakage of a dam, a pandemic also does not allow much time for supply chains to adapt, especially in the case of a global supply chain (PHILLIPS et al., 2022).

Likewise, in other works dealing with the use of 3D Printing to help in distressing situations, as is the case of the tourniquet testing system in Liu et al. (2023), the Maker Networks here had an open-source approach, sourcing the digital models from freely accessible archives on the internet, and a 3D Printer as the primary manufacturing resource.

'Gambiarra' models, like the face shield developed by an RHMS member, based on PVC pipes, have great value, principally when only that is available as a resource to build what is necessary. Nonetheless, regarding reproducibility and overall quality of the final product, using 3D Printers has a significant advantage over a makeshift (BOW et al., 2022; WITTBRODT et al., 2013).

Besides emergencies, RDM-Maker Networks can also contribute with their smaller manufacturing nodes (when compared to a mass manufacturing centralised factory). For example, recalling the article from So, Reeves and Pearce (2023), Maker Networks, operating as an RDM business, could provide affordable and customisable walkers for people with locomotive limitations. That is because the source of the walker' materials' is local (SO; REEVES; PEARCE, 2023), or, at least, available as usual input materials in projects developed in Makerspaces (HENNELLY et al., 2019).

5.2.3 Distribute, Again?

Following the possibility of operating in situations other than emergencies, as mentioned in the last subsection, let us understand this possibility for Maker Networks, focusing on the RDM model again.

The analysis requires bringing to mind the RDM's axes of location and scale again, which play a significant role in the RDM model, as shown in Subsection 2.2.3.

In terms of location, the Maker Networks studied here were all close to the hospitals where they delivered the face shields: same or adjacent neighbourhood, if not no farther than the same city. Although the pandemic's restrictions may have influenced this, that was not a necessary condition for the production to be localised.

That means that Maker Networks may address the local demand for specific products it can manufacture, either because of a necessary condition or by intentional design.

On the scale axis, the Maker Networks observed exactly fit the RDM tendency to small-scale manufacturing. Also, it relates to the location axis because the production capacity of each of the Networks' productive nodes could attend to only part of the local demand.

One of the possible conclusions from this is that to expand and acquire a greater production capacity, an RDM-Maker Network needs to incorporate more nodes in more locations within the same territory. Maybe redistribute the expected overall manufacturing yield to the newer nodes.

Otherwise, if a Maker Network would grow a productive node's scale, it would go against the RDM principle of small-scale manufacturing. Besides, if going out of a specific territory, it would start losing the localisation characteristic, which is fundamental to enable prosumption and customisation, according to the RDM model (HENNELLY et al., 2019; SRAI; HARRINGTON; TIWARI, 2016).

5.3 RESOURCEFUL ALLIANCE

The present work builds design proposals from the association of the RDM model with Maker Networks. These proposals are a support for future works to assess these subjects. Thus, let us evaluate the proposals considering the sets of characteristics from RDM. The reader can refer to Section 4.4 for the proposals and Section 2.3 for the RDM characteristics.

The 'user participation' guideline addresses the level of co-creation of the final product that the RDM's Product Requirement set of characteristics implies regarding the end user, in this case, healthcare professionals working at the hospitals receiving the PPE from the Networks.

The 'coordinating node' was a way to ensure that the PPE model, created or approved with the participation of a healthcare professional, would be manufactured with a regular output in all the productive nodes from the Network.

The 'open-source' approach was essential as a faster way to attain the user's desire since the Network would not need to build the digital model from scratch.

'Node diversity' allowed one of the Networks (BCV) to manufacture more complex designs that depend on more advanced 3D Printing technology than FDM. This fact aligns with the complexity of fabrication and the variety of materials supported by the Enabling Technology characteristics.

The 'cultural aspect' of the Networks was encouraging the members through statements regarding the importance of what they were doing in the face of the challenges imposed by the pandemic. That reinforced the necessity to work in a collaborative network, which aligns with the definition of the Actor Transformation set of characteristics, specifically concerning the idea of non-centralising and non-hierarchical governance of supporting actors.

Besides contributing to processes' digitalisation, the 'online processes' guideline, better exemplified by the Telegram® groups from the BCV case, also represents an innovation to configure the supply chain governance compared to traditional centralised models. Those groups, for instance, split into eight different areas that should contribute to the Network in a collaborative, horizontal way. None of them was hierarchically superior to the others, but each had a function as important as the others (BRASIL CONTRA O VIRUS, 2020).

Following the above reasoning, the 'multidisciplinary' characteristic of the Networks makes innovation and decentralised supply chain governance easier. The Telegram® groups and their equivalence in terms of importance were only possible due to the presence of experts related to the group's area in each of them. For example, the Network idealiser, Thabata Ganga, is a Biomedical Engineer and participated in the 'Biomedical Engineering and Health' group. Another example is the contribution of lawyers to the 'Legislation' group (BRASIL CONTRA O VIRUS, 2020).

The 'networked activities' aspect works alongside the Networks' cultural aspect. As stated before, the collaborative networked activities were themselves fundamental as a motivation to the Maker Networks' participants to keep contributing to the objectives of the Network. Thus, this network-like organisation is the physical form through which a transformative culture in supply chain governance can be achieved, as indicated by the definition of the 'Actors Transformation' set of characteristics.

Recalling the definition of the 'Local Enablement' set of characteristics in Section 2.3, that description mainly entails using local resources and generating resources for the local community. The two proposals deriving from this set of RDM characteristics stipulate precisely that.

The first, 'institutional support', advises that a Network shall consider what local institutions, like research institutions, already have to offer regarding manufacturing resources that the Network can access. Another possibility is the institution integrating the Network for an expanded production capacity and capability.

The second is the relationship between the Network's 'actors and the community', which is about a community of people directly interacting with the Network. That is why the evidence for that guideline is a Network member's participation in a social project.

The Business Model set of RDM characteristics supports two proposals. One relates to the Networks' financing; the other is a confirmation of previous proposals.

Regarding financing, the most common way to source financial support for the Networks was through 'crowdfunding'. Again, that is a way that a local organisation has to manage local resources that it intends to return to the local community regarding goods and services.

A guideline for the ‘confirmation of previous proposals’ may seem circular in logic, but it follows the idea that a business model shall embrace all its planned characteristics. Thus, this guideline follows what the previous proposals have established so far. For instance, an RDM “business model implies that local material resources are used locally to locally produce goods for local consumption and disposal” (HENNELLY et al., 2019, p. 544).

The considerations above altogether indicate that Maker Networks operating with RDM characteristics are a resourceful way society has to create solutions for local demands, either in emergency scenarios, like the COVID-19 pandemic, or just by the interest of a group of people and organisations to build solutions within the context of Maker Networks in alliance with the RDM model.

6 FUTURE WORKS

This chapter aims to provide several indications for future investigations following the present work based on the discussion of the results and the limitations of the present research.

6.1 WORKS ON MAKER NETWORKS

As seen in the design of this research, Subsection 3.2.2, the selection of cases to study depended on applying several filters. So, a first and straightforward way to envision future works concerns the variation of the parameters those filters represent.

The most basic filter for selecting cases in a case study research is the context in which the research happens (YIN, 2018). Thus, future works may focus on the characteristics of Maker Networks observed out of an emergency or in a kind of emergency other than a pandemic (LIU et al., 2023; SO; REEVES; PEARCE, 2023).

The present study focused on Maker Networks in a specific Brazilian region. Studies concerning other and more comprehensive areas in the same country and worldwide can reveal more general details concerning the Maker Movement's initiatives.

Studies comparing Maker Networks composed of different productive nodes may add to the literature with works concerning the different capabilities these networks can offer. For example, is there such a Network formed only by Repair Cafés or Hackerspaces? If so, how do they differ?

How would a Maker Network use Maker Movement-related technologies other than 3D Printing, like cutters and even wood crafting?

6.2 WORKS ON REDISTRIBUTED MANUFACTURING

The RDM axes of scale and location were fundamental to this work. The Maker Networks studied here had the characteristics supported by these axes. Thus, future works on RDM may investigate the limits for those two axes.

For example, to what limit can a productive node of an RDM initiative scale its production before getting to the classic mass production scenario?

Moreover, regarding location, how far can the production output of an RDM business be delivered so it does not become a usual organisation trying to sell to whatever extent still profitable?

In the years to come, some of the existing nomenclatures under the umbrella term ‘distributed manufacturing’ may cease. RDM may be one of them. Fusion of terminologies may happen, reassessments of the literature may point to the necessity of a better term, another utterly different paradigm may appear in manufacturing models, and so on.

Thence, future works, like a comprehensive literature review on distributed manufacturing and related forms of production, will be of extreme value to contribute to the current understanding deriving from the many terms present in literature, like social production and social manufacturing, peer production and peer manufacturing, collaborative production and collaborative manufacturing, and so forth (SRAI et al., 2016).

7 CONCLUSION

An RDM-Maker Network is a collaborative network of people and organisations related to the Maker Movement producing some good or delivering some service when following the Redistributed Manufacturing model.

As collaborative networks (MANZINI, 2012), RDM-Maker Networks may increase the resilience levels in communities to overcome harsh constraints like the difficulties imposed by the COVID-19 pandemic. The RDM model represents a way for a local economy to become more independent from global supply chains and mass-production-oriented models. The Maker Networks analysed in this work developed small-scale distributed manufacturing with a “moderate volume manufacturing of products in multiple locations while providing mass customisation” (KUMAR et al., 2020, p. 11).

This work adds to the current literature on RDM implementation cases, previously described mainly in Europe, with a few cases in India, all in an early development phase (LUTHRA; MANGLA; YADAV, 2019). The present work stems from a research that contributes threefold to the literature.

The first contribution is the theoretical development in Chapter 2, which stems from a literature review. That development explores and correlates various themes concerning the Maker Movement and RDM. This exploration goes beyond the mainstream literature by exploring and deriving fundamental definitions in topics such as the presence of the Maker Movement in the Global South, the historical contexts of the Maker Movement and RDM, the nuances of each of the latter two topics and the relationship between them, besides the perspectives from recent developments in the academic literature.

The results are the second contribution.

The present research creates a qualitative instrument for analysing RDM implementations relating to the Maker Movement. That instrument translates “key RDM-Makerspace characteristics” (HENNELLY et al., 2019, p. 543) into a set of questions that, when applied to cases, returns the description of the studied cases in terms of those characteristics.

Also, integrating the results, there is a series of design proposals aiming to help the exploration of other Maker Networks regarding RDM features. These proposals may support researchers, decision-makers and policymakers as an initial input to future works, investments or projects dedicated to supply chain resiliency and local resiliency.

The present work proposes four uses for the design proposals in Subsection 4.4.1:

a) similar Maker Networks;
b) maker businesses;
c) maker education; and
d) research related to the present subject matters.

The third contribution derives from the other two. In Chapter 5, this work develops a discussion backed by the theoretical background. In Chapter 6, the present work proposes future works that may address several of the questions arising from the limitations of the present research.

REFERENCES

ABBASSI, Wyssal; HARMEL, Aida; BELKAHLA, Wafa; BEN REJEB, Helmi. Maker movement contribution to fighting COVID-19 pandemic: insights from Tunisian FabLabs. **R&D Management**, New York, v. 52, n. 2, p. 343–355, 2022. DOI: 10.1111/radm.12503. Disponível em: https://onlinelibrary.wiley.com/doi/10.1111/radm.12503.

ADLER, Paul S.; GOLDOFTAS, Barbara; LEVINE, David I. Flexibility Versus Efficiency? A Case Study of Model Changeovers in the Toyota Production System. **Organization Science**, Catonsville, v. 10, n. 1, p. 43–68, 1999. DOI: 10.1287/orsc.10.1.43. Disponível em: http://pubsonline.informs.org/doi/abs/10.1287/orsc.10.1.43.

ANDERSON, Barnell. **Whatever Happened To Local Motors?** 2022. Disponível em: https://www.slashgear.com/891064/whatever-happened-to-local-motors/. Acesso em: 9 mar. 2023.

ANDERSON, Chris. **Makers: The new industrial revolution**. First ed. New York: Crown Publishing Group, 2012. Disponível em: https://www.penguinrandomhouse.com/books/207933/makers-by-chris-anderson/.

ANVISA. **Resolução de Diretoria Colegiada - RDC Nº356**. 2020. Disponível em: http://portal.anvisa.gov.br/documents/10181/5809525/RDC_356_2020_.pdf. Acesso em: 15 out. 2020.

ARROYO, Lizbeth; SANCHEZ-ASIN, J. Javier; VALLS-PASOLA, Jaume; HORMIGA, Esther. The Coronavirus Makers Network. Understanding the Success of an Innovation Community Facing COVID-19 in Spain. *In*: STANCU, Alin; GRIGORE, Georgiana; LUNDSTRÖM, Anders; TESFAYE, Besrat; SÖRENSSON, Anna (org.). **Corporate Responsibility and Sustainability during the Coronavirus Crisis**. London: Palgrave Macmillan Cham, 2021. p. 15–36. DOI: 10.1007/978-3-030-73847-1_2. Disponível em: https://link.springer.com/10.1007/978-3-030-73847-1_2.

ASSOUAD, Lydia; CHANCEL, Lucas; MORGAN, Marc. Extreme Inequality: Evidence from Brazil, India, the Middle East, and South Africa. **AEA Papers and Proceedings**, Pittsburgh, v. 108, p. 119–123, 2018. DOI: 10.1257/pandp.20181076. Disponível em: https://pubs.aeaweb.org/doi/10.1257/pandp.20181076.

ATKINSON, Paul. Do it yourself: Democracy and design. **Journal of Design History**, Oxford, v. 19, n. 1, p. 1–10, 2006. DOI: 10.1093/jdh/epk001. Disponível em: https://academic.oup.com/jdh/article-lookup/doi/10.1093/jdh/epk001.

AWORI, Jonathan; LEE, Joyce M. A maker movement for health a new paradigm for health innovation. **JAMA Pediatrics**, Chicago, v. 171, n. 2, p. 107–108, 2017. DOI: 10.1001/jamapediatrics.2016.3747. Disponível em: http://archpedi.jamanetwork.com/article.aspx?doi=10.1001/jamapediatrics.2016.3747.

AZEVEDO, Flávio S. The Tailored Practice of Hobbies and Its Implication for the Design of Interest-Driven Learning Environments. **Journal of the Learning Sciences**, London, v. 22, n. 3, p. 462–510, 2013. DOI: 10.1080/10508406.2012.730082. Disponível em: http://www.tandfonline.com/doi/abs/10.1080/10508406.2012.730082.

BARRETT, Thomas; PIZZICO, Matthew; LEVY, Bryan; NAGEL, Robert; LINSEY, Julie; TALLEY, Kimberly; FOREST, Craig; NEWSTETTER, Wendy. A Review of University Maker Spaces. *In*: 2015 ASEE ANNUAL CONFERENCE AND EXPOSITION PROCEEDINGS 2015, Seatle. **Anais** [...]. Seatle: ASEE Conferences, 2015. p. 26.101.1-26.101.17. DOI: 10.18260/p.23442. Disponível em: http://peer.asee.org/23442.

BARTON, Angela Calabrese; TAN, Edna; GREENBERG, Day. The makerspace movement: Sites of possibilities for equitable opportunities to engage underrepresented youth in STEM. **Teachers College Record**, New York, v. 119, n. 6, p. 1–44, 2017. DOI: 10.1177/016146811711900608. Disponível em: http://journals.sagepub.com/doi/10.1177/016146811711900608.

BHANDARE, Namita. Breaking New Ground: Films on Menstruation Shatter an Old Silence. **Indian Journal of Gender Studies**, Thousand Oaks, v. 26, n. 1–2, p. 196–206, 2019. DOI: 10.1177/0971521518808050. Disponível em: http://journals.sagepub.com/doi/10.1177/0971521518808050.

Biosensors - ScienceDirect. 2023. Disponível em: https://www.sciencedirect.com/topics/engineering/biosensors. Acesso em: 10 mar. 2023.

BOUTINET, Jean-Pierre. **Anthropologie du projet**. 2e. ed. Paris: Presses Universitaires de France, 2012. DOI: 10.3917/puf.bouti.2012.01. Disponível em: http://www.cairn.info/anthropologie-du-projet--9782130594611.htm.

BOW, J. K.; GALLUP, N.; SADAT, S. A.; PEARCE, J. M. Open source surgical fracture table for digitally distributed manufacturing. **PLoS ONE**, San Francisco, v. 17, n. 7 July, p. 1–40, 2022. DOI: 10.1371/journal.pone.0270328. Disponível em: https://dx.plos.org/10.1371/journal.pone.0270328.

BRASIL CONTRA O VIRUS. **Brasil contra o Vírus: Rede colaborativa de combate ao COVID-19 no Brasil**. 2020. Disponível em: https://brcontraovirus.org/. Acesso em: 9 out. 2020.

BRAVI, Laura; MURMURA, Federica; SANTOS, Gilberto. Manufacturing labs: Where new digital technologies help improve life quality. **International Journal for Quality Research**, Kragujevac, v. 12, n. 4, p. 957–974, 2018. DOI: 10.18421/IJQR12.04-11. Disponível em: http://www.ijqr.net/paper.php?id=711.

BRENNAN, Louis; FERDOWS, Kasra; GODSELL, Janet; GOLINI, Ruggero; KEEGAN, Richard; KINKEL, Steffen; SRAI, Jagjit Singh; TAYLOR, Margaret. Manufacturing in the world: where next? **International Journal of Operations and Production Management**, Leeds, v. 35, n. 9, p. 1253–1274, 2015. DOI: 10.1108/IJOPM-03-2015-0135. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/IJOPM-03-2015-0135/full/html.

BROWDER, Russell E.; ALDRICH, Howard E.; BRADLEY, Steven W. The emergence of the maker movement: Implications for entrepreneurship research. **Journal of Business Venturing**, Bloomington, v. 34, n. 3, p. 459–476, 2019. DOI: 10.1016/j.jbusvent.2019.01.005. Disponível em: https://doi.org/10.1016/j.jbusvent.2019.01.005.

BUCHANAN, Richard. Thinking about Design: An Historical Perspective. *In*: MEIJERS, Anthonie (org.). **Philosophy of Technology and Engineering Sciences**. North-Holland: Elsevier, 2009. p. 409–453. DOI: 10.1016/B978-0-444-51667-1.50020-3. Disponível em: https://www.sciencedirect.com/science/article/abs/pii/B9780444516671500203.

BURTET, Cecília Gerhardt. **(Re)pensando a inovação e o conceito de inovação inclusiva: um estudo do movimento maker no Brasil à luz da teoria ator-rede**. 2019. Tese (Doutorado em Administração) - Universidade do Vale do Rio dos Sinos, Porto Alegre, 2019. Disponível em: http://www.repositorio.jesuita.org.br/handle/UNISINOS/8692.

BURTET, Cecilia; KLEIN, Amarolinda. Inclusive Innovation Based on ICT: Lessons from the Maker Movement in Brazil. *In*: CONF-IRM 2021 PROCEEDINGS 2021, Springfield. **Anais** [...]. Springfield: Association for Information Systems, 2021. p. 11. Disponível em: https://aisel.aisnet.org/confirm2021/14. Acesso em: 6 abr. 2023.

BYARD, Dennis J.; WOERN, Aubrey L.; OAKLEY, Robert B.; FIEDLER, Matthew J.; SNABES, Samantha L.; PEARCE, Joshua M. Green fab lab applications of large-area waste polymer-based additive manufacturing. **Additive Manufacturing**, Amsterdam, v. 27, p. 515–525, 2019. DOI: 10.1016/j.addma.2019.03.006. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S221486041830695X.

CAMPBELL, Angus Donald. Lay Designers: Grassroots Innovation for Appropriate Change. **Design Issues**, Cambridge, v. 33, n. 1, p. 30–47, 2017. DOI: 10.1162/DESI_a_00424. Disponível em: https://direct.mit.edu/desi/article/33/1/30-47/69255.

CAMPOS, David; CIPOLLA, Carla. Maker Networks Fighting Covid-19: Design Guidelines for Redistributed Manufacturing (RDM) Models. **Strategic Design Research Journal**, São Leopoldo, v. 14, n. 1, p. 209–223, 2021. DOI: 10.4013/sdrj.2021.141.18. Disponível em: https://revistas.unisinos.br/index.php/sdrj/article/view/sdrj.2021.141.18.

CATTABRIGA, Andrea. A Makerspace Network as Part of a Regional Innovation Ecosystem, the Case of Emilia-Romagna. **European Journal of Creative Practices in Cities and Landscapes**, Bologna, v. 2, n. 2, p. 83–104, 2019. DOI: 10.6092/issn.2612-0496/9536. Disponível em: https://cpcl.unibo.it/article/view/9536/10450. Acesso em: 9 jun. 2023.

CHANDIMA RATNAYAKE, R. M. Enabling RDM in challenging environments via additive layer manufacturing: enhancing offshore petroleum asset operations. **Production Planning and Control**, London, v. 30, n. 7, p. 522–539, 2019. DOI: 10.1080/09537287.2018.1540054. Disponível em: https://www.tandfonline.com/doi/full/10.1080/09537287.2018.1540054.

CHEN, Ying; WU, Can. The hot spot transformation in the research evolution of maker. **Scientometrics**, Dordrecht, v. 113, n. 3, p. 1307–1324, 2017. DOI: 10.1007/s11192-017-2542-4. Disponível em: http://link.springer.com/10.1007/s11192-017-2542-4.

CHIARINI, Andrea; GRANDO, Alberto; BELVEDERE, Valeria. Disruptive social manufacturing models: lessons learned from Ferrari cars and Isinnova networks for a post-pandemic value creation path. **Production Planning and Control**, London, v. 34, n. 12, p. 1135–1148, 2023. DOI: 10.1080/09537287.2021.1986865. Disponível em: https://www.tandfonline.com/doi/full/10.1080/09537287.2021.1986865.

CORONADO, Adrian E.; LYONS, Andrew C.; KEHOE, Dennis F.; COLEMAN, J. Enabling mass customization: Extending build-to-order concepts to supply chains. **Production Planning and Control**, London, v. 15, n. 4, p. 398–411, 2004. DOI: 10.1080/0953728042000238809. Disponível em: https://www.tandfonline.com/doi/full/10.1080/0953728042000238809.

CUNTZ, Alexander; PEUCKERT, Jan. From hackers to start-ups: Innovation commons and local entrepreneurial activity. **Research Policy**, Amsterdam, v. 52, n. 2, p. 1–17, 2023. DOI: 10.1016/j.respol.2022.104675. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0048733322001962.

DADOS, Nour; CONNELL, Raewyn. The Global South. **Contexts**, Los Angeles, v. 11, n. 1, p. 12–13, 2012. DOI: 10.1177/1536504212436479. Disponível em: http://journals.sagepub.com/doi/10.1177/1536504212436479.

DAHLIN, Kristina; TAYLOR, Margaret; FICHMAN, Mark. Today's Edisons or weekend hobbyists: Technical merit and success of inventions by independent inventors. **Research Policy**, Amsterdam, v. 33, n. 8, p. 1167–1183, 2004. DOI: 10.1016/j.respol.2004.06.003. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0048733304000848.

DAILY, Larry Z. Towards a definition of "hobby": An empirical test of a proposed operational definition of the word hobby. **Journal of Occupational Science**, London, v. 25, n. 3, p. 368–382, 2018. DOI: 10.1080/14427591.2018.1463286. Disponível em: https://www.tandfonline.com/doi/full/10.1080/14427591.2018.1463286.

DARGAHI, Rambod; NAMIN, Aidin; KETRON, Seth. Co-production or DIY: an analytical model of consumer choice and social preferences. **Journal of Product and Brand Management**, Leeds, v. 30, n. 2, p. 306–319, 2020. DOI: 10.1108/JPBM-09-2019-2565. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/JPBM-09-2019-2565/full/html.

DE UGARTE, B. Saenz; ARTIBA, A.; PELLERIN, R. Manufacturing execution system - A literature review. **Production Planning and Control**, London, v. 20, n. 6, p. 525–539, 2009. DOI: 10.1080/09537280902938613. Disponível em: https://www.tandfonline.com/doi/full/10.1080/09537280902938613.

DEMIR, Kadir Alpaslan; DÖVEN, Gözde; SEZEN, Bülent. Industry 5.0 and Human-Robot Co-working. **Procedia Computer Science**, Amsterdam, v. 158, p. 688–695, 2019. DOI: 10.1016/j.procs.2019.09.104. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S1877050919312748.

DIAZ, Jérémy; TOMÀS, Mariona; LEFEBVRE, Sylvain. Are public makerspaces a means to empowering citizens? The case of Ateneus de Fabricació in Barcelona. **Telematics and Informatics**, Amsterdam, v. 59, p. 1–10, 2021. DOI: 10.1016/j.tele.2020.101551. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0736585320302100.

DOUGHERTY, Dale; CONRAD, Ariane. **Free to Make: How the Maker Movement Is Changing Our Schools, Our Jobs, and Our Minds.** Berkeley: North Atlantic Books, 2016. Disponível em: https://books.google.com.br/books/about/Free_to_Make.html?id=hzvqDAAAQBAJ.

DOUGHERTY, Dale; O'REILLY MEDIA. Make: **Make: magazine**, Sebastopol, v. 1, n. 1, p. 192, 2005. Disponível em: https://makezine.com/.

EISENHARDT, Kathleen M. Building Theories from Case Study Research. **Academy of Management Review**, Westchester County, v. 14, n. 4, p. 532–550, 1989. DOI: 10.5465/amr.1989.4308385. Disponível em: http://journals.aom.org/doi/10.5465/amr.1989.4308385.

ELEKTOR INTERNATIONAL MEDIA. **About Elektor**. 2019. Disponível em: https://www.elektor.com/about-elektor. Acesso em: 19 fev. 2021.

ELEKTOR PUBLISHERS LTD. Elektor. **Elektor Magazine**, Canterbury, v. 1, n. 1, p. 66, 1974. Disponível em: https://www.elektormagazine.com/.

EMELOGU, Adindu; MARUFUZZAMAN, Mohammad; THOMPSON, Scott M.; SHAMSAEI, Nima; BIAN, Linkan. Additive manufacturing of biomedical implants: A feasibility assessment via supply-chain cost analysis. **Additive Manufacturing**, Amsterdam, v. 11, p. 97–113, 2016. DOI: 10.1016/j.addma.2016.04.006. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S2214860416300756.

EYERS, Daniel R.; POTTER, Andrew T. E-commerce channels for additive manufacturing: An exploratory study. **Journal of Manufacturing Technology Management**, Leeds, v. 26, n. 3, p. 390–411, 2015. DOI: 10.1108/JMTM-08-2013-0102. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/JMTM-08-2013-0102/full/html.

FAVERO, Renato; ISINNOVA. **Emergency mask for hospital ventilators**. 2020. Disponível em: https://www.isinnova.it/easy-covid19-eng/. Acesso em: 1 jul. 2020.

FAWCETT, Stanley E.; WALLER, Matthew A. Supply chain game changers-mega, nano, and virtual trends-and forces that impede supply chain design (i.e., Building a Winning Team). **Journal of Business Logistics**, Hoboken, v. 35, n. 3, p. 157–164, 2014. DOI: 10.1111/jbl.12058. Disponível em: https://onlinelibrary.wiley.com/doi/10.1111/jbl.12058.

FEINGOLD, Mordechai. History of universities. *In*: **History of Universities**. Dordrecht: Springer Netherlands, 2018. v. 31p. 1–230. DOI: 10.1093/oso/9780198827344.001.0001. Disponível em: http://link.springer.com/10.1007/978-1-4020-4012-2_10.

FERRETTI, Federico. Mapping do-it-yourself science. **Life Sciences, Society and Policy**, Cham, v. 15, n. 1, p. 1, 2019. DOI: 10.1186/s40504-018-0090-1. Disponível em: https://lsspjournal.biomedcentral.com/articles/10.1186/s40504-018-0090-1.

FINN, Donovan. DIY urbanism: implications for cities. **Journal of Urbanism**, London, v. 7, n. 4, p. 381–398, 2014. DOI: 10.1080/17549175.2014.891149. Disponível em: http://www.tandfonline.com/doi/abs/10.1080/17549175.2014.891149.

FLUSSER, Vilém. **The Shape of Things: A Philosophy of Design**. London: Reaktion Books, 1999. Disponível em: https://press.uchicago.edu/ucp/books/book/distributed/S/bo3535939.html.

FLUSSER, Vilém. **Into the Universe of Technical Images**. 1st. ed. Minneapolis: University of Minnesota Press, 2011. DOI: 10.5749/minnesota/9780816670208.001.0001. Disponível em: https://www.upress.umn.edu/book-division/books/into-the-universe-of-technical-images.

FORD, Simon; MINSHALL, Tim. Defining the Research Agenda for 3D Printing-Enabled Re-distributed Manufacturing. *In*: (Shigeki Umeda, Masaru Nakano, Hajime Mizuyama, Hironori Hibino, Dimitris Kiritsis, Gregor von Cieminski, Org.)IFIP ADVANCES IN INFORMATION AND COMMUNICATION TECHNOLOGY 2015, Cham. **Anais** [...]. Cham: Springer, 2015. p. 156–164. DOI: 10.1007/978-3-319-22759-7_18. Disponível em: http://link.springer.com/10.1007/978-3-319-22759-7_18.

FOREST, Craig R.; MOORE, Roxanne A.; JARIWALA, Amit S.; FASSE, Barbara Burks; LINSEY, Julie; NEWSTETTER, Wendy; NGO, Peter; QUINTERO, Christopher. The invention studio: A university maker space and culture. **Advances in Engineering Education**, Washington, D.C., v. 4, n. 2, p. 1–32, 2014. Disponível em: https://advances.asee.org/?publication=the-invention-studio-a-university-maker-space-and-culture.

FOX, Sarah; ULGADO, Rachel Rose; ROSNER, Daniela K. Hacking culture, not devices: Access and recognition in feminist hackerspaces. *In*: CSCW 2015 - PROCEEDINGS OF THE 2015 ACM INTERNATIONAL CONFERENCE ON COMPUTER-SUPPORTED COOPERATIVE WORK AND SOCIAL COMPUTING 2015, New York. **Anais** [...]. New York: ACM, 2015. p. 56–68. DOI: 10.1145/2675133.2675223. Disponível em: https://dl.acm.org/doi/10.1145/2675133.2675223.

FOX, Stephen. Paradigm shift: Do-it-yourself (DIY) invention and production of physical goods for use or sale. **Journal of Manufacturing Technology Management**, Leeds, v. 24, n. 2, p. 218–234, 2013. DOI: 10.1108/17410381311292313. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/17410381311292313/full/html.

FOX, Stephen. Third Wave Do-It-Yourself (DIY): Potential for prosumption, innovation, and entrepreneurship by local populations in regions without industrial manufacturing infrastructure. **Technology in Society**, Oxford, v. 39, p. 18–30, 2014. DOI: 10.1016/j.techsoc.2014.07.001. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0160791X14000396.

FREEMAN, Rachel; MCMAHON, Chris. The Potential Role of Re-Distributed Manufacturing in Improving Industrial Sustainability. *In*: HASHMI, Saleem; CHOUDHURY, Imtiaz Ahmed (org.). **Encyclopedia of Renewable and Sustainable Materials: Volume 1-5**. Amsterdam: Elsevier, 2020. v. 1–5p. 451–457. DOI: 10.1016/B978-0-12-803581-8.10910-5. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/B9780128035818109105.

FREEMAN, Rachel; MCMAHON, Chris; GODFREY, Patrick. Design of an Integrated Assessment of Re-distributed Manufacturing for the Sustainable, Resilient City. *In*: (Rossi Setchi, Robert J. Howlett, Ying Liu, Peter Theobald, Org.)SUSTAINABLE DESIGN AND MANUFACTURING 2016 2016, Crete. **Anais** [...]. Crete: Springer International Publishing, 2016. p. 601–612. DOI: 10.1007/978-3-319-32098-4_51. Disponível em: http://link.springer.com/10.1007/978-3-319-32098-4_51.

FREEMAN, Rachel; MCMAHON, Chris; GODFREY, Patrick. An exploration of the potential for re-distributed manufacturing to contribute to a sustainable, resilient city. **International Journal of Sustainable Engineering**, Oxford, v. 10, n. 4–5, p. 260–271, 2017. DOI: 10.1080/19397038.2017.1318969. Disponível em: https://www.tandfonline.com/doi/full/10.1080/19397038.2017.1318969.

GAGNIDZE, Ineza. Industry 4.0 and industry 5.0: can clusters deal with the challenges? (A systemic approach). **Kybernetes**, Leeds, v. 52, n. 7, p. 2270–2287, 2023. DOI: 10.1108/K-07-2022-1005. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/K-07-2022-1005/full/html.

GAO, Wei et al. The status, challenges, and future of additive manufacturing in engineering. **CAD Computer Aided Design**, Oxford, v. 69, p. 65–89, 2015. DOI: 10.1016/j.cad.2015.04.001. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0010448515000469.

GAVER, William; BOUCHER, Andy; VANIS, Michail; SHEEN, Andy; BROWN, Dean; OVALLE, Liliana; MATSUDA, Naho; ABBAS-NAZARI, Amina; PHILLIPS, Robert. My naturewatch camera disseminating practice research with a cheap and easy DIY design. *In*: CONFERENCE ON HUMAN FACTORS IN COMPUTING SYSTEMS - PROCEEDINGS 2019, New York. **Anais** [...]. New York: ACM, 2019. p. 1–13. DOI: 10.1145/3290605.3300532. Disponível em: https://dl.acm.org/doi/10.1145/3290605.3300532.

GEISSDOERFER, Martin; SAVAGET, Paulo; BOCKEN, Nancy M. P.; HULTINK, Erik Jan. The Circular Economy – A new sustainability paradigm? **Journal of Cleaner Production**, Oxford, v. 143, p. 757–768, 2017. DOI: 10.1016/j.jclepro.2016.12.048. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0959652616321023.

GELBER, Steven M. A Job You Can't Lose: Work and Hobbies in the Great Depression. **Journal of Social History**, Oxford, v. 24, n. 4, p. 741–766, 1991. DOI: 10.1353/jsh/24.4.741. Disponível em: https://academic.oup.com/jsh/article-lookup/doi/10.1353/jsh/24.4.741.

Genetic Engineering - ScienceDirect. 2023. Disponível em: https://www.sciencedirect.com/topics/neuroscience/genetic-engineering. Acesso em: 10 mar. 2023.

GHISELLINI, Patrizia; ULGIATI, Sergio. Circular economy transition in Italy. Achievements, perspectives and constraints. **Journal of Cleaner Production**, Oxford, v. 243, p. 1–18, 2020. DOI: 10.1016/j.jclepro.2019.118360. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0959652619332305.

GILSON, Dirk. **Arunachalam Muruganantham: India's Menstrual Man**. 2016. Disponível em: http://interactive.aljazeera.com/aje/shorts/india-menstruation-man/. Acesso em: 17 abr. 2023.

GIUSTI, Jessica D.; ALBERTI, Fernando G.; BELFANTI, Federica. Makers and clusters. Knowledge leaks in open innovation networks. **Journal of Innovation and Knowledge**, Amsterdam, v. 5, n. 1, p. 20–28, 2020. DOI: 10.1016/j.jik.2018.04.001. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S2444569X18300453.

GOFUNDME. **About us**. 2023. Disponível em: https://www.gofundme.com/c/about-us. Acesso em: 9 mar. 2023.

GREEN, David; KIRK, David. Open design, inclusivity and the intersections of making. *In*: PROCEEDINGS OF THE 2018 DESIGNING INTERACTIVE SYSTEMS CONFERENCE 2018, New York. **Anais** [...]. New York: ACM, 2018. p. 173–186. DOI: 10.1145/3196709.3196718. Disponível em: https://dl.acm.org/doi/10.1145/3196709.3196718.

GUPTA, Anil K. Innovations for the poor by the poor. **International Journal of Technological Learning, Innovation and Development**, Geneva, v. 5, n. 1–2, p. 28–39, 2012. DOI: 10.1504/IJTLID.2012.044875. Disponível em: http://www.inderscience.com/link.php?id=44875.

GUPTA, Himanshu; LAWAL, Jennifer Nguseer; ORJI, Ifeyinwa Juliet; KUSI-SARPONG, Simonov. Closing the Gap: The Role of Distributed Manufacturing Systems for Overcoming the Barriers to Manufacturing Sustainability. **IEEE Transactions on Engineering Management**, New York, v. 70, n. 5, p. 1754–1773, 2023. DOI: 10.1109/TEM.2021.3059231. Disponível em: https://ieeexplore.ieee.org/document/9397296/.

hack - Collins Online Dictionary. 2023. Disponível em: https://www.collinsdictionary.com/dictionary/english/hack. Acesso em: 5 mar. 2023.

HADDAD, Yousef; SALONITIS, Konstantinos; EMMANOUILIDIS, Christos. Design of redistributed manufacturing networks: a model-based decision-making framework. **International Journal of Computer Integrated Manufacturing**, Philadelphia, v. 34, n. 10, p. 1011–1030, 2021. DOI: 10.1080/0951192X.2021.1946860. Disponível em: https://www.tandfonline.com/doi/full/10.1080/0951192X.2021.1946860.

HALVERSON, Erica Rosenfeld; SHERIDAN, Kimberly. The Maker Movement in Education. **Harvard Educational Review**, Boston, v. 84, n. 4, p. 495–504, 2014. DOI: 10.17763/haer.84.4.34j1g68140382063. Disponível em: https://meridian.allenpress.com/her/article/84/4/495/32157/The-Maker-Movement-in-Education.

HAMALAINEN, Markko; KARJALAINEN, Jesse. Social manufacturing: When the maker movement meets interfirm production networks. **Business Horizons**, Bloomington, v. 60, n. 6, p. 795–805, 2017. DOI: 10.1016/j.bushor.2017.07.007. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0007681317301052.

HATCH, Mark. **The Maker Movement Manifesto: Rules for Innovation in the New World of Crafters, Hackers, and Tinkerers**. New York: McGraw-Hill Education, 2014. Disponível em: https://www.oreilly.com/library/view/the-maker-movement/9780071821124/.

HEARST MAGAZINES. **About Us**. 2018. Disponível em: https://www.popularmechanics.com/about/a45/about-us/. Acesso em: 16 fev. 2021.

HENNELLY, Patrick A.; SRAI, Jagjit Singh; GRAHAM, Gary; MERITON, Royston; KUMAR, Mukesh. Do makerspaces represent scalable production models of community-based redistributed manufacturing? **Production Planning & Control**, London, v. 30, n. 7, p. 540–554, 2019. DOI: 10.1080/09537287.2018.1540056. Disponível em: https://www.tandfonline.com/doi/abs/10.1080/09537287.2018.1540056.

HIRSCHER, Anja-Lisa; MAZZARELLA, Francesco; FUAD-LUKE, Alastair. Socializing Value Creation Through Practices of Making Clothing Differently: A Case Study of a Makershop With Diverse Locals. **Fashion Practice**, Oxford, v. 11, n. 1, p. 53–80, 2019. DOI: 10.1080/17569370.2019.1565377. Disponível em: https://www.tandfonline.com/doi/full/10.1080/17569370.2019.1565377.

HOLMSTRÖM, Jan; HOLWEG, Matthias; KHAJAVI, Siavash H.; PARTANEN, Jouni. The direct digital manufacturing (r)evolution: definition of a research agenda. **Operations Management Research**, New York, v. 9, n. 1–2, p. 1–10, 2016. DOI: 10.1007/s12063-016-0106-z. Disponível em: http://link.springer.com/10.1007/s12063-016-0106-z.

HONEY, Margaret; KANTER, David E. Have fun—learn something, do something, make something. *In*: HONEY, Margaret; KANTER, David E. (org.). **Design, Make, Play: Growing the Next Generation of STEM Innovators**. New York: Routledge, 2013. p. 32–37. Disponível em: https://www.taylorfrancis.com/books/edit/10.4324/9780203108352/design-make-play-margaret-honey-david-kanter.

HUI, Julie S.; GERBER, Elizabeth M. Developing makerspaces as sites of entrepreneurship. *In*: PROCEEDINGS OF THE ACM CONFERENCE ON COMPUTER SUPPORTED COOPERATIVE WORK, CSCW 2017, New York. **Anais** [...]. New York: ACM, 2017. p. 2023–2038. DOI: 10.1145/2998181.2998264. Disponível em: https://dl.acm.org/doi/10.1145/2998181.2998264.

Human Computer Interaction - ScienceDirect. 2023. Disponível em: https://www.sciencedirect.com/topics/computer-science/human-computer-interaction. Acesso em: 27 mar. 2023.

IFIXIT. **iFixit's Story**. 2023. Disponível em: https://www.ifixit.com/Info/background. Acesso em: 9 maio. 2023.

IRIE, Natalie Roote; HSU, Yu Chang; CHING, Yu Hui. Makerspaces in Diverse Places: A Comparative Analysis of Distinctive National Discourses Surrounding the Maker Movement and Education in Four Countries. **TechTrends**, New York, v. 63, n. 4, p. 397–407, 2019. DOI: 10.1007/s11528-018-0355-9. Disponível em: http://link.springer.com/10.1007/s11528-018-0355-9.

IVANOV, Dmitry. The Industry 5.0 framework: viability-based integration of the resilience, sustainability, and human-centricity perspectives. **International Journal of Production Research**, Oxford, v. 61, n. 5, p. 1683–1695, 2023. DOI: 10.1080/00207543.2022.2118892. Disponível em: https://www.tandfonline.com/doi/full/10.1080/00207543.2022.2118892.

IVESON, Kurt. Cities within the City: Do-It-Yourself Urbanism and the Right to the City. **International Journal of Urban and Regional Research**, Oxford, v. 37, n. 3, p. 941–956, 2013. DOI: 10.1111/1468-2427.12053. Disponível em: https://onlinelibrary.wiley.com/doi/abs/10.1111/1468-2427.12053.

JAMES, Laura. Opportunities and challenges of distributed manufacturing for humanitarian response. *In*: 2017 IEEE GLOBAL HUMANITARIAN TECHNOLOGY CONFERENCE 2017, San Jose. **Anais** [...]. San Jose: IEEE, 2017. p. 1–9. DOI: 10.1109/GHTC.2017.8239297. Disponível em: http://ieeexplore.ieee.org/document/8239297/.

JOHNS, Jennifer; HALL, Sarah Marie. 'I have so little time […] I got shit I need to do': Critical perspectives on making and sharing in Manchester's FabLab. **Environment and Planning A: Economy and Space**, Thousand Oaks, v. 52, n. 7, p. 1292–1312, 2020. DOI: 10.1177/0308518X19897918. Disponível em: http://journals.sagepub.com/doi/10.1177/0308518X19897918.

KARKI, Srijana. Addressing a Hygiene Crisis. **Women's Reproductive Health**, Oxford, v. 7, n. 2, p. 150–152, 2020. DOI: 10.1080/23293691.2019.1690304. Disponível em: https://www.tandfonline.com/doi/full/10.1080/23293691.2019.1690304.

KEUNE, Anna; PEPPLER, Kylie. Materials-to-develop-with: The making of a makerspace. **British Journal of Educational Technology**, Oxford, v. 50, n. 1, p. 280–293, 2019. DOI: 10.1111/bjet.12702. Disponível em: https://bera-journals.onlinelibrary.wiley.com/doi/10.1111/bjet.12702.

KICKSTARTER PBC. **About us**. 2023. Disponível em: https://www.kickstarter.com/about. Acesso em: 9 mar. 2023.

KIESLINGER, Barbara; SCHAEFER, Teresa; FABIAN, Claudia Magdalena; BIASIN, Elisabetta; BASSI, Enrico; FREIRE, Ricardo Ruiz; MOWOH, Nadine; ARIF, Nawres; MELIS, Paulien. Covid-19 Response From Global Makers: The Careables Cases of Global Design and Local Production. **Frontiers in Sociology**, Lausanne, v. 6, p. 45, 2021. DOI: 10.3389/fsoc.2021.629587. Disponível em: https://www.frontiersin.org/articles/10.3389/fsoc.2021.629587/full. Acesso em: 23 abr. 2021.

KLAMKA, Konstantin; DACHSELT, Raimund. Pushables: A DIY approach for fabricating customizable and self-contained tactile membrane dome switches. *In*: UIST 2018 ADJUNCT - ADJUNCT PUBLICATION OF THE 31ST ANNUAL ACM SYMPOSIUM ON USER INTERFACE SOFTWARE AND TECHNOLOGY 2018, New York. **Anais** [...]. New York: ACM, 2018. p. 1–4. DOI: 10.1145/3266037.3266082. Disponível em: https://dl.acm.org/doi/10.1145/3266037.3266082.

KOHTALA, Cindy. Making "Making" Critical: How Sustainability is Constituted in Fab Lab Ideology. **Design Journal**, Oxford, v. 20, n. 3, p. 375–394, 2017. DOI: 10.1080/14606925.2016.1261504. Disponível em: https://www.tandfonline.com/doi/full/10.1080/14606925.2016.1261504.

KOHTALA, Cindy; BOSQUÉ, Camille. The story of MIT-Fablab Norway: community embedding of peer production. **Journal of Peer Production**, Edinburgh, n. 5, 2014. Disponível em: http://peerproduction.net/issues/issue-5-shared-machine-shops/peer-reviewed-articles/the-story-of-mit-fablab-norway-community-embedding-of-peer-production/. Acesso em: 1 jul. 2020.

KÜHNLE, Hermann. Distributed Manufacturing: Paradigms, Concepts, Solutions and Examples. *In*: KÜHNLE, Hermann (org.). **Distributed Manufacturing**. London: Springer London, 2010. p. 1–9. DOI: 10.1007/978-1-84882-707-3_1. Disponível em: http://link.springer.com/10.1007/978-1-84882-707-3_1.

KULL, Thomas J.; BOYER, Ken; CALANTONE, Roger. Last-mile supply chain efficiency: An analysis of learning curves in online ordering. **International Journal of Operations and Production Management**, Leeds, v. 27, n. 4, p. 409–434, 2007. DOI: 10.1108/01443570710736985. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/01443570710736985/full/html.

KUMAR, Mukesh; TSOLAKIS, Naoum; AGARWAL, Anshul; SRAI, Jagjit Singh. Developing distributed manufacturing strategies from the perspective of a product-process matrix. **International Journal of Production Economics**, Amsterdam, v. 219, p. 1–17, 2020. DOI: 10.1016/j.ijpe.2019.05.005. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0925527319301744.

KUMAR, Vipin; CHAND, Vijaya Sherry; ZHANG, Liyan; HOPPERS, Catherine A. Odor.; ZHANG, Wei; ESDERS, Marianne; GUPTA, Anil K. Grassroots Innovations for Inclusive Development: Need for a Paradigmatic Shift. **Vikalpa**, Ahmedabad, v. 38, n. 3, p. 103–122, 2013. DOI: 10.1177/0256090920130307. Disponível em: http://journals.sagepub.com/doi/10.1177/0256090920130307.

KUZNETSOV, Stacey; PAULOS, Eric. Rise of the expert amateur: DIY projects, communities, and cultures. *In*: NORDICHI 2010: EXTENDING BOUNDARIES - PROCEEDINGS OF THE 6TH NORDIC CONFERENCE ON HUMAN-COMPUTER INTERACTION 2010, New York. **Anais** [...]. New York: ACM Press, 2010. p. 295–304. DOI: 10.1145/1868914.1868950. Disponível em: http://portal.acm.org/citation.cfm?doid=1868914.1868950.

LAB ESCOLA 3D. **Lab Escola 3D – Rio DESIS Lab**. 2020. Disponível em: https://desis.rio.br/lab-escola-3d/. Acesso em: 8 mar. 2021.

LANGE, Bastian; BÜRKNER, Hans Joachim. Open workshops as sites of innovative socio-economic practices: approaching urban post-growth by assemblage theory. **Local Environment**, Oxford, v. 23, n. 7, p. 680–696, 2018. DOI: 10.1080/13549839.2017.1418305. Disponível em: https://www.tandfonline.com/doi/full/10.1080/13549839.2017.1418305.

LAPLUME, Andre; ANZALONE, Gerald C.; PEARCE, Joshua M. Open-source, self-replicating 3-D printer factory for small-business manufacturing. **International Journal of Advanced Manufacturing Technology**, London, v. 85, n. 1–4, p. 633–642, 2016. DOI: 10.1007/s00170-015-7970-9. Disponível em: http://link.springer.com/10.1007/s00170-015-7970-9.

LEONARDI, Paul M. Materiality, Sociomateriality, and Socio-Technical Systems: What Do These Terms Mean? How are They Related? Do We Need Them? **SSRN Electronic Journal**, Philadelphia, p. 25–48, 2012. DOI: 10.2139/ssrn.2129878. Disponível em: http://www.ssrn.com/abstract=2129878.

LEVY, Bryan; MOROCZ, Ricardo Jose; FOREST, Craig; NAGEL, Robert L.; NEWSTETTER, Wendy C.; TALLEY, Kimberly Grau; SMITH, Shaunna Fultz; LINSEY, Julie S. MAKER: How to make a university maker space. *In*: ASEE ANNUAL CONFERENCE AND EXPOSITION, CONFERENCE PROCEEDINGS 2016, New Orleans. **Anais** [...]. New Orleans: ASEE Conferences, 2016. p. 1–9. DOI: 10.18260/p.25623. Disponível em: http://peer.asee.org/25623.

LHOSTE, Evelyne F. Can do-it-yourself laboratories open up the science, technology, and innovation research system to civil society? **Technological Forecasting and Social Change**, New York, v. 161, p. 1–5, 2020. DOI: 10.1016/j.techfore.2020.120226. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0040162520310520.

LI, Junjie; ZHAN, Guohui; DAI, Xin; QI, Meng; LIU, Bangfan. Innovation and Optimization Logic of Grassroots Digital Governance in China under Digital Empowerment and Digital Sustainability. **Sustainability**, Basel, v. 14, n. 24, p. 28, 2022. DOI: 10.3390/su142416470. Disponível em: https://www.mdpi.com/2071-1050/14/24/16470.

LI, Phoebe; FAULKNER, Alex; MEDCALF, Nicholas. 3D bioprinting in a 2D regulatory landscape: gaps, uncertainties, and problems. **Law, Innovation and Technology**, Oxford, v. 12, n. 1, p. 1–29, 2020. DOI: 10.1080/17579961.2020.1727054. Disponível em: https://www.tandfonline.com/doi/full/10.1080/17579961.2020.1727054.

LIM, Stanley Frederick W. T.; JIN, Xin; SRAI, Jagjit Singh. Consumer-driven e-commerce: A literature review, design framework, and research agenda on last-mile logistics models. **International Journal of Physical Distribution and Logistics Management**, Leeds, v. 48, n. 3, p. 308–332, 2018. DOI: 10.1108/IJPDLM-02-2017-0081. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/IJPDLM-02-2017-0081/full/html.

LINDTNER, Silvia. Hacking with Chinese Characteristics. **Science, Technology, & Human Values**, Thousand Oaks, v. 40, n. 5, p. 854–879, 2015. DOI: 10.1177/0162243915590861. Disponível em: http://journals.sagepub.com/doi/10.1177/0162243915590861.

LINDTNER, Silvia; HERTZ, Garnet; DOURISH, Paul. Emerging sites of HCI innovation: Hackerspaces, hardware startups & incubators. *In*: CONFERENCE ON HUMAN FACTORS IN COMPUTING SYSTEMS - PROCEEDINGS 2014, New York. **Anais** [...]. New York: ACM, 2014. p. 439–448. DOI: 10.1145/2556288.2557132. Disponível em: https://dl.acm.org/doi/10.1145/2556288.2557132.

LIU, Dawei; KULKARNI, Apoorv; JAQUA, Victoria F.; COLE, Christina A.; PEARCE, Joshua M. Distributed manufacturing of an open-source tourniquet testing system. **HardwareX**, Oxford, v. 15, p. 1–20, 2023. DOI: 10.1016/j.ohx.2023.e00442. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S2468067223000494.

LIU, Peng; HUANG, Samuel H.; MOKASDAR, Abhiram; ZHOU, Heng; HOU, Liang. The impact of additive manufacturing in the aircraft spare parts supply chain: Supply chain operation reference (scor) model based analysis. **Production Planning and Control**, London, v. 25, n. 13–14, p. 1169–1181, 2014. DOI: 10.1080/09537287.2013.808835. Disponível em: https://www.tandfonline.com/doi/full/10.1080/09537287.2013.808835.

LONGO, Francesco; PADOVANO, Antonio; UMBRELLO, Steven. Value-oriented and ethical technology engineering in industry 5.0: A human-centric perspective for the design of the factory of the future. **Applied Sciences**, Basel, v. 10, n. 12, p. 1–25, 2020. DOI: 10.3390/APP10124182. Disponível em: https://www.mdpi.com/2076-3417/10/12/4182.

LUTHRA, Sunil; MANGLA, Sachin Kumar; YADAV, Gunjan. An analysis of causal relationships among challenges impeding redistributed manufacturing in emerging economies. **Journal of Cleaner Production**, Oxford, v. 225, p. 949–962, 2019. DOI: 10.1016/j.jclepro.2019.04.011. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0959652619310790.

MA, Tongmao; MÉNDEZ-MERINO, David; URÍA-REGOJO, Graciela; SÁNCHEZ-FERNÁNDEZ, Cristina; GINER-SÁNCHEZ, Lucía; GUERRERO-ASPIZUA, Sara; QUÍLEZ-LÓPEZ, Cristina; RODRÍGUEZ-PATÓN, Alfonso. BioBlocksLab: A portable DIY Bio Lab using BioBlocks language. **Methods**, Thousand Oaks, v. 210, p. 36–43, 2023. DOI: 10.1016/j.ymeth.2023.01.001. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S1046202323000075.

MADDIKUNTA, Praveen Kumar Reddy; PHAM, Quoc Viet; B, Prabadevi; DEEPA, N.; DEV, Kapal; GADEKALLU, Thippa Reddy; RUBY, Rukhsana; LIYANAGE, Madhusanka. Industry 5.0: A survey on enabling technologies and potential applications. **Journal of Industrial Information Integration**, Amsterdam, v. 26, p. 100257, 2022. DOI: 10.1016/j.jii.2021.100257. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S2452414X21000558.

MADDOCKS, Sarah; JENKINS, Rowena. **Understanding PCR**. 1st. ed. London: Elsevier, 2017. DOI: 10.1016/c2014-0-02305-2. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/C20140023052.

MADON, Julie. Free repair against the consumer society: How repair cafés socialize people to a new relationship to objects. **Journal of Consumer Culture**, Thousand Oaks, v. 22, n. 2, p. 534–550, 2022. DOI: 10.1177/1469540521990871. Disponível em: http://journals.sagepub.com/doi/10.1177/1469540521990871.

MAKERBOT INDUSTRIES. **Thingiverse - Digital Designs for Physical Objects**. 2023. Disponível em: https://www.thingiverse.com/. Acesso em: 12 out. 2023.

MAKERS CONTRA A COVID-19. **Makers Contra a Covid-19**. 2020. Disponível em: https://makerscontracovid.net.br/. Acesso em: 9 out. 2020.

MANZINI, Ezio. Design Research for Sustainable Social Innovation. *In*: **Design Research Now**. Basel: Birkhäuser Basel, 2012. p. 233–245. DOI: 10.1007/978-3-7643-8472-2_14. Disponível em: https://link.springer.com/chapter/10.1007/978-3-7643-8472-2_14.

MARAVILHAS, Sérgio; MARTINS, Joberto. Strategic knowledge management a digital environment: Tacit and explicit knowledge in Fab Labs. **Journal of Business Research**, New York, v. 94, p. 353–359, 2019. DOI: 10.1016/j.jbusres.2018.01.061. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0148296318300675.

MARSHALL, Jill A.; HARRON, Jason R. Making learners: A framework for evaluating making in STEM education. **Interdisciplinary Journal of Problem-based Learning**, West Lafayette, v. 12, n. 2, p. 1–13, 2018. DOI: 10.7771/1541-5015.1749. Disponível em: https://docs.lib.purdue.edu/ijpbl/vol12/iss2/3.

MARTIN, Lee. The promise of the maker movement for education. **Journal of Pre-College Engineering Education Research**, West Lafayette, v. 5, n. 1, p. 30–39, 2015. DOI: 10.7771/2157-9288.1099. Disponível em: https://docs.lib.purdue.edu/jpeer/vol5/iss1/4.

MCPHERRON, Shannon P.; ALEMSEGED, Zeresenay; MAREAN, Curtis W.; WYNN, Jonathan G.; REED, Denné; GERAADS, Denis; BOBE, René; BÉARAT, Hamdallah A. Evidence for stone-tool-assisted consumption of animal tissues before 3.39 million years ago at Dikika, Ethiopia. **Nature**, London, v. 466, n. 7308, p. 857–860, 2010. DOI: 10.1038/nature09248. Disponível em: https://www.nature.com/articles/nature09248.

MEISSNER, Dirk; SARPONG, David; OFOSU, George; BOTCHIE, David. The rise of do-it-yourself (DiY) laboratories: Implications for science, technology, and innovation (STI) policy. **Technological Forecasting and Social Change**, New York, v. 165, p. 120589, 2021. DOI: 10.1016/j.techfore.2021.120589. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0040162521000214.

MELO, Marijel; MARCH, Laura; HIRSH, Kimberly; ARNSBERG, Emily. Description framework of makerspaces: Examining the relationship between spatial arrangement and diverse user populations. **Journal of the Association for Information Science and Technology**, Chichester, v. 74, n. 5, p. 506–516, 2023. DOI: 10.1002/asi.24741. Disponível em: https://onlinelibrary.wiley.com/doi/10.1002/asi.24741.

MENICHINELLI, Massimo; BIANCHINI, Massimo; CAROSI, Alessandra; MAFFEI, Stefano. Makers as a New Work Condition Between Self-employment and Community Peer-production. Insights from a survey on Makers in Italy. **JOURNAL OF PEER PRODUCTION**, Edinburgh, v. 10, p. 1–16, 2017. Disponível em: http://peerproduction.net/issues/issue-10-peer-production-and-work/peer-reviewed-papers/makers-as-a-new-work-condition-between-self-employment-and-community-peer-production-insights-from-a-survey-on-makers-in-italy/. Acesso em: 1 jul. 2020.

MERSAND, Shannon. The State of Makerspace Research: a Review of the Literature. **TechTrends**, New York, v. 65, n. 2, p. 174–186, 2021. DOI: 10.1007/s11528-020-00566-5. Disponível em: http://link.springer.com/10.1007/s11528-020-00566-5.

MFG. **About us**. 2023. Disponível em: https://www.mfg.com/about-us/. Acesso em: 10 mar. 2023.

MICHEL, Janet; METTLER, Annette; SCHÖNENBERGER, Silvia; GUNZ, Daniela. Period poverty: why it should be everybody's business. **Journal of Global Health Reports**, Edinburgh, v. 6, n. 2023, p. 4, 2022. DOI: 10.29392/001c.32436. Disponível em: https://www.joghr.org/article/32436-period-poverty-why-it-should-be-everybody-s-business.

MIKKOLA, Juliana Hsuan; SKJØTT-LARSEN, Tage. Supply-chain integration: Implications for mass customization, modularization and postponement strategies. **Production Planning and Control**, London, v. 15, n. 4, p. 352–361, 2004. DOI: 10.1080/09537280420002388845. Disponível em: https://www.tandfonline.com/doi/full/10.1080/09537280420002388845.

MILLARD, Jeremy; SORIVELLE, Marie N.; DELJANIN, Sarah; UNTERFRAUNER, Elisabeth; VOIGT, Christian. Is the maker movement contributing to sustainability? **Sustainability**, Basel, v. 10, n. 7, 2018. DOI: 10.3390/su10072212. Disponível em: http://www.mdpi.com/2071-1050/10/7/2212.

MINISTÉRIO DA SAÚDE. **Coronavírus Brasil**. 2020. Disponível em: https://covid.saude.gov.br/. Acesso em: 7 jan. 2021.

MOALEM, Rikke Marie; MOSGAARD, Mette Alberg. A critical review of the role of repair cafés in a sustainable circular transition. **Sustainability**, Basel, v. 13, n. 22, p. 1–25, 2021. DOI: 10.3390/su132212351. Disponível em: https://www.mdpi.com/2071-1050/13/22/12351.

MOHOLY-NAGY, László. **Vision in Motion**. First ed. Chicago: Paul Theobald & Co, 1947. Disponível em: https://books.google.com.br/books/about/Vision_in_Motion.html?id=HWpTAAAAMAAJ

MOILANEN, Jarkko. Emerging hackerspaces - Peer-production generation. *In*: (Imed Hammouda, Björn Lundell, Tommi Mikkonen, Walt Scacchi, Org.)IFIP ADVANCES IN INFORMATION AND COMMUNICATION TECHNOLOGY 2012, Hammamet. **Anais** [...]. Hammamet: Springer, 2012. p. 94–111. DOI: 10.1007/978-3-642-33442-9_7. Disponível em: http://link.springer.com/10.1007/978-3-642-33442-9_7.

MORITA, Atsuro; TSUDA, Kazutoshi. Fab Cities as Infrastructures for Ecological Reparation: Maker Activism, Vernacular Skills and Prototypes for Self-Grounding Collective Life. *In*: PAPADOPOULOS, Dimitris; BELLACASA, Maria Puig de La; TACCHETTI, Maddalena (org.). **Ecological Reparation**. Bristol, UK: Bristol University Press, 2023. p. 90–103. DOI: 10.51952/9781529239560.ch005. Disponível em: https://doi.org/10.51952/9781529239560.ch005.

NAHAVANDI, Saeid. Industry 5.0-a human-centric solution. **Sustainability**, Basel, v. 11, n. 16, p. 4371, 2019. DOI: 10.3390/su11164371. Disponível em: https://www.mdpi.com/2071-1050/11/16/4371.

NASCIMENTO, Susana; PÓLVORA, Alexandre. Maker Cultures and the Prospects for Technological Action. **Science and Engineering Ethics**, Dordrecht, v. 24, n. 3, p. 927–946, 2018. DOI: 10.1007/s11948-016-9796-8. Disponível em: http://link.springer.com/10.1007/s11948-016-9796-8.

NAY, Leanne. In good company: Engaging in the maker movement alongside campus partners. **College and Undergraduate Libraries**, Philadelphia, v. 27, n. 2–4, p. 326–338, 2021. DOI: 10.1080/10691316.2020.1865859. Disponível em: https://www.tandfonline.com/doi/full/10.1080/10691316.2020.1865859.

NGO, Tuan D.; KASHANI, Alireza; IMBALZANO, Gabriele; NGUYEN, Kate T. Q.; HUI, David. Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. **Composites Part B: Engineering**, Oxford, v. 143, p. 172–196, 2018. DOI: 10.1016/j.compositesb.2018.02.012. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S1359836817342944.

NIEMEYER, Dodie J.; GERBER, Hannah R. Maker culture and Minecraft : implications for the future of learning. **Educational Media International**, Abingdon, v. 52, n. 3, p. 216–226, 2015. DOI: 10.1080/09523987.2015.1075103. Disponível em: http://www.tandfonline.com/doi/full/10.1080/09523987.2015.1075103.

NIF - INDIA. **Mini sanitary napkin making machine**. 2009. Disponível em: http://nif.org.in/upload/innovation/5th/10-mini-sanitary-napkin-making.pdf. Acesso em: 17 abr. 2023.

NIF - INDIA. **National Innovation Foundation-India**. 2021. Disponível em: https://innovation.nif.org.in/. Acesso em: 17 abr. 2023.

NOTÍCIA PRETA. **Mais um jovem negro é morto ao ter furadeira confundida com arma no Rio - Noticia Preta - NP**. 2019. Disponível em: https://noticiapreta.com.br/mais-um-jovem-negro-e-morto-ao-ter-furadeira-confundida-com-arma-no-rio/. Acesso em: 11 abr. 2023.

OLABI. **protegeBR: Rede de apoio aos profissionais de saúde contra COVID-19**. 2020. Disponível em: https://protegebr.org/. Acesso em: 9 out. 2020.

OLABI. **Olabi**. 2022. Disponível em: https://www.olabi.org.br/. Acesso em: 9 out. 2023.

OLIVER, Kevin M. Professional Development Considerations for Makerspace Leaders, Part One: Addressing “What?” and “Why?” **TechTrends**, New York, v. 60, n. 2, p. 160–166, 2016. DOI: 10.1007/s11528-016-0028-5. Disponível em: http://link.springer.com/10.1007/s11528-016-0028-5.

ONIONS, C. T.; FRIEDRICHSEN, G. W. S.; BURCHFIELD, R. W. **The Oxford Dictionary of English Etymology**. Oxford, England: OXFORD UNIV PRESS, 1966. Disponível em: https://global.oup.com/academic/product/the-oxford-dictionary-of-english-etymology-9780198611127.

ORDIERES-MERÉ, Joaquín; GUTIERREZ, Miguel; VILLALBA-DÍEZ, Javier. Toward the industry 5.0 paradigm: Increasing value creation through the robust integration of humans and machines. **Computers in Industry**, Amsterdam, v. 150, p. 103947, 2023. DOI: 10.1016/j.compind.2023.103947. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0166361523000970.

OSSEO-ASARE, D. K.; ABBAS, Yasmine. Occupying Africa: Prototyping a Transformal Makerspace Network. **Architectural Design**, London, v. 91, n. 5, p. 62–69, 2021. DOI: 10.1002/ad.2733. Disponível em: https://onlinelibrary.wiley.com/doi/10.1002/ad.2733.

outsource - Collings Online Dictionary. 2023. Disponível em: https://www.collinsdictionary.com/dictionary/english/outsource. Acesso em: 10 mar. 2023.

OUYANG, Liwei; YUAN, Yong; WANG, Fei Yue. A Blockchain-based Framework for Collaborative Production in Distributed and Social Manufacturing. *In*: IEEE INTERNATIONAL CONFERENCE ON SERVICE OPERATIONS AND LOGISTICS, AND INFORMATICS 2019 2019, Zhengzhou, China. **Anais** [...]. Zhengzhou, China: IEEE, 2019. p. 76–81. DOI: 10.1109/SOLI48380.2019.8955075. Disponível em: https://ieeexplore.ieee.org/document/8955075/.

ÖZDEMIR, Vural; HEKIM, Nezih. Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, “the Internet of Things” and Next-Generation Technology Policy. **OMICS A Journal of Integrative Biology**, Westchester County, v. 22, n. 1, p. 65–76, 2018. DOI: 10.1089/omi.2017.0194. Disponível em: http://www.liebertpub.com/doi/10.1089/omi.2017.0194.

PATREON. **About**. 2023. Disponível em: https://www.patreon.com/about. Acesso em: 9 mar. 2023.

PEARSON, Hannah; NOBLE, Glen; HAWKINS, Joshua. **Re-distributed manufacturing workshop report**. 2013. Disponível em: https://epsrc.ukri.org/newsevents/pubs/re-distributed-manufacturing-workshop-report/. Acesso em: 1 jul. 2020.

PEI, Eujin; RESSIN, Malte; CAMPBELL, R. I.; EYNARD, Benoit; XIAO, Jinhua. Investigating the impact of additive manufacturing data exchange standards for re-distributed manufacturing. **Progress in Additive Manufacturing**, Berlin, v. 4, n. 3, p. 331–344, 2019. DOI: 10.1007/s40964-019-00085-7. Disponível em: http://link.springer.com/10.1007/s40964-019-00085-7.

PEP. **Apresentação**. 2023. Disponível em: http://www.producao.ufrj.br/index.php/br/o-pep/apresentacao. Acesso em: 7 jul. 2023.

PEPPLER, Kylie; BENDER, Sophia. Maker Movement Spreads Innovation One Project at a Time. **Phi Delta Kappan**, Arlington, v. 95, n. 3, p. 22–27, 2013. DOI: 10.1177/003172171309500306. Disponível em: http://journals.sagepub.com/doi/10.1177/003172171309500306.

PHILLIPS, Wendy; ROEHRICH, Jens K.; KAPLETIA, Dharm; ALEXANDER, Elizabeth. Global Value Chain Reconfiguration and COVID-19: Investigating the Case for More Resilient Redistributed Models of Production. **California Management Review**, California, v. 64, n. 2, p. 71–96, 2022. DOI: 10.1177/00081256211068545. Disponível em: http://journals.sagepub.com/doi/10.1177/00081256211068545.

Polo Maker. 2021. Disponível em: https://www.polomaker.com.br/. Acesso em: 19 mar. 2021.

POPULAR MECHANICS CO. **Popular Mechanics**. 1902. Disponível em: https://archive.org/details/sim_popular-mechanics_1902-01-11_1_1/. Acesso em: 5 mar. 2023.

PRASETYO, Yanu Endar. Building Innovation from Grassroots: Learning from Grassroots Innovation Movement in India, China, and Brazil. **SSRN Electronic Journal**, Philadelphia, p. 1–15, 2017. DOI: 10.2139/ssrn.2931600. Disponível em: https://www.ssrn.com/abstract=2931600.

PRENDEVILLE, Sharon; HARTUNG, Grit; PURVIS, Erica; BRASS, Clare; HALL, Ashley. Makespaces: From redistributed manufacturing to a circular economy. *In*: **Smart Innovation, Systems and Technologies**. Berlin: Springer International Publishing, 2016. v. 52p. 577–588. DOI: 10.1007/978-3-319-32098-4_49. Disponível em: http://link.springer.com/10.1007/978-3-319-32098-4_49.

PRUSA RESEARCH, Akciová Společnost; PRUSA, 3D. **3D printed face shields for medics and professionals**. 2020. Disponível em: https://www.prusa3d.com/covid19/. Acesso em: 1 jul. 2020.

PWC; NAM. **3D printing and the new shape of industrial manufacturing**. 2014. Disponível em: https://www.pwc.se/sv/pdf-reports/3d-printing-and-the-new-shape-of-industrial-manufacturing.pdf. Acesso em: 15 abr. 2021.

RAMAKURTHI, Veerababu; MANUPATI, V. K.; MACHADO, José; VARELA, Leonilde; BABU, Suresh. An innovative approach for resource sharing and scheduling in a sustainable distributed manufacturing system. **Advanced Engineering Informatics**, Oxford, v. 52, p. 1–21, 2022. DOI: 10.1016/j.aei.2022.101620. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S1474034622000866.

RAUCH, Erwin; DALLINGER, Matthias; DALLASEGA, Patrick; MATT, Dominik T. Sustainability in manufacturing through distributed manufacturing systems (DMS). **Procedia CIRP**, Amsterdam, v. 29, p. 544–549, 2015. DOI: 10.1016/j.procir.2015.01.069. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S2212827115005089.

REZAEE VESSAL, Saeedeh; PARTOUCHE-SEBBAN, Judith; SCUOTTO, Veronica; MAALAOUI, Adnane. Overcoming stressful life events at do-it-yourself (DIY) laboratories. A new trailblazing career for disadvantaged entrepreneurs. **Technological Forecasting and Social Change**, New York, v. 164, p. 120506, 2021. DOI: 10.1016/j.techfore.2020.120506. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0040162520313329.

RHMS. **Rio Hacker Maker Space**. 2020. Disponível em: https://www.riohms.com.br/. Acesso em: 9 out. 2020.

RICHTERICH, Annika. Hackerspaces as technofeminist sites for experiential learning. **Learning, Media and Technology**, Oxford, v. 47, n. 1, p. 11–25, 2022. DOI: 10.1080/17439884.2021.2018604. Disponível em: https://www.tandfonline.com/doi/full/10.1080/17439884.2021.2018604.

RIO DESIS LAB. **Rio DESIS Lab**. 2020. Disponível em: https://desis.rio.br/. Acesso em: 9 out. 2020.

RITZER, George; JURGENSON, Nathan. Production, Consumption, Prosumption: The nature of capitalism in the age of the digital “prosumer”. **Journal of Consumer Culture**, London, v. 10, n. 1, p. 13–36, 2010. DOI: 10.1177/1469540509354673. Disponível em: http://journals.sagepub.com/doi/10.1177/1469540509354673.

ROBINSON, John; ARJUNAN, Arun; BAROUTAJI, Ahmad; MARTÍ, Miguel; TUÑÓN MOLINA, Alberto; SERRANO-AROCA, Ángel; POLLARD, Andrew. Additive manufacturing of anti-SARS-CoV-2 Copper-Tungsten-Silver alloy. **Rapid Prototyping Journal**, Leeds, v. 27, n. 10, p. 1831–1849, 2021. DOI: 10.1108/RPJ-06-2021-0131. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/RPJ-06-2021-0131/full/html.

RODGERS, Waymond; AL SHAMMAKHI, Badriya N.; JEANETH, Johansson; WINCENT, Joakim; ADAMS, Kweku. DIY Entrepreneurship: a decision-pathway framework for ethical thought structures. **Technological Forecasting and Social Change**, New York, v. 161, p. 120290, 2020. DOI: 10.1016/j.techfore.2020.120290. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0040162520311161.

ROEDL, David; BARDZELL, Shaowen; BARDZELL, Jeffrey. Sustainable Making? Balancing Optimism and Criticism in HCI Discourse. **ACM Transactions on Computer-Human Interaction**, New York, v. 22, n. 3, p. 1–27, 2015. DOI: 10.1145/2699742. Disponível em: https://dl.acm.org/doi/10.1145/2699742.

ROGERS, Helen; BRAZIOTIS, Christos; PAWAR, Kulwant S. Special issue on 3D printing: opportunities and applications for supply chain management. **International Journal of Physical Distribution and Logistics Management**, Leeds, v. 47, n. 10, p. 950–953, 2017. DOI: 10.1108/IJPDLM-08-2017-0248. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/IJPDLM-08-2017-0248/full/html.

ROMERO-TORRES, Alejandro; VIEIRA, Darli Rodrigues. IS 3D printing transforming the project management function in the aerospace industry? **Journal of Modern Project Management**, Solihull, v. 4, n. 1, p. 113–119, 2016. Disponível em: https://journalmodernpm.com/article-view/?id=221.

ROSCOE, Samuel; BLOME, Constantin. Understanding the emergence of redistributed manufacturing: an ambidexterity perspective. **Production Planning and Control**, London, v. 30, n. 7, p. 496–509, 2019. DOI: 10.1080/09537287.2018.1540051. Disponível em: https://www.tandfonline.com/doi/abs/10.1080/09537287.2018.1540051.

ROSER, Christoph. **Faster, Better, Cheaper in the History of Manufacturing**. 1st. ed. Boca Raton: CRC Press, 2016. DOI: 10.1201/9781315367941. Disponível em: https://www.taylorfrancis.com/books/9781498756310.

SANTOS, Gilberto; MURMURA, Federica; BRAVI, Laura. Fabrication laboratories. **Journal of Manufacturing Technology Management**, Leeds, v. 29, n. 8, p. 1332–1357, 2018. DOI: 10.1108/JMTM-03-2018-0072. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/JMTM-03-2018-0072/full/html.

SAORÍN, José Luís; MELIAN-DÍAZ, Dámari; BONNET, Alejandro; CARBONELL CARRERA, Carlos; MEIER, Cecile; DE LA TORRE-CANTERO, Jorge. Makerspace teaching-learning environment to enhance creative competence in engineering students. **Thinking Skills and Creativity**, Amsterdam, v. 23, p. 188–198, 2017. DOI: 10.1016/j.tsc.2017.01.004. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S1871187116300487.

SARPONG, David; OFOSU, George; BOTCHIE, David; CLEAR, Fintan. Do-it-yourself (DiY) science: The proliferation, relevance and concerns. **Technological Forecasting and Social Change**, New York, v. 158, p. 120127, 2020. DOI: 10.1016/j.techfore.2020.120127. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0040162520309537.

SASSANELLI, C.; TAISCH, M.; TERZI, S. History and Future of Manufacturing. *In*: RATCHEV, Svetan; SUNDARRAJ, R. P.; PAWAR, Kulwant; AMIT, R. K. (org.). **Advances in Digital Manufacturing Systems**. Singapore: Springer Nature Singapore, 2023. p. 13–36. DOI: 10.1007/978-981-19-7071-9_2. Disponível em: https://link.springer.com/10.1007/978-981-19-7071-9_2.

SCHMIDT, Suntje; BRINKS, Verena. Open creative labs: Spatial settings at the intersection of communities and organizations. **Creativity and Innovation Management**, Chichester, v. 26, n. 3, p. 291–299, 2017. DOI: 10.1111/caim.12220. Disponível em: https://onlinelibrary.wiley.com/doi/10.1111/caim.12220.

SHARMA, Gautam; KUMAR, Hemant. Commercialising innovations from the informal economy. **South Asian Journal of Business Studies**, Leeds, v. 8, n. 1, p. 40–61, 2019. DOI: 10.1108/SAJBS-12-2017-0142. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/SAJBS-12-2017-0142/full/html.

SHARMA, Ramesh; CHANDRA NATH, Pinku; KUMAR HAZARIKA, Tridip; OJHA, Amiya; KUMAR NAYAK, Prakash; SRIDHAR, Kandi. Recent advances in 3D printing properties of natural food gels: Application of innovative food additives. **Food Chemistry**, New York, v. 432, p. 137196, 2024. DOI: 10.1016/j.foodchem.2023.137196. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0308814623018149.

SHERIDAN, Kimberly; HALVERSON, Erica Rosenfeld; LITTS, Breanne; BRAHMS, Lisa; JACOBS-PRIEBE, Lynette; OWENS, Trevor. Learning in the Making: A Comparative Case Study of Three Makerspaces. **Harvard Educational Review**, Boston, v. 84, n. 4, p. 505–531, 2014. DOI: 10.17763/haer.84.4.brr34733723j648u. Disponível em: https://meridian.allenpress.com/her/article/84/4/505/32162/Learning-in-the-Making-A-Comparative-Case-Study-of.

SHERIDAN, Kimberly M.; KONOPASKY, Abigail. Designing for Resourcefulness in a Community-Based Makerspace. *In*: PEPPLER, Kylie; HALVERSON, Erica Rosenfeld; KAFAI, Yasmin B. (org.). **Makeology**. 1st. ed. New York : Routledge, 2016.: Routledge, 2016. p. 77–94. DOI: 10.4324/9781315726519. Disponível em: https://www.taylorfrancis.com/books/9781317537151.

SINCLAIR, Matt; SHELDRICK, Leila; MORENO, Mariale; DEWBERRY, Emma. Consumer Intervention Mapping—A Tool for Designing Future Product Strategies within Circular Product Service Systems. **Sustainability**, Basel, v. 10, n. 6, p. 2088, 2018. DOI: 10.3390/su10062088. Disponível em: http://www.mdpi.com/2071-1050/10/6/2088.

SMITH, Adrian; STIRLING, Andrew. Innovation, Sustainability And Democracy: An Analysis of Grassroots Contributions. **Journal of Self-Governance and Management Economics**, Woodside, v. 6, n. 1, p. 64, 2018. DOI: 10.22381/JSME6120183. Disponível em: https://addletonacademicpublishers.com/contents-jgme/1097-volume-6-1-2018/3111-innovation-sustainability-and-democracy-an-analysis-of-grassroots-contributions.

SMITH, Paul. Digital Maker Networks. Benefits, barriers and opportunities for re-localised UK manufacturing for the future. **Design Journal**, Oxford, v. 20, n. sup1, p. S2657–S2666, 2017. DOI: 10.1080/14606925.2017.1352777. Disponível em: https://www.tandfonline.com/doi/full/10.1080/14606925.2017.1352777.

SO, Anita; REEVES, Jacob M.; PEARCE, Joshua M. Open-Source Designs for Distributed Manufacturing of Low-Cost Customized Walkers. **Inventions**, Basel, v. 8, n. 3, p. 1–25, 2023. DOI: 10.3390/inventions8030079. Disponível em: https://www.mdpi.com/2411-5134/8/3/79.

SOOMRO, Sohail Ahmed; CASAKIN, Hernan; NANJAPPAN, Vijayakumar; GEORGIEV, Georgi V. Makerspaces Fostering Creativity: A Systematic Literature Review. **Journal of Science Education and Technology**, Dordrecht, v. 32, p. 530–548, 2023. DOI: 10.1007/s10956-023-10041-4. Disponível em: https://link.springer.com/10.1007/s10956-023-10041-4.

SOS 3D COVID19. **SOS 3D COVID19**. 2020. Disponível em: https://www.sos3dcovid19.com.br/. Acesso em: 9 out. 2020.

SPEKKINK, Wouter; RÖDL, Malte; CHARTER, Martin. Repair Cafés and Precious Plastic as translocal networks for the circular economy. **Journal of Cleaner Production**, Oxford, v. 380, p. 1–17, 2022. DOI: 10.1016/j.jclepro.2022.135125. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0959652622046996.

SRAI, Jagjit Singh et al. Distributed manufacturing: scope, challenges and opportunities. **International Journal of Production Research**, Oxford, v. 54, n. 23, p. 6917–6935, 2016. DOI: 10.1080/00207543.2016.1192302. Disponível em: https://www.tandfonline.com/doi/full/10.1080/00207543.2016.1192302.

SRAI, Jagjit Singh; HARRINGTON, Tomás Seosamh; TIWARI, Manoj Kumar. Characteristics of redistributed manufacturing systems: a comparative study of emerging industry supply networks. **International Journal of Production Research**, Oxford, v. 54, n. 23, p. 6936–6955, 2016. DOI: 10.1080/00207543.2016.1214765. Disponível em: https://www.tandfonline.com/doi/full/10.1080/00207543.2016.1214765.

STEVENSON, Angus (ORG.). **Oxford Dictionary of English**. 3rd. ed. Oxford: Oxford University Press, 2010. DOI: 10.1093/acref/9780199571123.001.0001. Disponível em: http://www.oxfordreference.com/view/10.1093/acref/9780199571123.001.0001/acref-9780199571123.

TABARÉS GUTIÉRREZ, Raúl. The significance of technological culture in the maker movement. **Arbor**, Toronto, v. 194, n. 789, p. 471, 2018. DOI: 10.3989/arbor.2018.789n3013. Disponível em: http://arbor.revistas.csic.es/index.php/arbor/article/view/2284.

TANENBAUM, Joshua G.; WILLIAMS, Amanda M.; DESJARDINS, Audrey; TANENBAUM, Karen. Democratizing technology: Pleasure, utility and expressiveness in DIY and Maker practice. *In*: CONFERENCE ON HUMAN FACTORS IN COMPUTING SYSTEMS - PROCEEDINGS 2013, New York. **Anais** [...]. New York: ACM, 2013. p. 2603–2612. DOI: 10.1145/2470654.2481360. Disponível em: https://dl.acm.org/doi/10.1145/2470654.2481360.

TATHAM, Peter; LOY, Jennifer; PERETTI, Umberto. Three dimensional printing – a key tool for the humanitarian logistician? **Journal of Humanitarian Logistics and Supply Chain Management**, Leeds, v. 5, n. 2, p. 188–208, 2015. DOI: 10.1108/JHLSCM-01-2014-0006. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/JHLSCM-01-2014-0006/full/html.

TED CONFERENCES. **Arunachalam Muruganantham: How I started a sanitary napkin revolution! | TED Talk**. 2012. Disponível em: https://www.ted.com/talks/arunachalam_muruganantham_how_i_started_a_sanitary_napkin_revolution. Acesso em: 17 abr. 2023.

TED CONFERENCES. **Our mission: Spread ideas, foster community and create impact**. 2022. Disponível em: https://www.ted.com/about/our-organization. Acesso em: 17 abr. 2023.

TELENKO, Cassandra; JARIWALA, Amit Shashikant; SALDANA, Christopher; SULCHEK, Todd; YEE, Shannon K.; NEWSTETTER, Wendy C.; KURFESS, Thomas. Examples of synergies between research and hands-on design-based learning. *In*: ASEE ANNUAL CONFERENCE AND EXPOSITION, CONFERENCE PROCEEDINGS 2016, New Orleans. **Anais** [...]. New Orleans: ASEE Conferences, 2016. p. 1–19. DOI: 10.18260/p.26798. Disponível em: http://peer.asee.org/26798.

THE CENTRE FOR COMPUTING HISTORY. **First Network Email sent by Ray Tomlinson - Event - Computing History**. 2023a. Disponível em: https://www.computinghistory.org.uk/det/6116/First-e-mail-sent-by-Ray-Tomlinson/. Acesso em: 8 jul. 2023.

THE CENTRE FOR COMPUTING HISTORY. **Tim Berners-Lee publishes the first ever website - Event - Computing History**. 2023b. Disponível em: https://www.computinghistory.org.uk/det/65289/Tim-Berners-Lee-publishes-the-first-ever-website/. Acesso em: 8 jul. 2023.

THE FAB FOUNDATION. **About the Fab Foundation**. 2023a. Disponível em: https://fabfoundation.org/about/. Acesso em: 8 maio. 2023.

THE FAB FOUNDATION. **Getting Started with Fab Labs**. 2023b. Disponível em: https://fabfoundation.org/getting-started/. Acesso em: 8 maio. 2023.

THE WORLD BANK GROUP. **WDI - Economy**. 2023. Disponível em: https://datatopics.worldbank.org/world-development-indicators//themes/economy.html. Acesso em: 8 abr. 2023.

THOMAS, Douglas. Costs, benefits, and adoption of additive manufacturing: a supply chain perspective. **International Journal of Advanced Manufacturing Technology**, London, v. 85, n. 5–8, p. 1857–1876, 2016. DOI: 10.1007/s00170-015-7973-6. Disponível em: http://link.springer.com/10.1007/s00170-015-7973-6.

THOMÉ, Antônio Márcio Tavares; SCAVARDA, Luiz Felipe; SCAVARDA, Annibal José. Conducting systematic literature review in operations management. **Production Planning and Control**, London, v. 27, n. 5, p. 408–420, 2016. DOI: 10.1080/09537287.2015.1129464. Disponível em: https://www.tandfonline.com/doi/full/10.1080/09537287.2015.1129464.

TIME USA. **The 100 Most Influential People 2014**. 2014. Disponível em: https://time.com/collection/2014-time-100/. Acesso em: 17 abr. 2023.

TINOCO, Dandara. **O cineasta que virou inventor pela necessidade social**. 2017. Disponível em: https://projetocolabora.com.br/ods8/o-inventor-nascido-da-necessidade/. Acesso em: 15 abr. 2023.

TÓTH, Attila; NAGY, László; KENNEDY, Roderick; BOHUŠ, Belej; ABONYI, János; RUPPERT, Tamás. The human-centric Industry 5.0 collaboration architecture. **MethodsX**, Amsterdam, v. 11, p. 102260–102267, 2023. DOI: 10.1016/j.mex.2023.102260. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S2215016123002571.

TRANFIELD, David; DENYER, David; SMART, Palminder. Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. **British Journal of Management**, Oxford, v. 14, n. 3, p. 207–222, 2003. DOI: 10.1111/1467-8551.00375. Disponível em: https://onlinelibrary.wiley.com/doi/10.1111/1467-8551.00375.

TREM MAKER. **Trem Maker contra o Covid-19**. 2020. Disponível em: https://tremmaker.com.br/. Acesso em: 9 out. 2020.

TURNER, Chris; MORENO, Mariale; MONDINI, Luigi; SALONITIS, Konstantinos; CHARNLEY, Fiona; TIWARI, Ashutosh; HUTABARAT, Windo. Sustainable Production in a Circular Economy: A Business Model for Re-Distributed Manufacturing. **Sustainability**, Basel, v. 11, n. 16, p. 4291, 2019. DOI: 10.3390/su11164291. Disponível em: https://www.mdpi.com/2071-1050/11/16/4291.

UNTERFRAUNER, Elisabeth; HOFER, Margit; PELKA, Bastian; ZIRNGIEBL, Marthe. A new player for tackling inequalities? Framing the social value and impact of the maker movement. **Social Inclusion**, Lisbon, v. 8, n. 2, p. 190–200, 2020. DOI: 10.17645/si.v8i2.2590. Disponível em: https://www.cogitatiopress.com/socialinclusion/article/view/2590.

VAKINHA. **O Maior Site de Vaquinhas do Brasil**. 2020. Disponível em: https://www.vakinha.com.br/. Acesso em: 8 jan. 2021.

VALLEJO, William; DIAZ-URIBE, Carlos; FAJARDO, Catalina. Do-it-yourself methodology for calorimeter construction based in Arduino data acquisition device for introductory chemical laboratories. **Heliyon**, Amsterdam, v. 6, n. 3, p. e03591, 2020. DOI: 10.1016/j.heliyon.2020.e03591. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S2405844020304369.

VAN DER VELDEN, Maja. 'Fixing the World One Thing at a Time': Community repair and a sustainable circular economy. **Journal of Cleaner Production**, Oxford, v. 304, p. 11, 2021. DOI: 10.1016/j.jclepro.2021.127151. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0959652621013706.

VAN HOLM, Eric Joseph. Makerspaces and Local Economic Development. **Economic Development Quarterly**, Thousand Oaks, v. 31, n. 2, p. 164–173, 2017. DOI: 10.1177/0891242417690604. Disponível em: http://journals.sagepub.com/doi/10.1177/0891242417690604.

VAN OVERVELD, Thijs; SOL, Daniel; BLANCO, Guillermo; MARGALIDA, Antoni; DE LA RIVA, Manuel; DONÁZAR, José Antonio. Vultures as an overlooked model in cognitive ecology. **Animal Cognition**, Berlin, v. 25, n. 3, p. 495–507, 2022. DOI: 10.1007/s10071-021-01585-2. Disponível em: https://link.springer.com/10.1007/s10071-021-01585-2.

VINCENT, Olga. An economy in the making: Negotiating capitalist and beyond-capitalist ontologies and relations in makerspaces. **Environment and Planning A**, Thousand Oaks, v. 55, n. 1, p. 3–21, 2023. DOI: 10.1177/0308518X221124140. Disponível em: http://journals.sagepub.com/doi/10.1177/0308518X221124140.

VIVA LAB. **Protective Goggles**. 2020. Disponível em: https://viralresponse.io/. Acesso em: 1 jul. 2020.

VON BUSCH, Otto. Molecular management: Protocols in the maker culture. **Creative Industries Journal**, Oxford, v. 5, n. 1–2, p. 55–68, 2012. DOI: 10.1386/cij.5.1-2.55_1. Disponível em: https://www.tandfonline.com/doi/full/10.1386/cij.5.1-2.55_1.

WAGNER, Stephan M.; WALTON, Robert O. Additive manufacturing's impact and future in the aviation industry. **Production Planning and Control**, London, v. 27, n. 13, p. 1124–1130, 2016. DOI: 10.1080/09537287.2016.1199824. Disponível em: https://www.tandfonline.com/doi/full/10.1080/09537287.2016.1199824.

WEF. **Global Information Technology Report 2015: ICTs for Inclusive Growth**. Geneva. v. 25 Disponível em: http://www3.weforum.org/docs/WEF_GITR2015.pdf.

WILCZYNSKI, Vincent. Academic Maker Spaces and Engineering Design. *In*: 2015 ASEE ANNUAL CONFERENCE AND EXPOSITION PROCEEDINGS 2015, Seatle. **Anais** [...]. Seatle: ASEE Conferences, 2015. p. 26.138.1-26.138.19. DOI: 10.18260/p.23477. Disponível em: http://peer.asee.org/23477.

WILLIAMS, Colin C. A lifestyle choice? Evaluating the motives of do-it-yourself (DIY) consumers. **International Journal of Retail & Distribution Management**, Leeds, v. 32, n. 5, p. 270–278, 2004. DOI: 10.1108/09590550410534613. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/09590550410534613/full/html.

WITTBRODT, B. T.; GLOVER, A. G.; LAURETO, J.; ANZALONE, G. C.; OPPLIGER, D.; IRWIN, J. L.; PEARCE, J. M. Life-cycle economic analysis of distributed manufacturing with open-source 3-D printers. **Mechatronics**, Oxford, v. 23, n. 6, p. 713–726, 2013. DOI: 10.1016/j.mechatronics.2013.06.002. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0957415813001153.

WOLF-POWERS, Laura; DOUSSARD, Marc; SCHROCK, Greg; HEYING, Charles; EISENBURGER, Max; MAROTTA, Stephen. The Maker Movement and Urban Economic Development. **Journal of the American Planning Association**, Philadelphia, v. 83, n. 4, p. 365–376, 2017. DOI: 10.1080/01944363.2017.1360787. Disponível em: https://www.tandfonline.com/doi/full/10.1080/01944363.2017.1360787.

WOLF, Patricia; TROXLER, Peter. Community-based business models Insights from an emerging maker economy. **Interaction Design and Architecture(s)**, Rome, v. 30, n. 1, p. 75–94, 2016. Disponível em: http://www.mifav.uniroma2.it/inevent/events/idea2010/doc/30_5.pdf. Acesso em: 1 jul. 2020.

WOLF, Patricia; TROXLER, Peter; KOCHER, Pierre-yves; HARBOE, Julie; GAUDENZ, Urs. Sharing is Sparing: Open Knowledge Sharing in Fab Labs. **Journal of Peer Production**, Edinburgh, n. 5, p. 1–11, 2014. Disponível em: http://peerproduction.net/issues/issue-5-shared-machine-shops/peer-reviewed-articles/sharing-is-sparing-open-knowledge-sharing-in-fab-labs/. Acesso em: 1 jul. 2020.

World Bank Open Data. 2023. Disponível em: https://data.worldbank.org/. Acesso em: 8 abr. 2023.

WULANDHARI, Nur Baiti Ingga; MISHRA, Nishikant; DORA, Manoj; SAMUEL, Fosso Wamba. Understanding rural Do-It-Yourself science through social learning in communities of practice. **Technological Forecasting and Social Change**, New York, v. 163, p. 1–11, 2021. DOI: 10.1016/j.techfore.2020.120411. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0040162520312373.

XU, Xun; LU, Yuqian; VOGEL-HEUSER, Birgit; WANG, Lihui. Industry 4.0 and Industry 5.0—Inception, conception and perception. **Journal of Manufacturing Systems**, Amsterdam, v. 61, p. 530–535, 2021. DOI: 10.1016/j.jmsy.2021.10.006. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0278612521002119.

YANG, Maolin; JIANG, Pingyu. Open Product Design for Social Manufacturing. *In*: **Social manufacturing: Fundamentals and applications**. Cham: Springer, 2019. p. 93–116. DOI: 10.1007/978-3-319-72986-2_5. Disponível em: http://link.springer.com/10.1007/978-3-319-72986-2_5.

YANG, Tzuyi L.; SZEWC, Jakub; ZHONG, Lingu; LEONOVA, Anna; GIEBUŁTOWICZ, Joanna; HABASHY, Rober; ISREB, Abdullah; ALHNAN, Mohamed A. The use of near-infrared as process analytical technology (PAT) during 3D printing tablets at the point-of-care. **International Journal of Pharmaceutics**, Amsterdam, v. 642, p. 1–9, 2023. DOI: 10.1016/j.ijpharm.2023.123073. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0378517323004933.

YIN, Robert K. **Case study research and applications: Design and methods**. Sixth ed. Los Angeles: Sage Publications Ltd., 2018. Disponível em: https://us.sagepub.com/en-us/nam/case-study-research-and-applications/book250150.

ZAPATA CAMPOS, María José; CARENZO, Sebastián; CHARLES, Goodluck; GUTBERLET, Jutta; KAIN, Jaan-Henrik; OLOKO, Michael O.; REYNOSA, Jessica Pérez; ZAPATA, Patrik. Grassroots innovations in 'extreme' urban environments. The inclusive recycling movement. **Environment and Planning C: Politics and Space**, Thousand Oaks, v. 41, n. 2, p. 351–374, 2023. DOI: 10.1177/23996544221118191. Disponível em: http://journals.sagepub.com/doi/10.1177/23996544221118191.

ZHANG, Liyan; MAHADEVIA, Darshini. Translating science and technology policies and programs into grassroots innovations in China. **Journal of Science and Technology Policy Management**, Leeds, v. 5, n. 1, p. 4–23, 2014. DOI: 10.1108/JSTPM-03-2014-0007. Disponível em: https://www.emerald.com/insight/content/doi/10.1108/JSTPM-03-2014-0007/full/html.

ZHANG, Xiaohui; HAN, Yuyan; KRÓLCZYK, Grzegorz; RYDEL, Marek; STANISLAWSKI, Rafal; LI, Zhixiong. Rescheduling of Distributed Manufacturing System with Machine Breakdowns. **Electronics**, Basel, v. 11, n. 2, p. 249–274, 2022. DOI: 10.3390/electronics11020249. Disponível em: https://www.mdpi.com/2079-9292/11/2/249.

ZHANG, Yali; TAN, Chrissie Diane; SUN, Jun; YANG, Zhaojun. Why do people patronize donation-based crowdfunding platforms? An activity perspective of critical success factors. **Computers in Human Behavior**, Amsterdam, v. 112, p. 106470, 2020. DOI: 10.1016/j.chb.2020.106470. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0747563220302223.