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Fab labs and digital manufacturing in Cameroon - Minimising work accidents through JSA and AS/NZS 4360:2004 standard

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Abstract

The democratization of industrial processes, fueled by the proliferation of fabrication laboratories (Fab Labs), is gradually paving the way for the accelerated development of the use of advanced manufacturing technologies in African countries. However, a comprehensive study that provides a holistic view of the contributions of the Fab Labs in Cameroon is lacking. Therefore, this paper presents a critical analysis of the state of Fab Labsdevelopment in Cameroon.A case study was used to analyze the occupational health and safety (OHS) risks at the laser cutting and milling operator workstations at XYZ Fabby using the Job Safety Analysis (JSA) to identify hazards and the AS/NZS 4360:2004 standardto calculate the risk score.The results showed that the Fab Lab ecosystem in Cameroon consists of 10 active labs, with universities hosting 40% and private companies and social enterprises hosting 60%. Through their various activities, these Fab Labs collectively empower user communities and bridge the digital divide, enabling economic and industrial development through innovative projects and better access to cross-cutting science, technology and engineering practices. The results of the risk analysis showed that the risk level of each hazardous activity of the laser cutter operator workstation consisted of two levels, i.e., substantial with 75.0% and acceptable with 25.0%. Meanwhile, the risk level of the milling machine operator workstation consisted of three risk levels, i.e., acceptable with 69.2%, priority 3 with 7.7% and substantial with 23.1%. Recommendations were made to reduce or eliminate the effects of hazards associated with machine use, such as proper training and adherence to clear safety policies and procedures to be implemented.University-industry partnerships were recommended to strengthen and expand the number of Fab Labs in Cameroon, promote rapid prototyping, and foster innovation and entrepreneurship from universities.

Keywords: Digestive upsets, Escherichia coli, pseudo-ruminants, ruminants, total coliform, and water quality

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1. Introduction

A Fab Lab is a small-scale workshop equipped with flexible computer controlled tools and systems for the production of digital fabrications of widely distributed products, which are used to encourage creativity and innovation among individuals irrespective of their anthropological status (Osunyomi *et al*, 2016). In the last decade, the processes of design, production and manufacturing have changed with the intrusion of new technologies and strengthening concepts such as digital manufacturing, Fab Labs, open innovation and Industry 4.0 (García-Ruiz and Lena-Acebo, 2022). This transformation has brought about a new industrial revolution, with the possibility for African countries, where the manufacturing sector is underperforming, largely due to inadequate use of advanced manufacturing concepts and technologies, as well as the insufficiently skilled workforce (Fofana *et* *al*, 2023), to achieve greater ease of access to information, knowledge and training in new skills and the necessary modern manufacturing technologies.

The democratization of industrial processes, fueled by the proliferation of Fab Labs in African countries, is gradually paving the way for the growth and accelerated development of the use of advanced manufacturing technologies previously reserved for highly industrial environments. In some African countries, Fab Labs have a very effective ecosystemfor supporting entrepreneurswho focus their efforts on creating positive societal impact through businesses thataddress pressing social, economic, environmental, or cultural issues(Kruger andSteyn, 2024) (Fahfouhi et al, 2022)(Schonwetter*et al,* 2020). In terms of technical skills, Fab Labs and makerspaces enable the development of skills beyond what is generally considered to be 21st century digital skills, because they combine digital skills with hands-on 'making' skills, as they are themselves mixed environments, both digital and physical (Rayna and Striukova, 2021).

In Fab Labs environments, users can acquire complex knowledge about digital technologies and modern manufacturing through social learning and the development of technologically advanced projects (García-Ruiz and Lena-Acebo, 2022)(Soomro*et al*, 2022). Kim (2020), views makerspaces as built environments used for interdisciplinary applications and research that help users coordinate across disciplines to develop complex engineering designs. It is guided by some standard features, including open technological knowledge and access to advanced technology and its strong international network structure. It provides affordable and accessible access to digital manufacturing tools. They emerged in the 2000s at the Massachusetts Institute of Technology (MIT) from Gershenfeld's subject "How to Make (Almost) Anything" (Gershenfeld, 2012). For the African continent, the maker movement represents a real development opportunity with multiple impacts on the economy, education, youth and women inclusion, training, and entrepreneurship (Schonwetter *et al,* 2020; Oladele-Emmanuel *et al*, 2018; Osunyomi *et al*, 2016).

Although these collaborative learning spaces provide greater access to cross-cutting science, technology, engineering, art, and mathematics (STEAM) practices and catalyze local sustainable development in Africa (Nkoudou, 2022), they pose inherent safety risks that are often overlooked (Love *et al*., 2022). As the number of Fab Labs has grown, health and safety hazards and workplace accidents have increased dramatically. Considering the workers as the most valuable resource of Fab Labs, Fab Manager and other stakeholders should pay special attention to OHS issues. Occupational health and safety efforts are generally aimed at protecting the workers from accidents and protecting the machine from damage (Ghasemi *et al*, 2023)(Palega, 2021), both during operation and during repair and maintenance activities. The application of an OHS management system can serve as an important tool for Fab Lab managers to ensure a healthy workplace for all makers, addressing not only OHS management but also quality management, environmental management, and social responsibility issues.

To date, there have been few studies on the impact of Fab Labs on developing innovation capabilities in training ecosystems in Cameroon (Nkoudou, 2022; Krewer et al, 2023). Research that provides a holistic view of the development of the Fab Labs in Cameroon is still lacking. In this study, we conducted a critical analysis of the state of development of Fab Labs in Cameroon andtheir impact on the diffusion of digital manufacturing processes and technologies. A case study of the Yaounde XYZ Fab Lab was used to identify, assess, and control risks; prevent and reduce workplace accidents in Fab Labs using the JSA- a systematic procedure that breaks down each job/task into key sequences, identifies safety elements of each job/task step, and trains the worker on how to avoid potential safety hazards; and the AS/NZS 4360:2004 standard to calculate the risk score. The study also briefly examined the development of Fab Labs on the African continent and their potential to bridge the digital divide and enable anyone to make almost anything. The results of the JSA can be used as a benchmark for OHS studies in Fab Labs on the African continent.

2. Relation to existing studies

2.1 Fablabs development in African continent

The Fab Lab approach, based on the ideas of collaboration, decentralization, participation, and democratization, has been recognized by the World Bank (Gadjanski *et al*, 2015) as a highly efficient way to: a) support STEM education, b) commercialize research in higher education institutions, c) develop smart cities and waste management, and d) develop local industries and entrepreneurship (WorldBank, 2014). Fab Lab technologies enable localized, decentralized production of myriad customized products without the need for expensive equipment and production lines; basic 3D printing can enable rapid and increasingly cost-effective local production of much-needed goods, empowering local actors and reducing dependence on imports and industrial-scale supply chains (Schonwetter*et al,* 2020).

Fab Labs represent a real opportunity for economic development and help to prevent social exclusion and unemployment, which are particularly relevant in developing countries, by promoting creativity and technological entrepreneurship based on knowledge of digital manufacturing skills, even for non-expert users, addressing concepts of the collaborative economy. This situation has been taken advantage of by various governments in different parts of the world, where programs aimed at improving innovation and entrepreneurship for local development are being implemented through actions that include the participation of Fab Labs as facilitators, constituting a new paradigm of technological inclusion through collaborative development (Vieria *et al*, 2017).

Since the introduction of the first Fab Lab on the African continent and the sixth Fab Lab in the world in 2004 at the Takoradi Technical Institution in Ghana by Neil Gershenfeld, the founder of the global Fab Lab movement, the total number of Fab Labs in Africa has grown significantly. It is difficult to determine the exact number of Fab Labs in Africa because there are many web platforms that list collaborative workshops around the world, such as the Fab Foundation's list; the list from the Fab LabWiki (wiki.fablab, 2024); the Makery journal's map of labs (makery.info, 2024), etc.In addition, many Fab Labs operate independently without joining networks of collaborative workshops around the world.Table 1 shows the number of registered Fab Labs in African countries as listed on the Fab Foundation website, an organization dependent on the Center for Bits and Atoms Fab Lab program at MIT that is responsible for supporting the expansion of Fab Labs on a global scale, which has the largest number of registered Fab Labs.

Table 1: Fab Labs distribution in Africa by country (https://www.fablabs.io, 2024)

Country	Labs	Country	Labs	Country	Labs	Country	Labs	Country	Labs
Egypt	30	Benin	4	Ethiopia	1	Cape Verde	0	Mauritius	0
Morocco	17	Burkina Faso	4	Djibouti	1	Central African Republic	0	Mozambique	0
DR Congo	9	Libya	4	Madagascar	1	Comoros	0	Niger	0
South Africa	8	Rwanda	3	Mauritania	1	Equatorial Guinea	0	Republic of the Congo	0
Nigeria	7	Mali	3	Namibia	1	Gabon	0	Sierra Leone	0
Ivory Coast	6	Algeria	2	Somalia	1	Gambia	0	South Sudan	0
Kenya	6	Ghana	2	Tanzania	1	Guinea-Bissau	0	Sudan	0
Senegal	6	Guinea	2	Angola	0	Liberia	0	Uganda	0
Tunisia	6	Togo	2	Botswana	0	Lesotho	0	Zambia	0
Cameroon	5	Chad	1	Burundi	0	Malawi	0	Zimbabwe	0

Fablabs.io is a collection of online resources for the international Fab Lab community and is the current official list of Fab Labs that share the same principles, tools, and philosophy about the future of technology and its role in society. Today, with over 2000 digital Fab Labs in over 120 countries registered on Fab Labs.io, the current134 registered Fab Labs in 54 African countries represent less than 7% of the total number of registered labs. To officially qualify as an MIT-affiliated Fab Lab, the Fab Lab must meet the following four qualities and requirements and may use of the Fab Lab logo in its activities (fabfoundation, 2024):

1. *Public Access*: The Fab Lab must consider itsef a community resource by providing public access to the Fab Lab. A Fab Lab is about democratizing access to the tools for personal expression and invention, so it must be open to the public for free or for a fee at least part of the time each week.

2. *Fab Labs support and subscribe to the Fab Charter*. The following seven principles are included in the Fab Lab Charter. a) Fab Labs are a global network of local labs that enable invention by providing access to tools for digital fabrication. b) Fab Labs share an evolving inventory of core capabilities to make (almost) anything, allowing people and projects to be shared. c) The Fab Lab network provides operational, educational, technical, financial and logistical support beyond what is available within a single lab. d) Fab Labs are available as a community resource, offering open access for individuals as well as scheduled access for programs. e) The Fab Lab's responsibilities include the following: Safety-Not hurting people or machines. Operations-help clean, maintain, and improve the lab. Knowledge-Contributing to documentation and instruction. f) Designs and processes developed in Fab Labs can be protected and sold however an inventor chooses, but should remain available for individuals to use and learn from. g) Commercial activities may be prototyped and incubated in Fab Labs, but they must not conflict with other uses, they should grow beyond the lab rather than within it, and they are expected to benefit the inventors, labs, and networks that contribute to their success.

3. *A Fab Lab must share a common set of tools and processes so that the all the labs can share knowledge, designs, and collaborate across international borders.* Fab Labs typically include: a laser cutter that makes 2D and 3D structures; a 3D printer; a high resolution CNC milling machine, electronic components and programming tools for low cost, high speed microcontrollers; and on-site rapid circuit prototyping, etc.

4. *Fab Labs must participate in the larger, global Fab Lab network and knowledge sharing community*. Collaborating and partnering with other labs in the network on workshops, challenges, or projects is another way.

As Fab Labs around the world went through a period of rapid growth in 2012, a number of initiatives appeared in corporate environment. For example, in 2016, the Orange Foundation lunched "The Solidarity Program Fab Lab," a digital education program that actively supports the future of young people by providing them the opportunity to express their talents with new technologies and training them in digital tools to develop their skills. Orange Digital Centers bring together several strategic programs in one place, includingan Orange Fab, a start-up accelerator that forges national and international business partnerships.A Code School, which acts as a center for vocational training and events. A digital manufacturing workshop that allows people to prototype and learn by doing. To date, the project has funded the creation of Fab Labs in Botwana, Burkina Faso, Cameroon, Cote d'Ivoire, Democratic Republic of Congo, Egypt, Guinea Bissau, Guinea Konakry, Liberia, Madagascar, Mali, Morocco, Senegal, Sierra Leone and Tunisia (Orange Foundation, 2024).

Fab Lab initiatives in Africa have been widely used to provide localized solutions to existing problems in communities. Birtchnell and Hoyle (2014) showed that 3D printing offers a wide range of applications that address the social needs of users and communities in the developing countries. Extrusion printers have been used tocustomizethe production of prosthetic fingers, prosthetic hands, and prosthetic legs (Thinglab, 2024), lower limb prostheses (Alonso-García et al, 2023) weather stations (Walker, 2016), and medical equipment (Clarke, 2017). 3D-printed headlamps made from locally available components to solve the problem of inadequate lighting for local fishermen working in the morning or evening darkness, and for customized shoes for people with deformed feet (Schonwetter, *et al* 2020). Fab Lab initiatives have led to the creation of a small wind turbine in Burkina Faso, the creation of solar panels and other renewable energy in Nigeria and Kenya, the creation of food processing machines in Ghana, and the manufacture and distribution of Arduino and other 3D printing components in Morocco (Oladele-Emmanuel *et al,* 2018).

The international 3D Printing for Development (3D4D) Challenge, in which participants from the Global South seek to produce the most scalable grassroots community action project using 3D printing, provides further examples of the use of digital manufacturing technologies to produce objects that can empower people in the developing world (3d4dchallenge, 2024). If properly harnessed, Fab Labs initiatives and other digital fabrication initiatives have a significant impact on economic and technological advancement and can be a viable way for Africa to strengthen its acquisition and use of knowledge and digital manufacturing technologies.

2.2 Risk level in Fab Labs

Fab Labsare high-risk environments because people with different levels of experience and training operate the equipment. The Fab Lab manager as per the Fab Charter, among other responsibilities should ensure no harm to people or machines (fabfoundation.org, 2024). The academic literature describes various quantitative and qualitative methods for conducting out OHS assessments in the workplace. The most commonly used risk analysis tools are Fault Tree Analysis (FTA), Failure Mode and Effect Analysis (FMEA), Hazard Operability Study (HAZOP), Hazard Identification and Risk Assessment (HIRA) and JSA. Compared to JSA and FMEA, FTA, and HAZOP methods do not take into account the task to be performed, and therefore JSA is a better choice to perform risk assessment (Gopinath and Johansen, 2016).

Job safety analysis is a popular hazard identification and risk assessment technique that focuses specifically on the hazards posed by the task performed by a worker. The technique aims to identify the existing and potential hazards of a task/job, assess their risks, and prevent losses by recommending and implementing effective control measures. Over the years, JSA and the AS/NZS 4360:2004 standard have been used in a wide range of industries and services, including process industries, construction, healthcare, etc. JSA is an integral part of any safety management system. Done properly, it can provide workers and employers with an in-depth understanding of how work should be done to prevent adverse outcomes, from which safety procedures, content and instructions can be developed (Ghasemi *et al*, 2023).

Albrechtsen *et al.* (2019) argued that JSA has at least six benefits: (1) formalization of work, (2) accountability, (3) employees participation (4) organizational learning, (5) hazard identification and situational awareness, and (6) loss prevention. Palega (2021) applied of the JSA method to assess the occupational hazards in the workplace of a laser cutter operator in a company providing laser cutting services and found thatthe preventive measures used were at an acceptable level. Wojtyto *et al* (2019), in the context of JSA-based risk management process, identified the risks associated with each activity at the workplace of the glass production line operator and proposed preventive measures. Arifin and Octaviani(2022) identified and evaluated ship repairment process, hull cleaning, and coatingbased on hazard identification and risk assessment using the AS/NZS 4360:2004 standardand found that basic risk consisted of five levels i.e., acceptable, priority 3, substantial, priority 1 and very high.Pramitasari et al(2022) used JSA method and AS/NZS 4360:2004 standard to analyze occupational safety and health risks in the informal welding workshop; study showed that there are 8 types of welding tasks, 21 potential hazards, and 24 health consequences in the welding process. Van Derlyke*et al* (2022) and Halim *et al* (2018) have found that proper JSA implementation is effective in preventing accidents and promoting safety behaviors. According to Love *et al.* (2022), safety training should be a requirement for every teacher who will be working around potential health and safety hazards resulting in potential risks to themselves and their students.

3. Methodology

The study was conducted through three main approaches. First, a desk research was conducted by consulting official reports, websites and social media pages of Fab Labs, and articles related to Fab Labs in Cameroon was carried out in order to obtain background information that would enable to take stock of the situation of existing Fab Labs in Cameroon (Schonwetter *et al,* 2020). Second, interviews were conducted with key stakeholders associated with Fab Lab activities from different sectors including higher education, entrepreneurs, as well as Fab managers. The intention was to investigate common tools and equipment in these Fab Labs and relevant activities. Third, site visits were made to a Fab Lab in Yaounde, where an OHS analysis was conducted (Arifin and Octaviani, 2022)(Pramitasari et al, 2022).

Occupational risk assessment was conducted at XYZ Fab Lab in the capital city of Yaounde over a period of two months. The research was conducted between November 2022 and January 2023 and concerned all makers who performed work activities at the CNC milling machine and laser cutter operator workstations. The data needed to determine the level of risk was collected through direct observation of makers at work, semi-structured interviews with staff and makers, review of accident/incident reports, housekeeping, observations and equipment manuals compiled in accordance with the aims and objectives of this study.

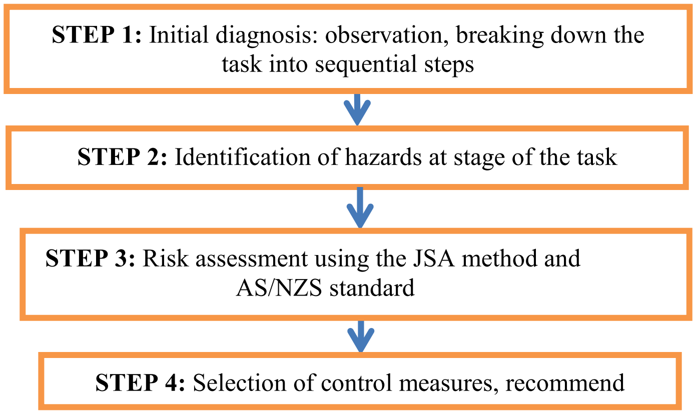


Figure 1 Methodology by Steps for JSAand Risk Management

Figure 1 shows the main steps for the OHS analysis. The first step involved making first-hand observations to describe the task of the maker at each station, and then breaking down the task/job into sequential steps. The second step involved identifying hazards that threaten the health and safety of the maker during each step of the task and developing a comprehensive list of hazards based on observations, interviews, brainstorming sessions and review of available documents, and previous incidents. To support the research, we reviewed some literature related to the potential hazards of operating a milling machine and laser cutter. The third step was to conduct a risk analysis, which included determining the value of the consequences, exposure, and likelihood of each work step, which was then used to determine the level of risk based on the AS/NZS 4360: 2004 standard, described in Tables 2 and 3 (Arifin and Octaviani, 2022). The fourth step was to select control measures and recommend and implement risk reduction measures.

Risk management according to AS/NZS 4360:2004 is the application of the policy system management, procedures, and practices for task communication, context setting, identification, analysis, evaluation, control, and monitoring of risks (AS/NZS 4360, 2004).The risk assessment is carried out using a semi-quantitative analysis, namely: the qualitative scale that has been described with numerical figures to provide a scale but not like the quantitative analysis. The value of the occupational risk is based on the level of impact or consequence, exposure, and the possibility or likelihood/probability of the occurrence of these potential hazards as provided in Table 2 and Table 3.

Table 2: Interpretation of the Risk Score (Arifin and Octaviani, 2022)

Risk classification	Risk Category	Hierarchical of control	Necessary actions
R>350	Very High	Engineering	Stop activity until risk reduced.
180 ≤ R< 350	Priority 1	Administration	Requires immediate corrective action
70 ≤ R < 180	Substantial	Training	Requires corrective action
20 ≤ R <70	Priority 3	Personal protective equipment	Requires attention and supervision
R < 20	Acceptable		The intensity of activities that pose a risk is reduced minimum

Table 3: Criteria for occupational risk analysis and assessment ((Arifin and Octaviani, 2022))

Consequences factors (C)		Exposure factors (E)		Probability factors (P)	
C Value	**Characteristic**	**E Value**	**Characteristic**	**P Value**	**Characteristic**
100	*Catastrophe* (Mass death, damage permanent in the local environment.)	10	*Continuously* (Occurs more than 1 time a day)	10	*Almost certain* (Most likely occur.)
50	*Disaster* (Death, permanent damage that locational to the environment)	6	*Frequently* (Happens about 1 time a day)	6	*Not likely, but possible* (Possible occurrence 50:50 accident)
25	*Very Serious* (Permanent disability, damage temporary environment)	3	*Occasionally* (Happens once a week up to once a month)	3	*Unusual but Possible* (Unusual to happen but possible)
15	*Serious* (Serious effects on workers but not permanent, adverse effects on the environment but massive)	2	*Infrequent* (Once a month until once a year)	1	*Remotely Possible* (Possible events happen very little)
5	*Important* (Need medical staff, emissions occur but do not cause damage)	1	*Rare* (It is not known when it happened)	0.5	*Conceivable* (Never happen accidents over the years, but they are possible)
1	*Noticeable* (Minor injury or illness, slight loss of production, minor loss of equipment or machinery but no effect on production)	0.5	*Very rare* (It is not known when this happened)	0.1	*Practically Impossible* (Very unlikely)

In order to calculate the value of the occupational risk at the CNC milling machine and laser cutter operator workstation, the following factors were used: values of consequences (C), exposure (E) and probability (P) using W.T. Fine's formula Eq. 1 (Wojtyto *et al*, 2019), each estimated hazard risk was calculated as

$$R = C \times E \times P. \qquad (1)$$

4. Results and discussions

The presentation of the resultsis divided into the followingsubsections: characteristics of Fab Lab initiatives in Cameroon and risk analysis of the laser cutting andmilling machinesof the Yaounde XYZ Fab Lab.

4.1 Characteristics of Fab Lab initiatives in Cameroon

It is difficult to determine the exact number of Fab Labs in Cameroon. However, by analyzing data from online platforms that list makerspaces around the world, such as the Fab Foundation's list and websites and social media pages related to Fab Labs in Cameroon, it was possible to get an overview of the Fab Labs ecosystem in Cameroon. Table 4 shows the list of Fab Lab initiatives active on social media pages in Cameroon.

Table 4: Summary of Fab Labs Initiatives in Cameroon

No.	Name	Year of Creation/ Inauguration	Location and URL	No.	Name	Year of Creation/ Inauguration	Location and URL
1	Ecolia Labs	2014	Mimboman, Yaounde https://www.fablabs.io/labs/ecolialabs	6	Fab Lab Energies Renouvelables	2023	Polytechnique Yaounde https://web.facebook.com/PDTIE.IFDD/posts/113584480948058/
2	OngolaFablab	2017	AUF-Campus Numerique Francophone, Yaounde https://www.fablabs.io/labs/ongolafablab	7	Sahel *Fablab*	2023	Campus numérique Francophone de Ngaoundéré https://guide.dadupa.com/annuaire-des-investisseurs/sahel-fablab-fablabs-solidaires-orange/
3	Africa Robot/Africa Academy	2018	Yaounde https://www.fablabs.io/labs/africarobot https://ar-ar.facebook.com/AfricaRobot/	8	*FAB-LAB AUI-Techno*	2015	*Yaoundé, Dschang*, Bafoussam and Douala
4	Yansokilab	2020	Institut Ucac-IcamDouala https://www.fablabs.io/labs/yansokilab	9	TechLab Fab Lab		Biyem Assi Accacia, Yaounde https://www.linkedin.com/in/paul-noumedem-107a6a135
5	WouriLab/Orange Digital Center FabLab	2021	Akwa, Douala https://www.fablabs.io/labs/wourilab	10	*Mboalab*	*2017*	Mefou-Assi, Yaounde https://mboalab.net/?lang=fr

Source: (Own elaboration)

Regarding the type of the institutions hosting the labs reported in Figure 2, universities (public universities or private universities) typically host the digital manufacturing laboratories in Table 4, at 40%. 10% were hosted by private companies and 50% were social enterprises. It should be noted that 50% of the Fab Labs in Table 4 (Fab Lab Energies Renouvelables,Sahel *Fablab, FABLAB AUI-Techno,* TechLab Fab Lab, *Mboalab*) have adopted the Fab Lab name, or refer to themselves as Fab Labs, without joining the international Fab Foundation network. Thus, the term Fab Lab has taken on a generic meaning (Schonwetter, 2020).

OngolaFablab, Yansokilab, Fab Lab Energies Renouvelables and Sahel *Fablab* are located on university campuses. OngolaFablab, is located on the campus of the AgenceUniversitaire de la Francophonie (AUF), Yaounde, was initially funded by the Orange Foundation. The RenewableEnergies Fab Lab is part of the EcoleNationaleSuperieurePolytechnique, Yaounde, and is funded by the Institut de la Francophonie pour le développement durable (IFDD) through the Project for the Deployment of Environmental Technologies and Innovations for Sustainable Development and Poverty Reduction (PDTIE). The Yansokilab is located at the Ucac-Icam Institute, Yansoki campus, in the city of Douala. Like the OngolaFablab, it was initially supported by the Orange Foundation. The Sahel Fab Lab, located at the University of Ngaoundere, is the result of a partnership between the AgenceUniversitaire de la Francophonie, the Orange Foundation and the University of Ngaoundere, and is funded by the Orange Foundation. Fab Labs in Cameroon are increasingly being adopted by public universities and private universities as incubators and platforms for project-based, hands-on STEM education.

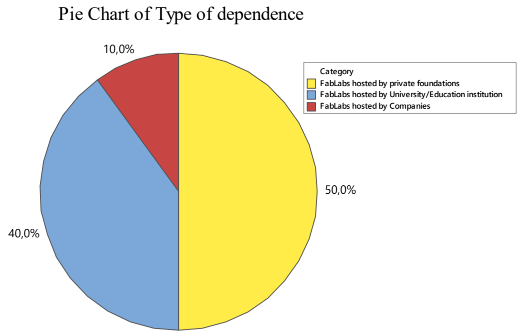


Figure 2: Disribution of Fab Labs depending on institution housing it

Ecolia Labs, Africa Robot, Orange Digital Center Fab Lab, TechLab Fab Lab, *Mboalab*, and OngolaFablab —have been organizing social entrepreneurial activities and while the makers make use of the Fab Labs to carry out their social entrepreneurship activities. Ecolia Labs, for example, is an environment that supports innovative entrepreneurship among young people by helping them to carry out their business projects. Since 2014, Ecolia Labs has been working in collaborations with organizations such as UNDP Cameroon, GIZ, the International Organization of La Francophonie, the European Union, Facebook, the Orange Foundation, etc. This has enabled the training and support of thousands of young people in the creation of their businesses, and the emergence of several other incubators that have made it possible to strengthen, improve and increase the support offer for start-ups in Cameroon.

Although machines for digital fabrication are becoming more affordable, not all the major towns, cities, higher institutions or communities have been able to set up labs. Most Fab Labs in Cameroon are located in large cities, limiting access for makers in rural areas or from less privileged backgrounds. In some cases, visiting existing makerspaces is problematic due to distance and accessibility. UIT the emergence of various self-reproducing open source 3D printer initiatives available online for free under open licences, makers, researchers, and hobbyists, can easily contribuye to increase of FabLabs in the Cameroon through low-cost manufacturing of equimpment for Fab Labs to be created, specifically printers derived from the RepRapmodel (Jones *et al.*, 2011).

The Fab Labs survey, included the assessment of common tools, equipment, and activities in Fab Labs in Cameroon. The results showed that most of the labs are equipped with state-of-the-art tools and resources, including 3D printers (FDM 3D printers, SLA 3D printers), laser cutters (CO_2 laser cutters, Fiber laser cutters), CNC milling machines, vinyl cutters, heat presses (digital sublimation T-Shirt heat presses), fabric printers, electronic prototyping tools, digital soldering station, 3D scanners (sense 3D scanner), sewing and embroidery machines, 3D and 2D modeling software, etc. These cutting-edge and accessible technologies (coexist with the tools of a traditional workshop, all at the service of Fab Lab users.

Knowledge sharing through training was one of the key activities that all the Fab Labs engaged in through activities such as training workshops, research, prototyping, and product development. They provided training in digital manufacturing, principles and practices, computer-aided design, manufacturing, embedded programming, 3D modeling, 3D scanning and printing, computer-controlled cutting, etc. Users of FabLabs are charged fees, including membership fees, training fees, and additional fees based on their individual needs. The lab fees are generally set at a low level to cover operating costs and can be a barrier to Access for some potencial users (Schonwetter *et al,* 2020).

The training provided by the majority of labs was in most cases both a means of economic support for the FabLabs, as well as a means of knowledge transfer and bridging the digital gap, but also other differences related to gender, culture or role. Usergroups, incluye entrepreneurs, high school students, university students, makers, and the general public, the majority from these cities. Three university-led labs - Yansokilab, Fab Lab Energies Renouvelables and Sahel *Fablab* - are predominantly used by students from their respective universities, while the other labs are used by students and the general public. In this way, they provide a framework for social relations in which there is an exchange of knowledge about technological aspects, democratizing and simplifying processes that were previously unthinkable for the ordinary users (García-Ruiz and Lena-Acebo, 2023). It has also been found that the makers often use and seek out free and open source CAD files available online.

A mobile Fab Lab is a solution for extending the hands-on learning and capabilities of stationary Fab Labs to a wider range of users. The mobile Fab Lab is designed to address the space, and funding constraints that limit many educational institutions (high schools, universities), libraries or communities in their ability to incorporate Fab Labs as a component of their instructional and curricular framework (Moorefield-Lang, 2015). The Agence Universitaire de la Francophonie (AUF) and the Orange Foundation inaugurated Cameroon's first mobile digital Fab Labon May 23, 2019, see Figure 3. The mission of the mobile Fab Lab is to support young people from all regions of Cameroon to realize their projects through digital fabrication training. The mobile Fab Lab has visited many universities in the country such as the University of Ngaoundere (July 2019), the University of Buea (February 2022), and the University of Douala (10 months in 2020), where students were trained in digital manufacturing. Some of these programs have strong support from foundations such as the Orange Foundation in “The Solidarity Program Fab Lab”. The Fab Lab seems to be the ideal environment to bring the possibilities of digital manufacturing technologies to the public (Mersand, 2021).

Figure 3 : Mobile Fab Lab at Ecole Nationale Superieure Polytechnique, Yaounde

The findings revealed that the Fab Labs also help provide engaging environments and technologies for developing creative solutions to real-world problems (Soomro *et al*, 2022), such as the problem of premature infant deaths in Cameroon. It is estimated that approximately 15,000 premature infant deaths could be prevented each year if the Cameroonian health system had adequate equipment. Serge Armel Njidjou, founder of the AUI-Techno Fab Lab, has become a champion in the fight against premature infant mortality by designing and manufacturing neonatal incubators adapted to the very specific needs of Cameroon and other sub-Saharan African countries. The Fab Lab movement is not exempt from criticism (Kohtala, 2016), with its characteristics of openness democracy, decentralized nature and against technocoloniality (Nkoudou, 2022), it is not without weaknesses. The main weaknesses faced by Fab Labs in Cameroon are lack of funding or insufficient financial resources, insufficient human resources, poor communication and incoherence with the global Fab Lab network (Oladele-Emmanuel *et al*, 2018).Government authorities and other stakeholders have to put in place all the mechanisms to allow a reliable digital growth in the country while universities must showcase for this revolution.

4.2 Risk analysisof the laser cutting and milling machinesat XYZ Fab Lab

In the initial diagnosis, the survey carried out during the research period on 12 people (9 makers, 3 supervisors) who make up the makers and staff of XYZ Fab Lab, allows us to observe that, at the demographic level, the population of the Fab Lab is 100% young (14-38 years old), there is a predominance of females (58%). The predominance of females confirms the fact that Fab Labs are not spaces that contribute to gender differences or discrimination, but they constitute a hope (Cartensen, 2013). The highest level of education corresponds to the supervisors. This diversity in user profiles brings about other benefits, such as the creation of multidisciplinary working groups that can undertake major projects that individually could not be performed (García-Ruiz and Lena-Acebo, 2022).

The list of accidents at work from the records of XYZ Fab Lab is shown in Figure 4. The highest number of accidents waslacerations, injuries, cuts with 7 accidents, followed by the fire during the operation of the laser cutter with 3 accidents and occupational illnesses with about 2 accidents. Other incidents were reported using other fabrication tools in the Fab Lab. The percentage of the work accidents is shown in Figure 4. In conducting the JSA in the workplace of a laser cutting and milling machine operators, observations were recorded on the JSA form and analyzed based on AS/NZS 4360 (2004) Risk Management Standard. The results of the analysis of OHS hazards in the makerspace are presented in Tables 5 and 6. Based on the risk assessment for 14 identified work steps at the laser cutter and milling machine workstations, the highest scoring OHS hazards for the laser cutter and milling machine were (1) Inhalation of noxious and harmful fumes or particles from the materials being processed. (2) Fire, burns from intense heat and concentrated light. (3) Eye damage from laser (4). Misalignment or dislodging during the operation. (5) Cutter dislodged from collet. (6) Operator entanglement, and (7) Injury from flying debris.

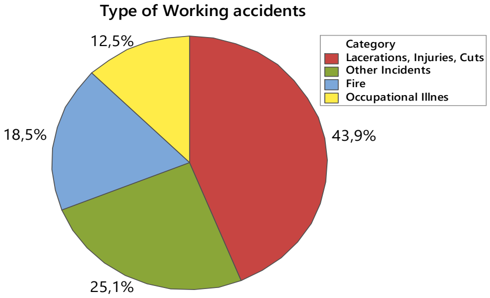


Figure 4: Percentage of working accidents at XYZ Fab Lab

Table 5: JSAand Existing Risk Levels for Operating a Laser Cutter

Task/Step	Hazard	C	E	P	R	Risk Level	Controls/Recommendations
Assess work area	• Slip, trip, or fall					Acceptable	• Safety talk: Clear work area of any obstructions; Housekeeping
Prepare computer and cutter for use: Turn on laser, turn on air assist extraction system, turn on computer connected to the laser cutter	• Low back problems, lumbar problems					Acceptable	• Safety talk, work procedure training, air assist should always be activated during vector cutting operations. • Use care when opening and closing doors
Place material into device and maintenance: Open laser lid, place material onto machine's work surface, maintenance, close the lid	• Trapped Fingers during routine setup tasks and maintenance, such as adjusting materials, cleaning the machine, or making adjustments to the focus lens					Acceptable	• Safety talk: Deburr material before handling, ensure that all hands and fingers are safely removed from the laser cutter before the guard screen is closed over.
Conduct laser operation: Load appropriate design or file onto the machine, adjust power, speed, frequency settings according to material being cut and/or engraved and perform all cutting/engraving operations necessary	• . Inhalation of noxious and harmful fumes or particles from the materials being processed (wood, acrylic, and other materials)					Substantial	• Training: JSA training on a regular basis, work procedure training • Safety talk: Use only approved materials in laser cutter; ensure ventilation system is activated; never leave the machine unattended when in operation; do not start the machine if the protective covers are damaged • Keep extinguisher ready for use • Only single materials must be cut as stacking increases the risk of fire • Safety glasses • Safety Earmuffs
	• Fire, burns from intense heat and concentrated light • Eye damage from laser	5				Substantial	
	• Noise emitted by machine			0		Acceptable	
*Remove material from device:*Open laser lid and retrieve material	• Even after cutting has stopped, there may still be noxious and harmful fumes inside the sealed machine • Pinching hazards for hands/fingers • Lacerations to hands/fingers from material					Acceptable	• Safety talk: Wait for a minute after the cut is complete before opening the lid to retrieve the material • Use leather gloves for sharp material
After cutting and engraving process: Open and inspect drop tray, confirm no accumulation ofmaterial drop pieces	• Accumulation of drop pieces of materials can lead to combustible conditions due to the presence of flammable materials such as wood, acrylic, or plastic					Acceptable	• Safety talk: Remove scrap material from the tray below or above the honeycomb grid, or any material stuck in the honeycomb grid.

Based on the result of the existing risk in Table 3, it can be analyzed that the risk level of each hazardous activity of laser cutter operation consists of two levels with acceptable which reaches 75,0 % and substantial with 25,0% as shown in Figure 5a. While shown the risk level at the milling machine operator workstation consists of acceptable which reaches 69.2%, priority 3 with 7.7% and substantial with 23.1% as shown in Figure 5b.

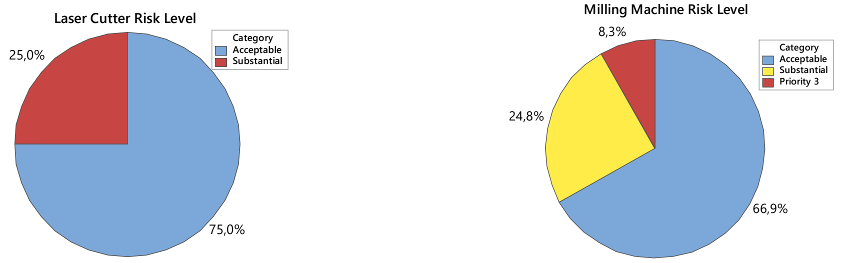
The hazard of noxious and harmful fumes in Fab Labs was given a probability (P) score of 6, because workers often experience this event due to the presence of hazardous chemicals and compounds generated during 3D printing, laser cutting, and other fabrication activities in the Fab Lab. The potential for exposure to these fumes or particles was low due to the use of ventilation systems in the Fab Lab, despite the unavailability of personal protective equipment. Health risks to workers from noxious and harmful fumes can be in the form of primarily as respiratory issues such as coughing, wheezing, and shortness of breath.

Table 6: JSA and Existing Risk Level for Operating a Vertical Milling Machine

Task/Step	Hazard	C	E	P	R	Risk Level	Controls/Recommendations
Assess work area	• Slip, trip, or fall	2	1	1	2	Acceptable	• Safety talk: Clear work area of any obstructions or slip/trip/fall hazards
Install vise or work piece	• Pinching hazard for hands or fingers • Foot injury from dropping of heavy objects	1	2	6	12	Acceptable	• Safety talk: Avoid pinch points, Position body to maintain balance, maximize use of legs, and ask for assistance if necessary • Work procedure training

Table 6 (cont'd): JSA and Existing Risk Level for Operating a Vertical Milling Machine

Task/Step	Hazard	C	E	P	R	Risk Level	Controls/Recommendations
Insert end mill into collet (or insert drill bit into drill chuck), then install it in the spindle of the milling machine	• Pinching hazards for hands and fingers during the insertion process • Lacerations to hands/fingers from sharp edges of the end mill or the collet	1	2	6	12	Acceptable	•Keep hands free from pinch points • Handle tool bit with care; avoid sharp edges • Ensure all 3 chuck jaws are making contact with the bit • Ensure the cutter is tightly secured in the collet before turning on the spindle
	• Misalignment or dislodging during the operation	5	2	3	30	Priority 3	
Adjust the gear and speed of the spindle for your application	• Pinching hazard for hands/fingers	2	2	2	8	Acceptable	• Avoid pinch points
Turn on spindle	• Cutter dislodged from collet • Operator entanglement	15	2	6	180	Substantial	• Ensure the cutter is tightly secured in the collet before turning on the spindle • Do not place your hands or fingers anywhere near the rotating cutter • Never wear loose clothing when operating, tie hair back and remove jewelry. • Regular maintenance and inspections of the collet and cutter
	• Lacerations to hands/fingers fromrotating cutter	1	2	6	12	Acceptable	
Feed cutter into workpiece	• Material dislodged from the vise • Burning hazards from chips • Lacerations to hands/fingers from the cut part, from rotating cutter, from chips	1	2	6	12	Acceptable	• Do not place your hands or fingers anywhere near the rotating cutter • Always wear safety glasses when operating equipment • Ensure the material is securely fastened in vise before making a cut • Never brush chips away with bare hands or fingers. Use a chip brush or pliers to remove chips. • Stand to the side of the cut or use a chip shield; hot chips can burn skin • Always your material/parts before handling • Wear ear plugs/muffs if necessary • Training: JSA training on a regular basis, work procedure training
	• Excessive noise and vibration	1	2	10	20	Acceptable	
	• Eye injury from flying debris	15	2	6	180	Substantial	
Turn off machine and remove cutter	• Pinching hazards • Lacerations to hands/fingers from bit	1	2	6	12	Acceptable	• Keep hands free from pinch points • Handle tool bit with care; avoid sharp edges
Remove finished work piece and clean machine	• Eye injury from flying debris	15	2	6	180	Substantial	• Never brush chips away with bare hands or fingers. Use a chip brush or pliers to remove chips. • Always your material/parts before handling • Do not use compressed air to clean table. Use a chip brush and wipe up excess oil.
	• Lacerations to hands/fingers from chips, from the cut part	1	2	6	12	Acceptable	



(a) **(b)**

Figure 5: Result of existing risk level for (a) laser cutter and (b) milling machine operators

Prolonged exposure can also cause in skin irritation, allergic reactions, and other dermatological issues. Additionally, inhaling noxious fumes can have long-term health effects, including damage to the lungs, liver, and nervous system. It is essential that Fab managers maintain adequate ventilation systems and provide personal protective equipment to mitigate the risks associated with fume exposure. In addition, regular air quality monitoring and conducting risk assessments can help identify and address potential workplace hazards. The second high risk hazard was fire, burns from intense heat and eye damage from laser cutting and were found to be substantial. However, the occurrence of this incidence was high because most makers were unskilled and didn't use personal protective equipment during laser cutting. A similar risk assessment study found that the risk of laser radiation, thermal burns and fire to operators was considered acceptable (Paella, 2021). Laser cutters generate intense heat that can ignite flammable materials in the vicinity if not used properly. It was recommended not to look directly at the work area and not to start the machine if the protective windows in the cab were damaged. Never leave the machine unattended while it is running, do not start the machine if the protective windows were damaged and use safety glasses for working when working with the laser cutter.

In Fab Labs, where precision machining and prototyping are common practices, the vertical milling machine is often used to shape and refine various materials. High risks have been identified from the hazards associated with operating a vertical milling machine. The rotating cutting tool and moving workpiece can pose a significant hazard to the operator if proper precautions are not taken. The hazards have been related to misalignment or dislodging during the operation, cutter dislodged from collet, operator entanglement, eye injury from flying debris. It is important for operators to ensure that the workpiece is securely aligned and properly secured in the machine before starting the milling operation. In addition, appropriate personal protective equipment, such as gloves, should be worn when operating the machine. Safety glasses should also be worn to protect against possible eye injury from flying debris. Only few makers were able to operate the milling machine, and the operators didn't wear personal protective equipment. The potential risk of a person being caught or entangled in the moving parts of a vertical milling machine during its operation was particularly high in Fab Lab, as people with varying levels of experience and training could be operating the machine. It is important to maintain a clear and unobstructed work area around the machine to minimise the risk of entanglement. It is essential that operators are trained in the safe use of the equipment and follow strict safety protocols. This includes wearing appropriate personal protective equipment such as gloves and goggles, and ensuring that loose clothing and jewellery are not worn when operating the machine. The dislodgment of the cutter from the collet during operation poses a serious threat to the overall safety and functionality of the fab labs. The occurrence of this incidence is high because most makers are unskilled and often neglect safety during milling activities. The dislodgment can result in the cutter being ejected from the machine at high speed, causing damage to the workpiece, the machine itself, and potentially causing injury to the operator. It is essential that operators to follow strict procedures for inserting and securing cutters into the collet to prevent any potential risks associated with dislodgement. Regular maintenance and inspection of the collet and cutter are also essential to ensure safe and efficient operation of the vertical milling machine in the Fab Lab.

5. Conclusions

Created to bring digital manufacturing opportunities to the public, Fab Labs initiatives in Cameroon have been catalyzing entrepreneurship and innovation since the creation of the first Fab Lab in 2014. Eighty percent (80%) of the active Fab Labs in Cameroon work to promote student entrepreneurship and help to popularize digital manufacturing technologies among users who were previously far from it in educational environments. Given the growing interest in the Fab Labs in Cameroon, their development is expected to continue. It would be particularly valuable to develop Fab Labs in high schools and more universities, as well as in small towns and villages, where access to digital manufacturing technologies is the most limited. Government authorities and other stakeholders need to put in place all the mechanisms to enable a reliable growth of digital manufacturing in the country, while universities need to be the showcase of this revolution. This study also presents the occupational risk assessment carried out at the laser cutting and milling operator workstations at XYZ Fab Lab using the JSA method and AS/NZS 4360 (2004) Risk Management Standard. Two JSA sheets were prepared for the laser cutting and milling operator workstations. The JSA revealed that the main hazards with a substantial risk level were inhalation of noxious and harmful fumes or particles from the materials being processed; fire/burns from intense heat and concentrated light; eye damage from laser; misalignment or dislodgement during the operation; cutter dislodgement from collet, operator entanglement, and injury from flying debris. It was recommended that, in addition to the use of personal protective equipment such as gloves, safety shoes, safety helmet, operators should receive regular training. The Fab Lab should have clear safety guidelines and work procedures in place to mitigate the risks associated with the use of all machines. All makers are strongly advised to remain vigilant during the operation of the vertical milling machine in order to mitigate various hazards and ensure a safe working environment in Fab Labs.

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References

Albrechtsen, E., Solberg, I., &Svensli, E. 2019.The application and benefits of job safety analysis. *Safety Science*. Vol.113, pp. 425-437. https://doi.org/10.1016/j.ssci.2018.12.007

Alonso-García, M., Valerga-Puerta, A. P., Barrachina, L. G., &Torán, M. M. 2023. Design of a low-cost transtibial prosthesis for emergency situations: The case of the Doula leprosarium digital fabrication lab. In *International Conference on The Digital Transformation in the Graphic Engineering.* Cham: Springer Nature Switzerland. pp. 140-149.

Arifin, M. D., &Octaviani, F. 2022. Occupational health and safety analysis using HIRA and AS/NZS 4360: 2004 standard at XYZ shipyard. *International Journal of Marine Engineering Innovation and Research*. Vol. 7, No. 3, pp.145-152. http://dx.doi.org/10.12962/j25481479.v7i3.14151

AS/NZS 4360:2004 2004. Risk Management Guidelines. Sidney: Standards Australia/ New Zealand International Standard: 52-55.

Birtchnell, T., Hoyle, W., Birtchnell, T., & Hoyle, W. 2014. The 3D4D Challenge. *3D Printing for Development in the Global South: The 3D4D Challenge*, pp.13-35.https://doi.org/10.1057/9781137365668_2

Cartensen, T. 2013. Gender Fab Labs? In Fab Lab: Of Machines, Makers and Inventors; Walter-Herrmann, J., Büching, C., Eds.; Transcript Cultural and Media Studies: Bielefeld, Germany.

Clarke, C. 2017. 3D printing to redefine the medical supply chain in Africa. https://3dprintingindustry.com/news/3d-printing-redefine-medical-supply-chain-africa-105989

3d4dchallenge. 2024.3D Printing for Development Challenge (3D4D Challenge). https://www.3d4dchallenge.org/.

De FabLab Wiki. 2024. http://wiki.fablab.is/wiki/Portal:Labs

Fab Foundation.2024. Labs Map.https://www.fablabs.io/. Accessed on January 3, 2024.

Fab Foundation 2024.Getting-started.https://fabfoundation.org/getting-started/.

Fahfouhi, K., Freitas, D., Poullain, P., Craveiro, F., &Bártolo, H. 2022. Digital Fabrication in Construction Industry in Africa. In *International Conference on Water Energy Food and Sustainability* Cham: Springer International Publishing. pp. 470-479.

Fofana, S. B., Nyarko, F. A., Mensah, L. D., & Takyi, G. 2023. Implementation of flexible manufacturing systems in Africa: multiple case studies in the Gambia and Ghana. *Nigerian Journal of Technological Development*. Vol. 20, No. 1, pp. 91-101. https://doi.org/10.4314/njtd.v20i1.1401

García-Ruiz, M. E., & Lena-Acebo, F. J. 2022. FabLabs: The Road to Distributed and Sustainable Technological Training through Digital Manufacturing. *Sustainability*. Vol.14, No. 7, p. 3938.

Gadjanski, I., Bioirc, B., & Ngo, F. I. 2015. Fabrication laboratories—fab labs—tools for sustainable development. *UN Global Sustainable*.

Ghasemi, F., Doosti-Irani, A., &Aghaei, H. 2023. Applications, shortcomings, and new advances of Job Safety Analysis (JSA): findings from a systematic review. *Safety and Health at Work*. Vol. 14, pp. 153-162.

Gershenfeld, N. 2012. How to make almost anything: The digital fabrication revolution. *Foreign Affairs*. Vol.91, pp. 43–57. https://www.jstor.org/stable/41720933

Gopinath, V., & Johansen, K. 2016.Risk assessment process for collaborative assembly–a job safety analysis approach. *Procedia CIRP*. Vol. 44, pp. 199-203. https://doi.org/10.1016/j.procir.2016.02.334

Halim, S. Z., Janardanan, S., Flechas, T., &Mannan, M. S. 2018. In search of causes behind offshore incidents: Fire in offshore oil and gas facilities. *Journal of Loss Prevention in the Process Industries*.Vol. 54, pp. 254-265. https://doi.org/10.1016/j.jlp.2018.04.006

Jones, R., Haufe, P., Sells, E., Iravani, P., Olliver, V., Palmer, C., & Bowyer, A. 2011. RepRap–the replicating rapid prototyper. *Robotica*.Vol. *29; No.* 1, pp. 177-191. https://doi.org/10.1017/S026357471000069X

Kim, S. W. 2020. An interdisciplinary capstone course on creative product development with cross-college collaboration. *International Journal of Engineering Education*. Vol. 36, No. 3, pp. 919-928.

Krewer, J., Leyronas, S., &Mboa, T. 2023. Digital Commons and Entrepreneurship: Alternative or Complementary Approaches? *The Commons*, p.131.

Kruger, S., & Steyn, A. A. 2024. Developing breakthrough innovation capabilities in university ecosystems: A case study from South Africa. *Technological Forecasting and Social Change.* Vol. 198, p. 123002. https://doi.org/10.1016/j.techfore.2023.123002

Kohtala, C. 2017. Making “Making” critical: How sustainability is constituted in fab lab ideology. *The Design Journal*. Vol. 20, No. 3, pp. 375-394.

Love, T. S., Roy, K. R., Gill, M., & Harrell, M. 2022. Examining the influence that safety training format has on educators’ perceptions of safer practices in makerspaces and integrated STEM labs. *Journal of safety research*.Vol. *82*, pp.112-123.

Makery. 2024. https://www.makery.info/en/map-labs/

Mersand, S. 2021. The state of makerspace research: A review of the literature. *TechTrends*. Vol. 65, No. 2, pp. 174-186. https://doi.org/10.1007/s11528-020-00566-5

Moorefield-Lang, H. M. 2015. When makerspaces go mobile: Case studies of transportable maker locations. *Library Hi Tech*. Vol.33, No. 4, pp. 462-471. https://doi.org/10.1108/LHT-06-2015-0061

Nkoudou, T. H. M. 2022. 15. High-stake conditions to catalyse local sustainable development through Fablabs in Africa. In *Handbook of Innovation & Appropriate Technologies for International Development,* Edward Elgar Publishing. pp. 222-239.

Oladele-Emmanuel, B. D., Rejeb, H. B., &Redlich, T. 2018. Strategic management: SWOT analysis of the African digital fabrication laboratories. In *2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC).* pp. 1-7.

Orange Foundation.2024. The Solidarity FabLabprogramme: an international digital education programme.

https://www.fondationorange.com/en/solidarity-fablab-programme-international-digital-education-programme**.**

Osunyomi, B., Redlich, T., Buxbaum-Conradi, S., Moritz, M., & Wulfsberg, J. 2016. Impact of the fablab ecosystem in the sustainable value creation process. *OIDA International Journal of Sustainable Development*. Vol. 9, No. 1, pp. 21-36.

Palega, M. 2021. Application of the job safety analysis (JSA) method to assessment occupational risk at the workplace of the laser cutter operator. *Management and Production Engineering Review*.Vol. 12, No. 3, pp. 40-50.

Pramitasari, R., Haikal, H., Yuantari, M. C., Dwi, K. I. K., &Treesak, C. 2022. Job safety analysis and hazard identification of welding process in Semarang-JSA Method AS/NZS 4360: 2004. *Disease Prevention and Public Health Journal*. Vol. 16, No. 1, pp. 62-69. https://doi.org/10.12928/dpphj.v16i1.4613

Rayna, T., & Striukova, L. 2021. Fostering skills for the 21st century: The role of Fab labs and makerspaces. *Technological Forecasting and Social Change*. Vol.*164*, *No.* 120391, pp. 1-15.

Schonwetter, T., &Van Wiele, B. 2020. Social entrepreneurs' use of fab labs and 3D printing in South Africa and Kenya. *The African Journal of Information and Communication*. Vol.*26*, pp. 1-24.https://doi.org/10.23962/10539/30356

Soomro, S. A., Casakin, H., & Georgiev, G. V. 2022. A Systematic Review on FabLab Environments and Creativity: Implications for Design.*Buildings* 2022.Vol 12, pp. 1-18.

Thinglab.2024. 3D printing mechanical hands Changing lives with patience, spirit, and makerbot.

https://freedspace.com.au/thinglab/case-studies/medical/makerbot-stories-3d-printing-mechanical-hands/.

WorldBank 2014.Communities of "Makers" Tackle Local Problems. http://www.worldbank.org/en/news/feature/2014/08/06/communities-of-makers-tackle-local-problems.Accessed on December 7, 2023.

Van Derlyke, P., Marin, L. S., &Zreiqat, M. 2022. Discrepancies between implementation and perceived effectiveness of leading safety indicators in the US dairy product manufacturing industry. *Safety and health at work*.Vol 13, No. 3, pp. 343-349. https://doi.org/10.1016/j.shaw.2022.04.004

Vieira, R. B., Bresciani, L. P., & dos Santos, I. C. 2017.Fab labs network in developing countries: `knowledge spillover effects or managing technology development within the scarcity economy? In *2017 Portland `International Conference on Management of Engineering and Technology (PICMET)* IEEE. pp. 1-9. https://doi.org/10.23919/PICMET.2017.8125265

Walker, K. 2016. 3D-printed weather stations help rural Zambian communities. http://www.designindaba.com/articles/creative-work/3d-printed-weather-stations-help-rural-zambian-communities.

Wojtyto, D., Rydz, D., Pałęga, M., &Arbuz, A. S. 2019. Job safety analysis in the context of the risk management process. *System Safety: Human-Technical Facility-Environment*. Vol. 1, No. 1, pp. 35-44.

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