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Value Creation: FabLab's Journey so far

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ABSTRACTS

From the slums in India to the shacks in South Africa, the need for the creation of global and sustainable values are of paramount importance. The value creation concept aims to create not just a paradigm shift in strategies, but also a shift in the distribution of livelihood, thereby providing adequate means of wealth and job creation to the populace of a developing and less developed countries.

From a global, national, and institutional level, many initiatives and organizations were rolled out to tackle the urgent issue of inadequate value creation, among which is FabLab. FabLab means fabrication laboratory, it 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 geographical and demographical status.

The focus of this paper is to uncover what FabLab is, study the strategies being utilised at FabLabs (that is, the mode of operation), and analyse the success rate of FabLabs by comparing FabLabs in developed countries to FabLabs in developing countries, so as to ascertain the accomplishment rate of the FabLab ecosystems.

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1. Introduction

From the inception of the early industrialization era (export-oriented industrialization and import-substituent industrialization), value creation was deemed to be autocratically for the generation of economic benefits for firms, industries and investors. However, this approach was based on top-down economics which gives little attention to the actual needs and values of the consumers. The emergence of the technology era facilitated a paradigm shift from the primitive export-oriented industrialization to a more open collaboration-oriented industrialization.

The collaboration-oriented industrialization characterizes the evolving principles of bottom-up economics, it fosters a reciprocal relationship and emphasizes the bidirectional increase of the participants' potential (Basmer *et al* 2014). It promotes a joint developmental process between the producer and consumer, thereby encouraging openness and knowledge transfer between the stakeholders, and it also develops trusts and a win-win situation for all the actors involved in the process.

The main goal of looking at value creation from the collaboration perspective is to create socially sustainable economic values for all stakeholders. Basmer *et al* (2014) highlighted that the new patterns of value creation (bottom-up economics and open production) based on the new manufacturing technologies generate chances for social sustainability, because they empower ordinary people to produce their own goods on their demand, and it also facilitates the participation of actors from the developing countries in the world's production.

In order to create self-sustainable environments, there needs to be concrete intervention to facilitate research and development (R&D), product invention, skills transfer, and creation of an entrepreneurial ecosystem irrespective of people's demographic and anthropologic status. The FabLab initiative rolled out by Massachusetts Institute of Technology's (MIT) centre for Bits and Atoms (CBA) enables a cost-effective R&D, it serves as a driving force in creating and engaging learning environments, and also as an effective means to valorise bottom-up innovation (Eychenne 2013).

Thus, in this paper a brief explanation of the FabLab movement is given, the deductive significance of FabLab on a country's performance on the global innovation index is examined.

This indicates whether the existence of FabLab has any significance to the country's performance on the global innovation index. Lastly, an in-depth survey analysis of FabLab's success is also conducted. Furthermore, at the end of the paper suggestions are raised on other areas that should be developed or included into the FabLab strategies.

2. What is a FabLab?

FabLab signifies 'fabrication laboratory', it is an innovative, sustainable and self-organised concept coined by MIT's Centre for Bits and Atoms (CBA). FabLab is a high tech laboratory or workshop where ordinary people can design just about anything from machines, to other artefacts which stimulates their livelihood (Sun 2009, De Weyer *et al* 2013, Schmidt *et al,* Mikhak *et al* 2002). This is otherwise known as personal fabrication (Sun 2009, De Weyer *et al* 2013, Schmidt *et al,* Mikhak *et al* 2002).

The Council for Scientific and Industrial Research in South Africa (CSIR 2007) describes FabLab as a hands-on laboratory that provides the technology to let people develop a conceptualised idea from inexpensive and readily available materials. FabLab is an idea incubator and opportunity creator that empowers people from all spheres of life to bring their imaginations to reality.

The FabLab workshop consists of a collection of tools for design and modelling, prototyping and fabrication, and other electronic tools, with open source software and other dedicated programs to bring advanced manufacturing technologies to ordinary people, by being involved in innovative experimental projects and peer-to-peer learning, and to also provide means to solve local problems creatively. Bosqué (2013) further invigorated this statement by stating that "*FabLabs are more about the people than the machines*". It is a centre where community and innovative development evolves. Subsequently, FabLab is creating an ecosystem for entrepreneurial empowerments that creates unprecedented domestic opportunities (See figure 1 below).

The FabLab is opened to people looking for practical training, Individuals, tinkerers, inventors, crafters, Children and youth, both school classes and neighbourhood groups, Community groups, adults, women, SME's, Innovation teams, researchers, students, and so on. the focus

of a basic FabLab is to assist individuals to conceptualize, design, develop, fabricate and test the products, using the equipments provided (Figure 2 below). In summary, FabLabs are open-source movements that practices rigid egalitarianism (Krebs 2014)

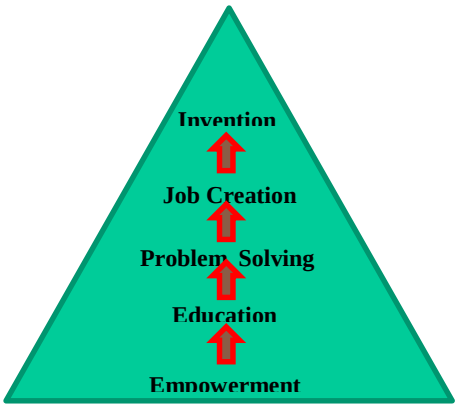

Figure 1: What FabLab offers (Van der Hijden & Mophuti 2012)

The Fab Charter

What is a fab lab?
Fab labs are a global network of local labs, enabling invention by providing access to tools for digital fabrication

What's in a fab lab?
Fab labs share an evolving inventory of core capabilities to make (almost) anything, allowing people and projects to be shared

What does the fab lab network provide?
Operational, educational, technical, financial, and logistical assistance beyond what's available within one lab

Who can use a fab lab?
Fab labs are available as a community resource, offering open access for individuals as well as scheduled access for programs

What are your responsibilities?
safety: not hurting people or machines,
operations: assisting with cleaning, maintaining, and improving the lab
knowledge: contributing to documentation and instruction

Who owns fab lab inventions?
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

How can businesses use a fab lab?
Commercial activities can be prototyped and incubated in a fab lab, but they must not conflict with other uses, they should grow beyond rather than within the lab, and they are expected to benefit the inventors, labs, and networks that contribute to their success

Figure 2: The Fab Charter (source: http://fab.cba.mit.edu/about/charter)

3. FabLab's Growth rate

Since the inception of FabLab at MIT in 2001, FabLab have been duplicated throughout the globe at an exponential rate. In 2002, the first three FabLabs outside MIT campus were opened in Boston's South End Technology Centre (SETC), Costa Rica Institute of Technology, and in Vigyan Ashram India respectively. One FabLab was reported established in 2003 and 2004. Some literatures on the FabLab initiative points out that the numbers of FabLab doubles every 18 months (Zijlstra 2013 & Gershenfeld 2009).

Figure 3: Globe view of FabLabs as of April 2015 (www.fablabs.io)

Figure 4 below shows the growth pattern of the FabLab initiative. After its commencement in 2001, the growth rate of the initiative was embryonic though promising. The surge of FabLab started in 2009, the pioneer of the initiative declared that 30 FabLabs were established in 2009 (Gershenfeld 2009), this later increased by 13.33% to 34 FabLabs in 9 countries by 2010 (IIT 2010). The numbers of FabLabs tripled from 34 to 100 in 2011, showing a percentage increase of 194%. This rose by 45% in 2012, 61.2% in 2013, 62.4% in 2014 and as of April 2015, there were 490 FabLabs workshops in 72 countries in the globe which is approximately 29% from the previous year's numbers.

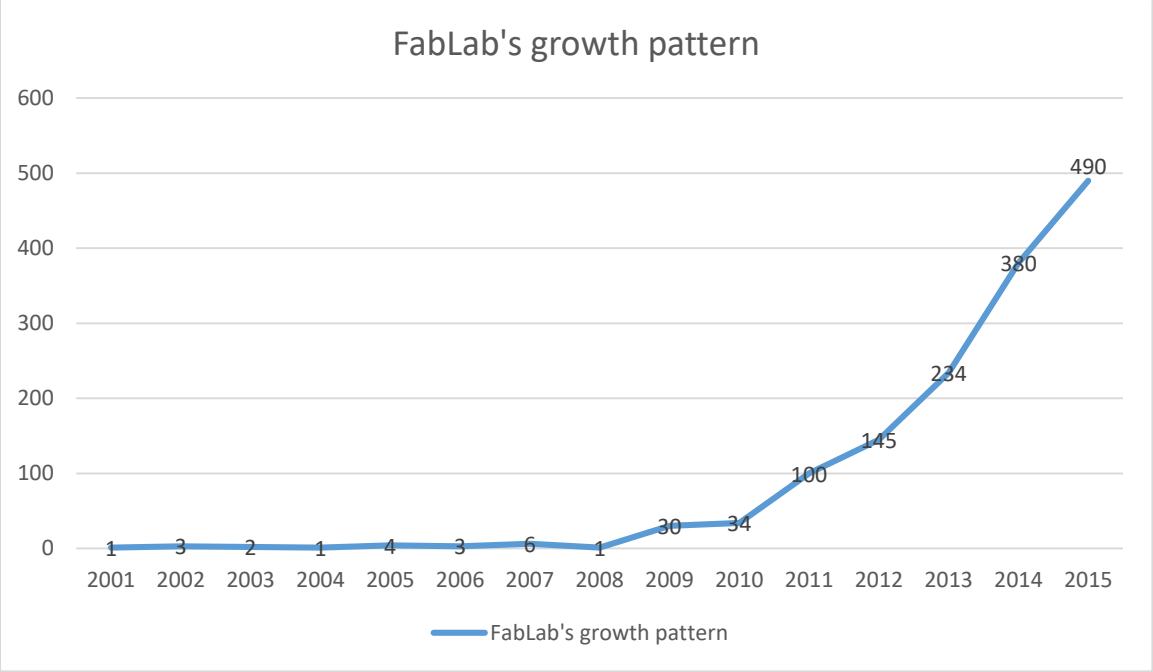

Figure 4: FabLab's growth pattern since inception

Applying the growth pattern of FabLab to the technology S-curve, it is evident that FabLab movement is still in its growth phase. The S-curve growth phase signifies that the knowledge about the initiative has accumulated and FabLab is now widely adopted (Cetindamar *et al* 2010). Moreover, its stage in the growth phase can only be empirically identified. Based on the reduction in the percentage from 2014 – 2015, can one say that the FabLab has reached its maturity phase, or at what time would FabLab get to the maturity stage of the S-curve? The assertiveness of this assumption will be left for another research study.

One of the goal of this section is to provide a comparison of FabLab's growth rate from the context of a developed country to that of a developing country. In 2002, Costa Rica's FabLab at Costa Rican institute of technology was the first FabLab opened outside of the United States and also in a developing world. Ever since the unveiling of the workshop, there has been a massive gap in the growth rate of the FabLab in developed and developing countries.

Table 1 below shows the continental breakdown of FabLab as at the time of this research project:

Continents	Numbers of FabLab Network
Africa	22
Asia	50
Australia and Oceania	6
Europe	273
North America	98
South America	41
Total	**490**

Table 1: Continental breakdown of the FabLab Network (as of April 2015)

35 of the 72 FabLab countries mentioned above are from the developed economies, and as of April 2015, there are 379 FabLab workshops in the developed country, which is approximately 11:1 ratios of FabLabs per country. Meanwhile in the developing countries, there are 111 FabLabs in 37 developing country, which is a 3:1 ratio. Comparing this statistics, it is evident that the developed economies are more oriented to the significance of the initiative to the development of their citizens and the sustenance of their economy as a whole.

Moreover, various scholarly articles states that, a focus on science, technology, engineering, arts and mathematics (STEAM) are crucial to foster a country's innovativeness (Schwab & Sala-i-Martín 2014; Kier *et al* 2014, Sarchinschi 2012). Hence, Innovation and R&D plays an important role as a driving force for ensuring economic growth and well-being of both developed and developing economies. As stated in earlier sections, FabLab educates by providing hands-on learning opportunities for all users, and also providing means for users to develop their ideas through rapid prototyping machines and other technological apparatus. Therefore, it is safe to say that FabLab is a cut-across initiative that bridges the gap between people, educational institutions and business organizations. Thereby, pioneering a real move for user and social innovation.

At this point in the research work, the question now is "could the presence of FabLabs be used as one of the quantifiers of a country's performance on the global innovation index (GII), value creation, and research and development"? Could the presence of FabLab improve a country's status on the GII? In what ways can the contribution of FabLab be measured? What

are the determinants of successful FabLab projects? These questions will be analysed in the later sections of the research study.

4. The significance of FabLab to Global innovation index

The global innovation index (GII) is an analytical tools developed by Cornell University, INSEAD, and the World Intellectual Property Organization (WIPO). As stated in the report, *GII is a 'unique tool for refining innovation policies for providing an accurate picture on the role of science, technology and innovation in sustainable development', and for assessing where more efforts are urgently needed* (GII 2014). The recent global innovation report was structured around the implication of human factor in innovation. The focus on the 'Human Factor in Innovation', explores the role of the individuals and teams behind the innovation process.

That being said, using the recent innovation index (GII 2014) as the foundation for this analysis, the aim of this section is to analyse if the FabLab initiative plays a part (if any) in a country's innovativeness (i.e. standing in the index), and also quantify its contributions to the countries where it is present.

Excerpts from the report stipulated that *workers with advanced degrees are an essential starting point for innovation. Yet their existence does not guarantee scientific or technological breakthroughs or other forms of non-technological or social innovations. Creative and critical thinking, and the appetite for taking risks and thinking entrepreneurially, often matter at least as much as technical qualifications. In addition, innovation is spurred by having favourable conditions in which actors and society are open to new approaches.* Moreover, the fundamental driver behind any innovation process is the human factor associated with it, other drivers such as technology and capital are in direct correlation to the human factor.

The statements given above corroborates the viability and contribution of a basic FabLab in ensuring the development and creation of a collaboration-oriented environment where all actors from sparse geographical areas can work together to co-create the favourable

conditions that promotes social and sustainable development. Hence, creating targeted and applicable values to solve local problems. According to a statement by Chandrajit (GII 2014), he stated that "*in order to build an innovation-driven nation we need to educate our people well, and to provide them enough resources and incentives to chase their dreams"*.

GII relies on two sub-indices, the Innovation Input Sub-Index and the Innovation Output Sub-Index, each built around key pillars. There are five input pillars that captures elements of the national economy that enable innovative activities: (1) Institutions, (2) Human capital and research, (3) Infrastructure, (4) Market sophistication, and (5) Business sophistication. Two output pillars capture actual evidence of innovation outputs: (6) Knowledge and technology outputs and (7) Creative outputs. According to the report, 143 countries were assessed on the basis of their innovativeness, and 67 of the countries has one or more FabLab workshops. Referring to the earlier sections, we realised there are 72 FabLab countries, this represents that 93% of the FabLab countries on the GII index.

From the sub-indices stated above, it can be extrapolated that FabLab does contribute to the innovation sequence. As highlighted in earlier sections, the aim of the FabLab initiative is to contribute to the innovation cycle, by educating, empowering and providing adequate means for an average individual to indulge in their creativity and bring their conceptual ideas into reality. Therefore, the effective implementation of a basic FabLab facility contributes to the efficacy of the GII's input sub-index and the output sub-index.

In addition, there are various factors that determines the growth of a country, out of which the ability to develop indigenous technologies is among, however, one of the under-emphasized but relevant key contributions to a country's innovation and growth is their absorptive capacity, that is their ability to absorb technological breakthroughs and innovative initiatives from other countries.

Reviewing the recent GII report (2014), we discovered that out of the top 20 innovative countries listed in the innovation index 18 have at least one FabLab workshop, this represents 90% of the top performing countries. The most innovative country in the world (Switzerland), has 11 functional FabLab workshops, while the 6th ranked country (United States of America)

has 81 functional FabLab workshops. We provide some cases below to determine the FabLab's contribution in the GII ranking. In the review, we looked at a country's standing before and after the introduction of FabLab, and make conclusions on the viability of the initiative to a country's innovativeness.

4.1. Case reviews Japan:

Though Japan has been one of the major players in the world's innovation index in time past, the first FabLab facility was opened in Japan in 2011. Reviewing Japan's ranking in the GII report before the introduction of FabLab, we uncovered that in 2009, Japan was ranked 9th in the GII report, in 2010 the ranking dropped to 13th, in 2011, Japan's ranking further dropped to 20th, and also in 2012 to 25th position on the GII ranking. In 2013, Japan's ranking rose to 22nd position, and presently, Japan is ranked 21 on the present GII report.

Even though the presence of FabLab cannot be vividly linked to a country's status in the GII index, however, it can be categorically stipulated to contribute in some forms. As we uncovered further, Japan rolled out 2 FabLab facilities in 2011, 1 FabLab in 2012, 3 in 2013, and presently has 11 FabLab workshops. Inquisitively, can we link the Japan's ranking to the numbers of FabLabs present at a particular instance?

4.2. Case review Australia:

Just like in the case of Japan, Australia have also been one of the major players in the world's innovation cycle. However, the first FabLab was introduced to Australia in 2013, and currently has 3 FabLabs in the country as a whole. In ascertaining FabLab's contribution to Australia's ranking, in 2011 Australia was ranked 21 on the GII index, the country's standing also dropped to 23 in 2012. However, in 2013, the country's status rose to 19, and in the present GII report, Australia is ranked 17.

4.3. Case review Burkina Faso:

Before Burkina Faso joined the FabLab movement, there rank on the GII was staggering. In 2009, Burkina Faso was ranked 115, and in 2010 they ranked 122. Burkina Faso has only one FabLab workshop which was initiated in 2011, and the country's rank on the GII rose by two points to 120, though the rise in rank does not signify the existence of FabLab as we observed a relapse in the ranking in 2012 to 122. However, Burkina Faso's status has been increasing ever since. In 2013, they were ranked 116, and in the recent GII 2014, they were ranked 109. So, could these growths in GII rating be atomically linked to the existence of FabLab, or how could the contribution of the initiative be examined?

Excerpts from this GII reports illustrated three key factors:

- The inexistence of FabLab in a country does not necessarily mean the country would not be innovative.
- The numbers of FabLab's workshops present in a country does not signify that the country is more innovative than the others
- FabLab's contributions in a country's innovation index is not quantifiable (yet)

Despite the factors stated above, there exists deductive, empirical and logical evidences based on the indices used to quantify the GII, and the factors used in measuring innovations activities (UNESCO 2009), that if efficiently utilized, the FabLab initiative contributes immensely in ensuring sustainable development thereby creating long-term values, which is the main aim of the GII reports.

After this analysis, the question that comes to mind is "Could the innovativeness of a country without a FabLab be increased by the introduction FabLab?", also "What metrics should be used to quantify the impact of FabLabs in a region, and the country as a whole"? These questions should be emphasized so the full impact of FabLab can be identified.

5. Determinants of Success

Burgelman & Maidique (1988) defined success as the achievement of something desired, planned, or attempted. In lieu of this definition, being a successful organization is more than

the financial income accumulated, though financial returns is one of the key determinants of success. According to this explanation, we outline that the success of an initiative is dependent on the accomplishment of their desired, planned, and attempted objectives. Also we structured the determinant of the FabLab success around the accomplishments of the Fab Charter (Figure 2).

As highlighted in the paragraph above, there are no specific ways in which success can be quantified, but for the aim of the research, the following factors will used as the determinants of FabLab's success. These factors were derived from the core value and focus of FabLab, as drafted in "The Fab Charter":

I. Contribution to innovations and R&D;
II. Contribution to human development (i.e. in empowering people);
III. Achievement of its goals and objectives;
IV. Types of users
V. Contributions to entrepreneurship and business development;
VI. Accessibility for users;
VII. Sustainability;
VIII. Collaboration within the FabLab network;
IX. Usage frequency;
X. Availability of raw materials

We aim to cover all these factors by grouping them into five categories during the data analysis section of the research report, and these categories are as follows: Focus and Equipment; Accessibility; Collaboration; Achievements; and Sustainability

6. Research Methods

This section aims to present a framework of actions to define a relation between the research questions and research objectives, and to elaborate on the design and methodology used during the research study. It is intended to outline the methodology followed as well as the main aspects of the research. For the purpose of this study, we motivate the utilization of both quantitative research method and qualitative case study review method, describing the components and procedures that were involved during the utilization of these methods.

As stated above and in earlier sections, we used the quantitative research method, through the conduction of an online survey, aimed and directed at managers, volunteers, and administrators of the FabLab facilities in order to gather adequate information. Also, the survey was structured in both open-ended and close-ended questions, this was done so as to gather more useful qualitative information from the survey participants (See Appendix 2 for the layout of the survey). The preceding section provides the analysis of the online survey conducted.

7. Survey Analysis

The online survey was designed in English, German, and French. This was done so as to eliminate the language barrier and gather more data from a broader perspective of the survey respondents. Moreover, the online survey was conducted for approximately two months, and a total number of 94 participants responded to the online survey globally. This equates to 95% confidence level, +/-9 confidence interval. The confidence level gives us 95% certainty to posit and make conclusions about the FabLab ecosystems.

As stated in the section above, the survey was structured with both open and close-ended questions, so as to gather viable information from the respondents. In this section we discuss the findings of the research survey, these findings are grouped into five (5) different categories, so the success can be effectively assessed from all stance. We provide the findings of each categories at the end of the categories.

7.1. Focus and Equipment

The aim of this category is to explore the focus and description of the FabLab facility, and to also uncover the types of equipment within the facilities. This category covers questions 3, 4, and 5 asked during the data gathering process (consult Appendix 2 for the survey questions and structure).

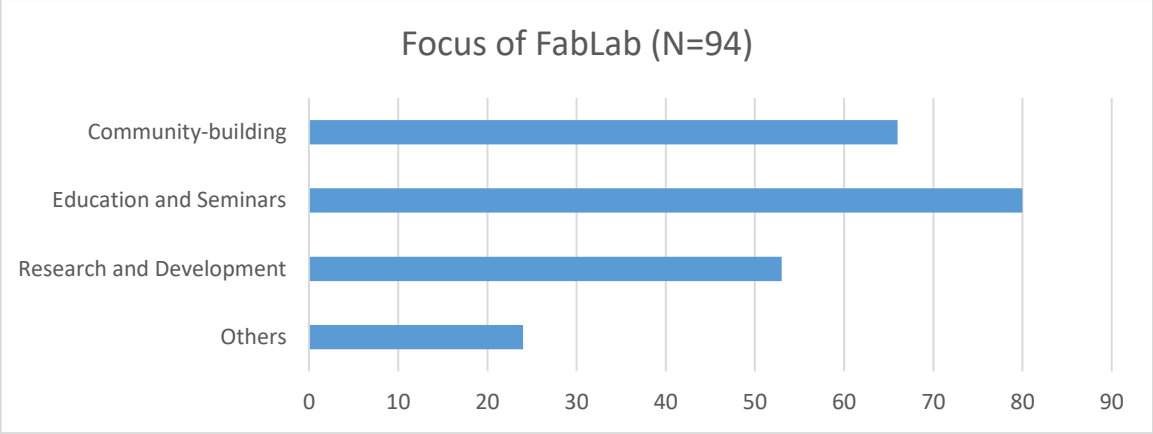

Figure 5: Focus of FabLab (N=94)

By community-building, we mean the empowerment of the general public within the locale of their workshop. The education and seminar portrays that their facility engages in mentoring, teaching, and providing educational workshops. Lastly, the R&D shows that they provide opportunities for individuals to discover and develop new products ideas.

According to figure 5, 66 of the respondents indicated their FabLab is focused on community-building, 80 indicated they also conduct educational seminars within their respective facilities, 53 indicated that they are more research oriented, finally, 24 participants indicated they have additional objectives, some of which are, to provide open and affordable access to machines and techniques that allows innovation and entrepreneurial flair to flourish, community outreach, architecture, to create new businesses based on digital designs and digital fabrication, Execute cultural and creative applications through Fab Lab concepts, smart city projects, and fostering digital competencies.

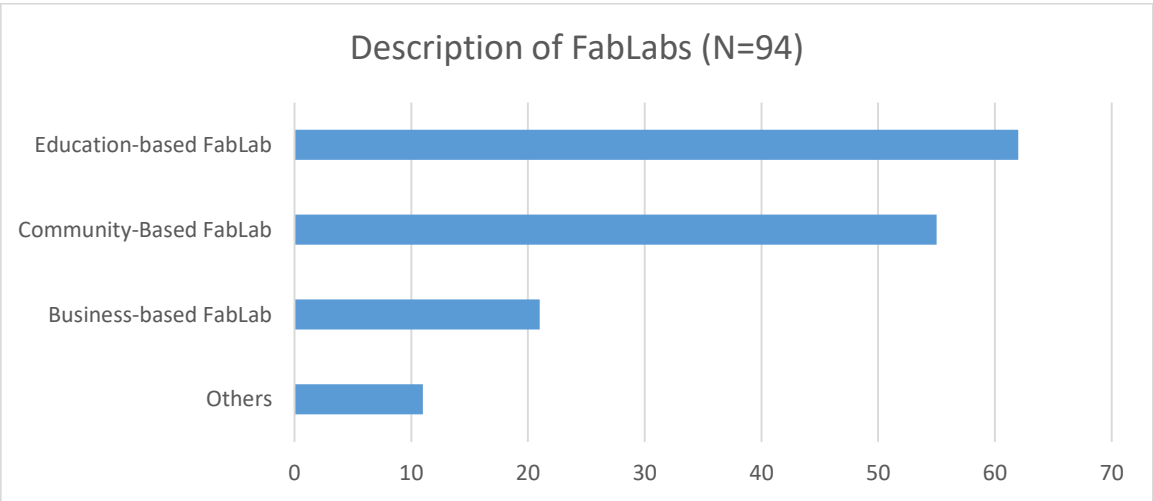

Figure 6: Description of the FabLab facilities (N=94)

By this, we mean the premises where the FabLab facility is situated. According to figure 6 above, 62 participants indicated that they are established within an educational organization, 55 indicated that they are located within a communal space, while 21 indicated that they are established within a business organization, while 11 indicated they are situated within a city-council/municipal space, and independent research facility, and a science centre.

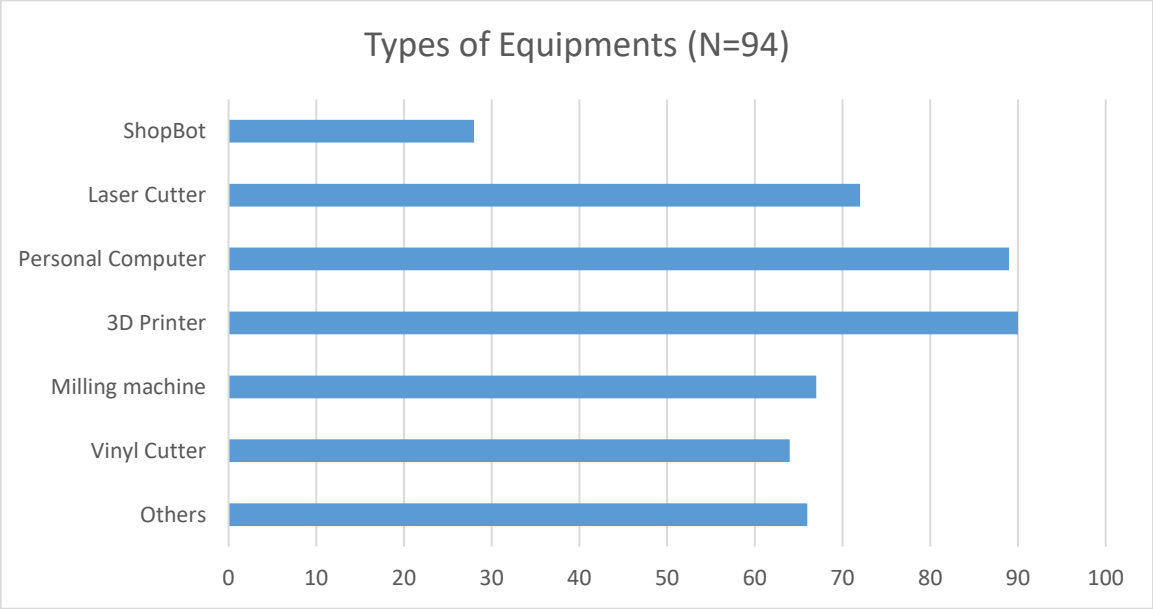

Figure 7: Equipment within the FabLab facilities (N=94)

As indicated in figure 7 above, 28 participants indicated they have ShopBot, 72 indicated they have laser cutters, 89 indicated they have computers, 90 indicated they have 3D printers, 67 indicated they have milling machines, 64 indicated they have vinyl cutters, while 66 indicated they have additional equipment not listed in the online survey. These equipment includes: Lathe machines, digital sewing machine, 3D Scanners, simulations software, CAD Arduino, Raspberry, UDOO, Annikken, Forrest CNC Router, materials for molding & casting, soldering irons, measuring equipment, Drill press, metal chop saw, vertical drilling machine, silkscreen printing, Oscilloscope, Graphics Design Workstation, Paintshop etc….

Results

Analysing the information given in this subcategory reveals that most of the FabLab workshops are in line with paragraph 1 and 2 of the fab charter, in providing a well-equipped

facility that enables invention by providing access to digital fabrication tools, and also by providing operational, educational, and technical within their facilities (see figure 2).

Moreover, according to figure 5, there are more FabLab focused on educating and providing workshop seminars for users, followed by community-building, and R&D. Also, figure 6 shows that more FabLabs are situated within an educational facility and communal space. Based on this finding, it is evident that the FabLab initiative intangibly contribute to the human developmental attributes (such as science, technology, engineering, arts, and mathematics (STEAM)), thereby enriching some of the factors that promotes innovation and sustainability as a whole.

7.2. Accessibility

The aim of this category is to explore in line with paragraph 4 of the fab charter (figure 2) which says that '*FabLabs are available as a community resource, offering open access for individuals as well as scheduled access for programs*', the accessibility of the FabLab facilities for an average user, which also emphasizes the types of users, their age group, the total numbers of weekly users that visits the facility, and the opening hours of the facilities. This category covers questions 6 to 10 of the online survey (consult Appendix 2 for the survey questions and structure).

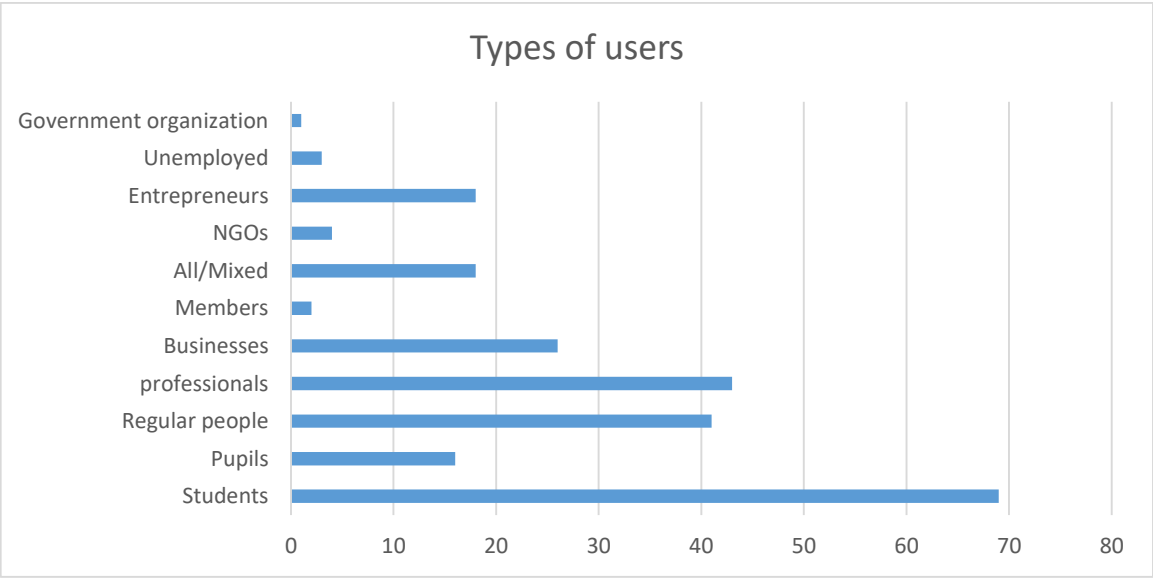

Figure 8: Types of users (N=94)

According to figure 8 above, 69 participants indicated that the types of users that visits their facilities are students, 16 indicated pupils, 41 indicated regular people (which includes retired people, community members, freelancers, and tourists), 43 participants indicated professionals (which includes Software engineers, engineers, artists, designers, teachers, researchers, makers, etc), 26 indicated business organizations, 2 indicated that they are strictly for their members, 18 participants indicated mixed visitors (which includes all types of users), 4 indicated non-governmental organizations (NGOs), 18 indicated entrepreneurs, 3 indicated unemployed, and lastly, 1 respondent indicated government organization.

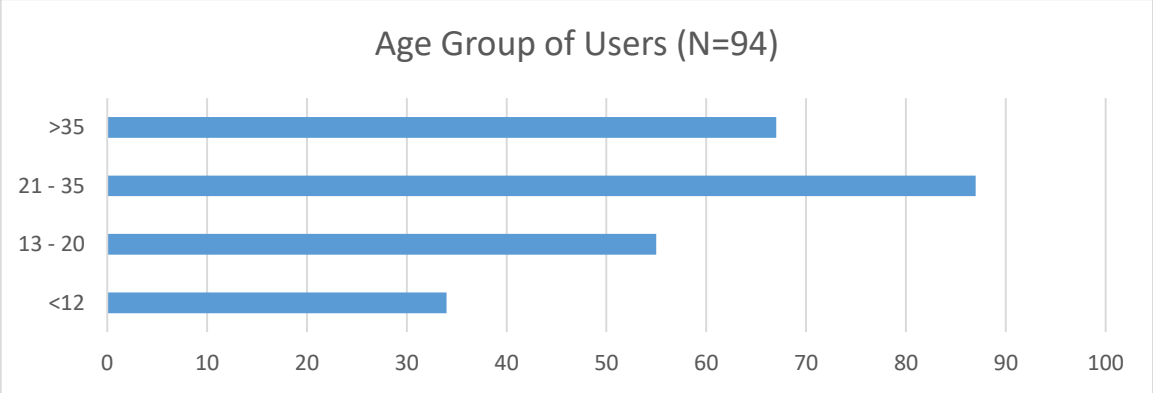

Figure 9: Age group of users (N=94)

According to Figure 9, 34 respondents identified attendances from children below the ages of 12, 55 respondents acknowledged attendance from the age group between 13 and 20, 87 participants acknowledged attendance from the age group 21 to 35, while 67 indicated attendances from the age group above 35.

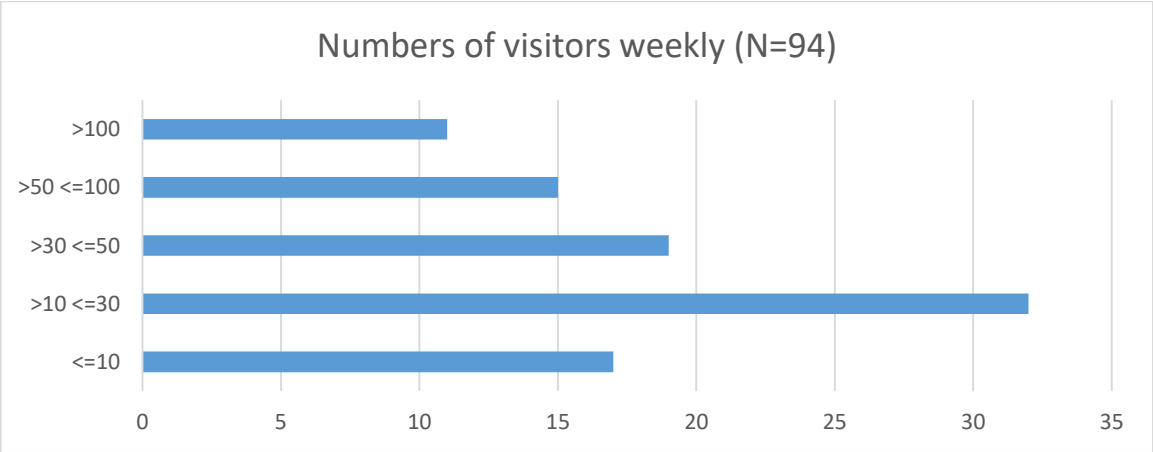

Figure 10: Numbers of visitors (N=94)

According to figure 10, 17 respondents indicated they have 10 or lower visitors weekly, 32 indicated they have from 10 to 30 visitors weekly, 19 indicated they have from 30 to 50 visitors weekly, while 15 indicated that they have from 50 to 100 visitors weekly, and lastly, 11 respondents indicated that they have above 100 visitors weekly.

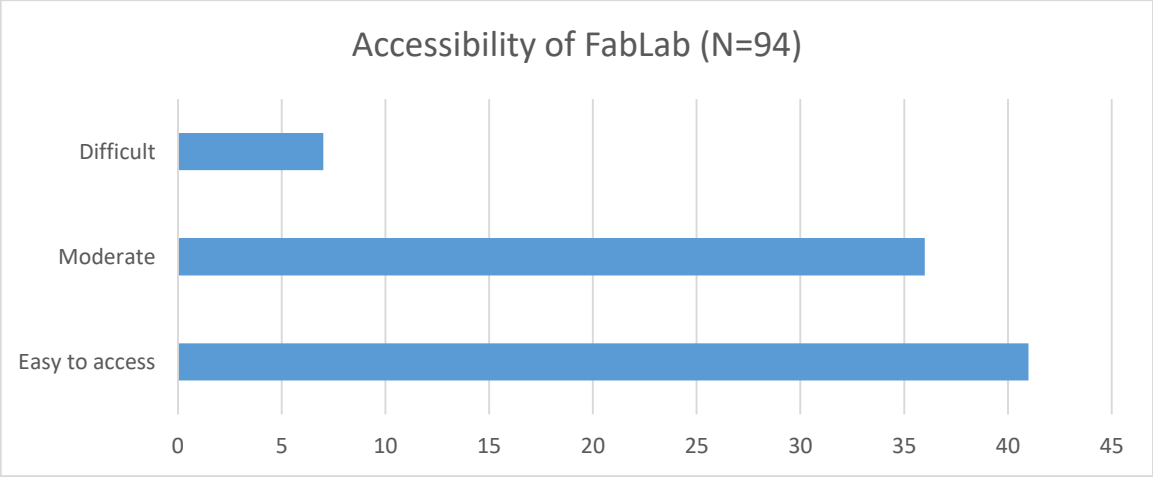

Figure 11: Accessibility of FabLab (N=94)

In terms of the accessibility of the FabLab facility (figure 11 above), 41 respondent indicated that their facility is easily accessible for most visitors (that is, they are either located at the city centre, or is a walking distance for most visitors, or it can be easily accessed by bicycle), while 36 indicated that their workshop can be accessed by public transportations (that is, buses, trams, and metro rails, or any other forms of transportation the visitor chooses to use), and finally, 7 specifically indicated that their facility is a little complicated to access, either due to the lack of public transportations or the distance between their facilities and the communities.

According to figure 12 below, the FabLabs have varying opening hours. 5 respondents indicated that they open once a week, 11 respondents indicated that they open twice a week, 8 indicated that they open three times in a week, while 2 participants indicated that they open four days in a week, 34 respondents indicated that their facility is opened daily, 24 indicated they open only during working hours (weekdays), 11 respondents outlined that they are opened only on appointment basis, while 6 respondents indicated that they do not have a fixed opening period or hours.

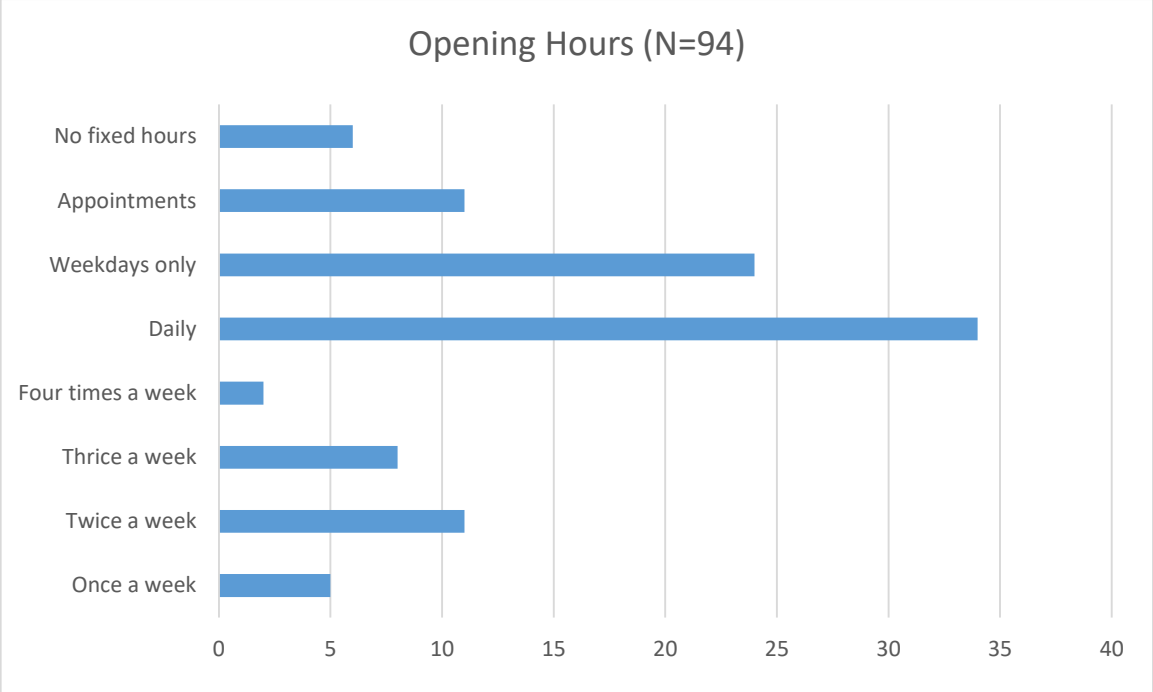

Figure 12: Opening period of the FabLab facility (N=94)

Results

From the information presented in this category, it was observed that most of the users that interacts with the FabLab facilities are mostly students, professionals, regular people, and business organizations (figure 8), this was further corroborated by the high frequency of the age groups 21 and above (figure 9).

In terms of meeting the accessibility section of the Fab charter, over 90% of the respondents indicated that their facilities are either easily or moderately accessible for users/visitors alike, and over 50% of the respondents indicated that they are either opened daily or weekdays. Therefore, it can be stipulated that the FabLabs facilities are offering adequate access to the populace. However, the tautology of open access being offered will be uncovered in the preceding categories.

7.3. Collaboration

According to paragraph 1 and 2 of the fab charter, an average FabLab belongs to a global network of local labs, which should share an evolving inventory of core capabilities. From this

information, it is evident that inasmuch as there needs to be an open access to digital equipment within the workshop, in order for any facilities to be referred to as FabLab, there needs to be collective participation and willingness to share and collaborate with other workshop on the global FabLab network. This category provides responses on questions 13 to 15 of the survey which looks at the state of collaboration between the FabLabs, and lastly stating the suggestions made by the participants on how collaborations within the network can be effectively enhanced.

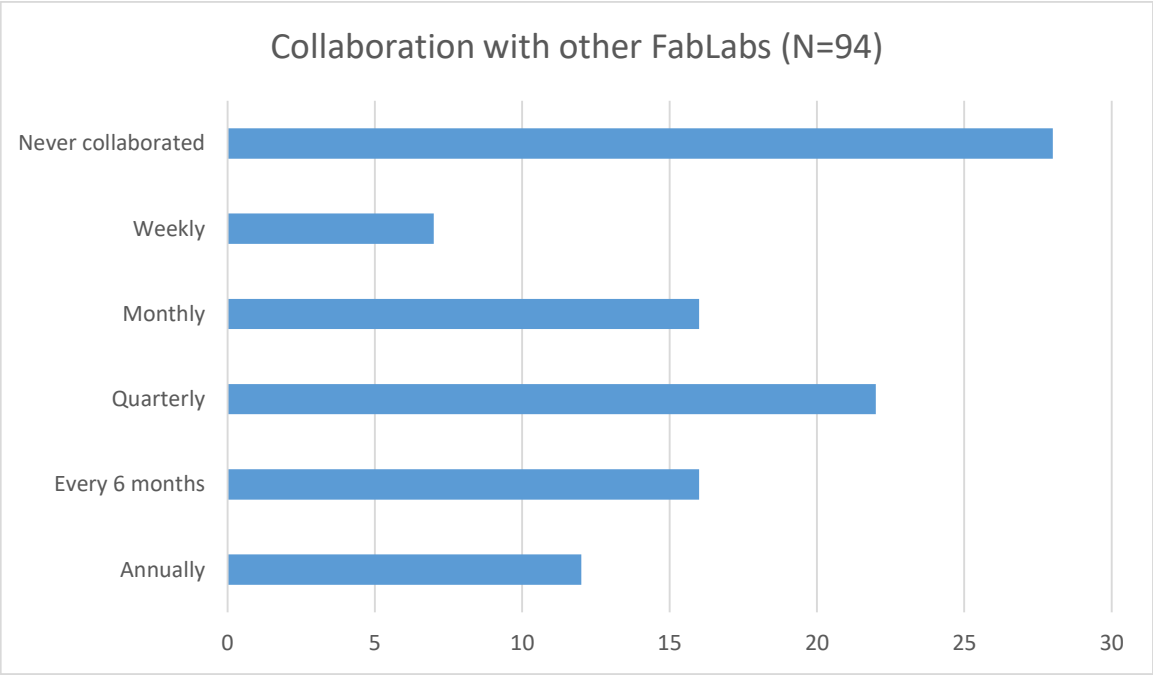

Figure 13: Collaboration within the Global network (N=94)

According to Figure 13, the state of collaboration within the FabLab network can be assessed. Though the frequency of collaboration varies within the network, more than 70% of the respondents indicated that they have collaborated with other FabLab. 12 respondents indicated that they do collaborate with other FabLabs within the network on an annual basis, while 16 indicated that they collaborate every 6 months, 22 indicated that they collaborate quarterly, while 16 respondents indicated that they collaborate monthly, 7 participants indicated that they collaborate weekly, while 28 respondents indicated that they have never collaborated with other FabLabs, either due to their stringent work schedule, the novelty of their FabLab facility, lack of technological capabilities, and the lack of standardized approach towards collaboration.

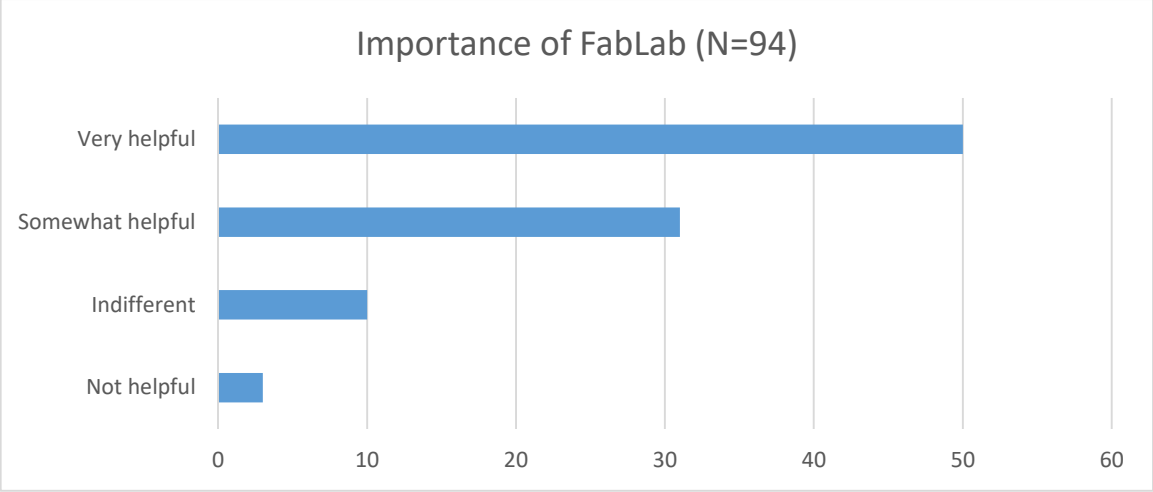

Figure 14: Importance of collaboration (N=94)

From the survey, we gathered the importance and ease of collaboration within the network. According to figure 14 above, 50 respondents indicated that collaborating with other FabLabs has been very helpful, while 31 respondents indicated that collaborating with other facilities was somewhat helpful, while 10 respondents indicated that collaborating was neither helpful nor unhelpful, lastly, 3 respondents indicated that collaborating with other FabLab facilities was not helpful.

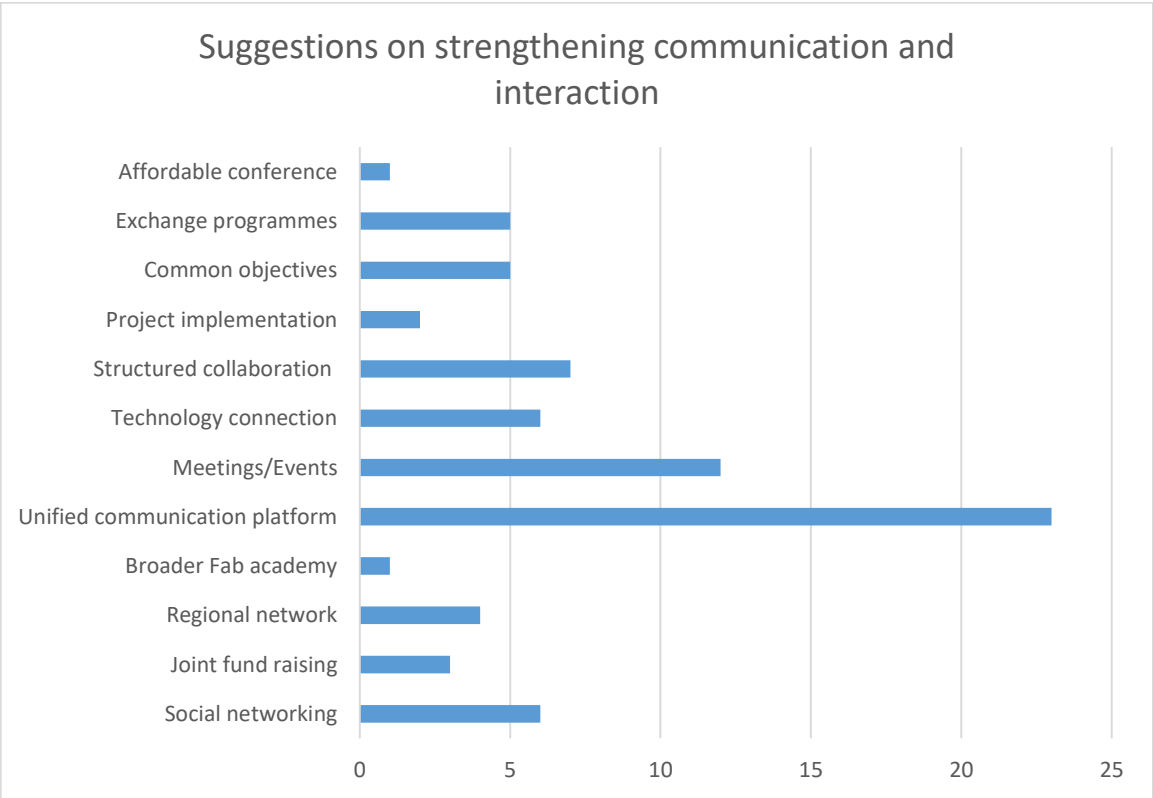

Figure 15: Suggestions on how FabLab collaboration can be strengthened

Finally, figure 15 above provides suggestions on how collaboration between FabLabs can be effective. Among all the suggestions raised, 23 respondents identified the need for a unified communication platform within the FabLab network to aid content and information sharing, and to also eliminate the confusion caused by dispersed information by different online platforms.

12 respondents indicated that there is a need for more regular meetings and joint events within the network, so relationship and joint focal area can be established. 6 suggested the need for a better technology connection within the network, while 7 suggested having a standardized and structured collaboration channel, 5 respondents suggested having a common objectives within the FabLab network, another 5 suggested promoting exchange programmes and field trips within the network, where volunteers and team members can be shared with other facilities.

4 participants indicated the need for a regional network to promote synergy among actors in the network, to oversee the basic affairs of the FabLab initiative, facilitating the distribution of information and formulation of a structured approach to enhance communication. 3 respondents suggested encouraging a collaborating funding opportunities, 6 suggested the effective utilization of the social media platform. Lastly, the remaining participants suggested having a broader fab academy that teaches anything, making the conferences more affordable, and a move into the project implementation phase rather than just deliberating.

Results

Van der Hijden & Juarez (2014) stated in their report that the worldwide FabLab ecosystem is an interesting source of information and collaboration, which can only be effectively sustained if there are bidirectional contributions between one or more FabLab. Based on this statement and the information gathered, it can be stipulated that the FabLab initiative is meeting its collaboration objective, though there is a great need for cohesion between the FabLab networks.

One effective way to implement synergy and cohesion within the network is by establishing a structured regional organization that coordinates, controls, monitors, and facilitate collaboration of innovative ideas and adequate distribution of information and resources within the network. Moreover, one evident pattern derived from this survey is that most respondents feel collaboration is solely dependent on the nearness to other FabLab facilities. Therefore, the creation of a structured communication platform should be elaborated.

Also, the lack of a standardized method of operation for the workshops within the FabLab Network should be focused on. As uncovered from the analysis, though most respondents indicated that they have collaborated, and that they find it helpful, the lack of a standardized method still poses as a barrier in encapsulating the full potentials of collaboration. Reviewing figure 15, most of the suggestions made could be effectively implemented with the existence of a more structured platform/method which any facility within the FabLab ecosystem needs to adhere to.

7.4. Sustainability

The productivity and longevity of any empowerment initiative is solely dependent on the efficacy of the sustainability plan implemented. According to a survey conducted by Boeck and Troxley (2011), the goals of sustainability are to balance dependency on grants, educational and government funding with growth in self-sustained funding, to nurture the Fab ecosystem with products, services and entrepreneurial enterprises, shared across the network of FabLabs worldwide. Additionally, to maintain the goals & values of the Fab charter & community, retaining an emphasis on open access, open information sharing, and sharing ideas, tools, and interoperability.

In this category, we sum up the responses on questions 11, 12, and 22 of the research survey (see Appendix 2), which aims to uncover the mode of operation of the facilities respectively, it also uncovers how the FabLab facilities have been sustained since inception, and lastly identifies some impediments to the FabLab facilities (if any).

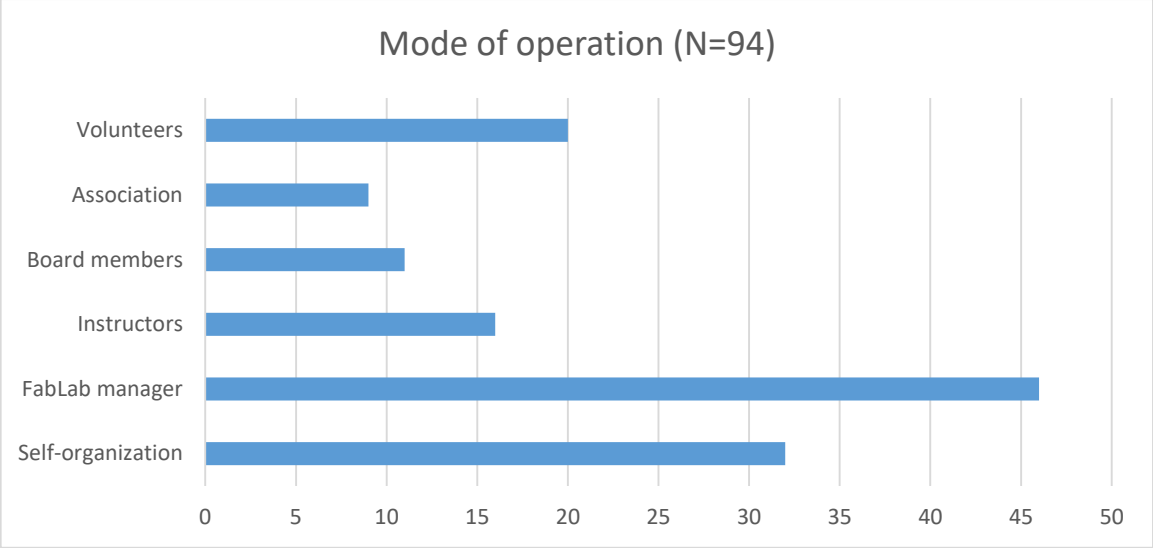

Figure 16: Mode of Operation (N=94)

From figure 16 above, 20 survey respondents indicated that they operate with the assistance of volunteering enthusiasts, while 9 respondents indicated that they function as an association, 11 respondents indicated that their functionality is dependent on their board members or board of directors, while 16 respondents indicated that they function by using instructors or advisors, 46 participants indicated that they have one or more managers in charge of their facilities, and finally, 32 indicated that the operate by self-organization.

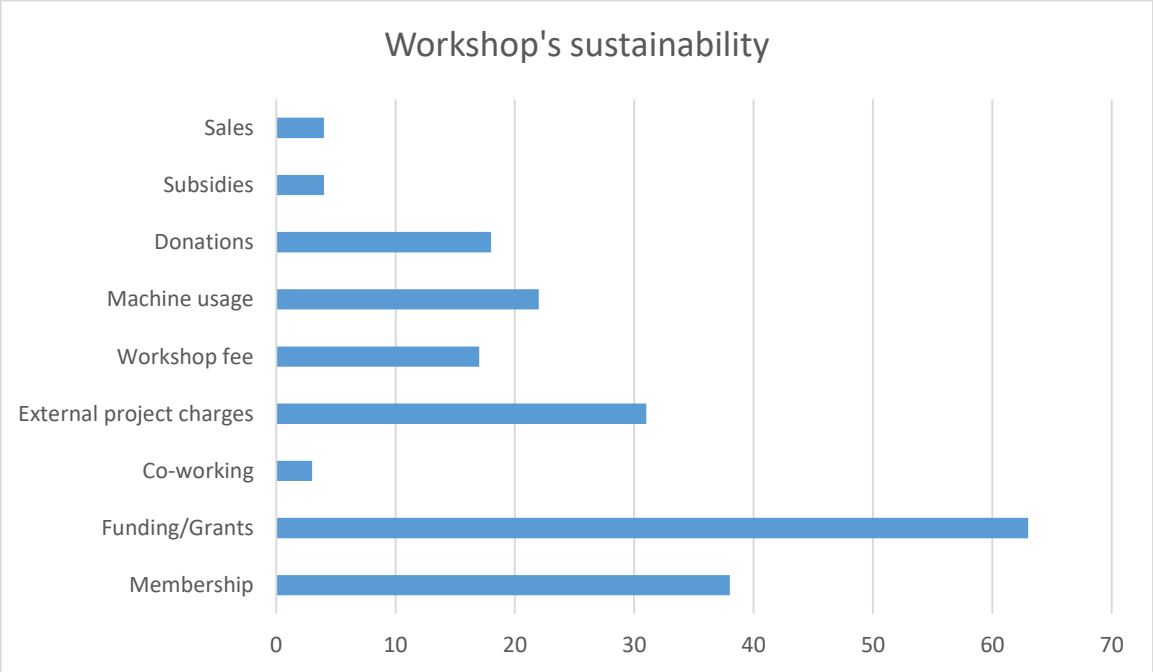

Figure 17: Sustainability of FabLab

As stated in the beginning of the section, the productivity and longevity of FabLab is also dependent on the efficacy of the sustainability plan implemented. Figure 17 above uncovers the means the responding FabLabs use in ensuring the annual operation of their facilities. From the illustration, 4 respondents indicated they are sustained by selling the products produced within their workshop, such as 3D printers and filaments, open source technologies, and awards and plaques etc. another 4 respondents indicated they are sustained by subsidies from external business organizations and partners.

While 18 respondents indicated that they also use donations from the community, businesses, and government organizations. 22 respondents indicated they charge users certain fees for using their machineries and equipment, 17 indicated that they charge for the workshop organized within their facilities, while 31 respondents indicated that their workshop is sustained by the external project done for corporate business, such as construction of prototypes. 63 respondents indicated that they use funding and grants from government and other sponsors, lastly, while 38 indicated that they charge their members certain amount for sustaining their workshops.

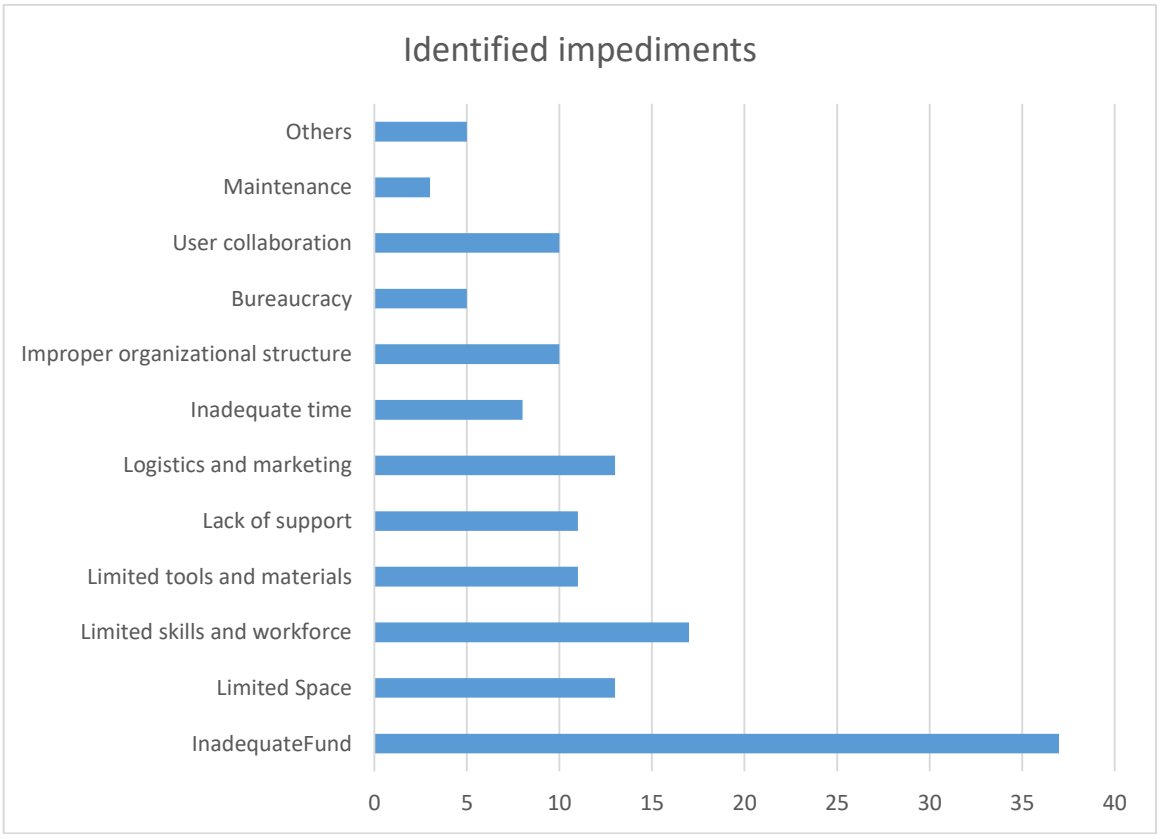

Figure 18: Impediments to FabLabs Success (N=94)

Figure 18 shows the impediments identified by the survey respondents, as expected, more respondents (37) indicated the shortage or lack of funds as the major constraint to their workshop, while some (13 respondents) indicated limited space, either because they have outgrown their present location or the lack of private office, or storage space etc. 17 respondents indicated shortage of skillful workforce and volunteers, 11 indicated inadequate tools and production materials, another 11 indicated lack of buy-ins and support from government and also from the community they are located in.

13 respondents indicated logistic and marketing constraints, 8 indicated inadequate time due to their employment status, which affects their productivity and opening hours. 10 respondents indicated the improper organizational structure used within the FabLab network (that is, the lack of standardized business model and work ethics), 5 indicated indicate institutional bureaucracy as a constraints, while another 10 respondents indicated the lack of user collaboration, while some indicated high cost of maintenance, competitions with other well established business organization, novelty of their workshop, and budget restrictions.

Results

From the information presented in the analysis, it is pertinent that the sustainability of the FabLab is reliant on the development of a schematic business model that serves as a guide for both new and existing workshops within the global FabLab network, which is also partly dependent on the development of a unified communication channel, and the formalization or expansion of the existing structure used within the FabLab ecosystem.

By having a formal structure and unified communication platform, information can be effectively distributed within the actors in the ecosystem, information such as how to make the FabLab sustainable (figure 19 below), also it will be useful in creating more awareness of the FabLab initiative, thereby eliminating impediments such as lack of support, inadequate workforce and lack of user collaboration. Also, it would also encourage more external research on additional developmental areas the initiative should focus on.

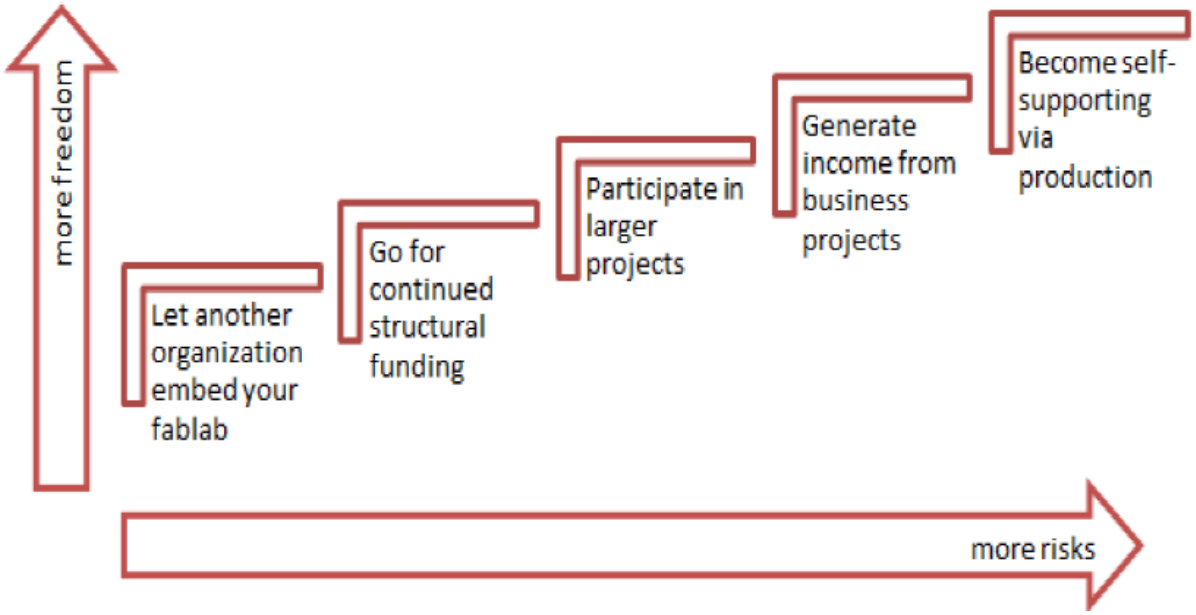

Figure 19: Five strategies for increasing FabLab income

7.5. Achievements

In the section that focused on how successful initiatives are assessed, we listed the following factors as part of the determinants of a successful project: contribution to innovations and R&D; contribution to human development (i.e. in empowering people); achievement of its goals and objectives; and contributions to entrepreneurship and business development.

The aim of this category is to explore in what ways the FabLab facilities have met the objectives highlighted in the factors listed above and in accordance to the Fab charter. This category covers questions 16 to 21 of the research survey (see Appendix 2).

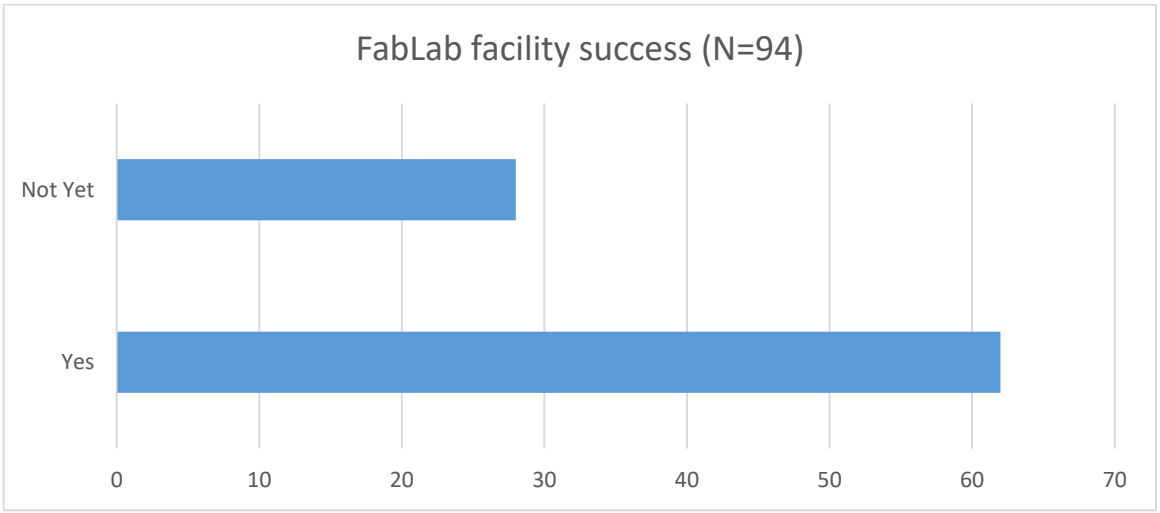

Figure 20: FabLab facility success (N=94)

According to figure 20 above, when asked whether their facility has been successful in the locale, 62 respondents indicated that their facilities has been highly successful, some of these success ranges from the recorded impact the facilities have in the community, to the higher demand from users, to the successful construction and maintenance of the facility with limited start-up funds, to the massive contribution towards STEM (science, technology, engineering, and mathematics), the start-ups of different entrepreneurial vocations, the consultation of external organizations seeking the expertise of the facilities for prototyping and other projects, and the development of innovative in-house products.

While 28 respondents indicated that their facility is yet to record any marginal success, some of which are due to the novelty of their facilities, the irregularities in user participation due to the distance between their facility and the city, lack of awareness of the FabLab initiative, to the lack of space due to lack of support from the local government, to the organizational restrictions on their mode of operation, to the lack of knowledge in the required field of competence, to the insufficient funds, tools and materials, to the high cost of maintenance, and the lack of a working business model.

7.5.1. Completed Projects and Entrepreneurship opportunities

The aim of this section is to explore the progress made by FabLab by exploring the projects completed within the Facilities, and also the entrepreneurial opportunities presented by the existence of the Fab ecosystem. This section provides the answers collected during the research survey on questions 17, 18, and 21.

Completed projects: for this question, we gathered a total of 90 responses, and approximately 93% (84) of the respondents indicated that they have worked on one or more basic or complex innovative projects, some of which include the following:

Online student mentorship, FabLab Kids, Cranial implants, city public furniture, 3D printed flying drones, wireless general purpose sensor aggregation, bus clock, gardening (automated device to monitor and correct greenhouse condition), recycling / reusing old electronics,

nautical projects (submarine drone, sail repairs), Educational/research robots, automotive harness design, Flat pack furniture, Robotics competitions, art projects, interactive glasses, FabLab in the city competition, keyboard and kayak kit for a person with a disability etc. While majority of the remaining respondents indicated the newness of their facility as the reason for not having any completed projects.

Entrepreneurship opportunities: Part of the objectives of a basic FabLab is to serve as a business incubation facilities. Therefore, the goal of this section is to ascertain if the responding workshops have accomplished this objective, and to also unveil the ways at which they accomplished this objective. For this section, we gathered a total number of 91 responses.

From the analysis of the survey, approximately 70% (64) of the respondents indicated that there has been at least one business start-up from their FabLab workshop. Also, some of the respondents indicated that they have been of immense assistance to start-ups from almost all economic sectors. While the remaining 30% (27 respondents) indicated that their facilities has not contributed to the development of any entrepreneurial activities.

7.5.2. FabLab Conformity Rating

The Fab Lab conformity rating is a code that describes how closely a lab meets the conditions for use of the Fab Lab label. It should be taken as a quick summary of the lab "now" and understood to be able to change over time. The conformity rating is self-assessed or community assessed (i.e., perceived rating by others) (wiki.fablab.is).

	access to the fab lab	adherence to the Fab Charter	common set of tools and processes	participate in the larger, global fab lab network
A	at least some free/open public access (but may assess real material costs)	charter explicitly on site and website	has all core tools & processes and possibly more	members actively contribute or collaborate with members from many other labs lab takes part in or leads network initiatives
B	paid public access only, but anyone can join	"in the spirit" of the charter	very close to but missing at least one core machine or process	members actively contribute or collaborate with a few other labs lab keeps up with network initiatives and discussions
C	closed or restricted user group	no mention of charter	difficult to do most fab projects or follow fab tutorials	very little, only passive, or no participation outside of local lab

Figure 21: Explanation of the FabLab conformity rating (Source: http://wiki.fablab.is/wiki/Fab_Lab_conformity_rating)

Reviewing the survey data, it was uncovered that majority (approximately 69%) of the participating workshops in the FabLab ecosystem do not know what their FabLab conformity rating is or do not have any formal idea on how to be rated (figure 22 below). This could be directly linked to the present semi-formal structure being utilized within the ecosystem.

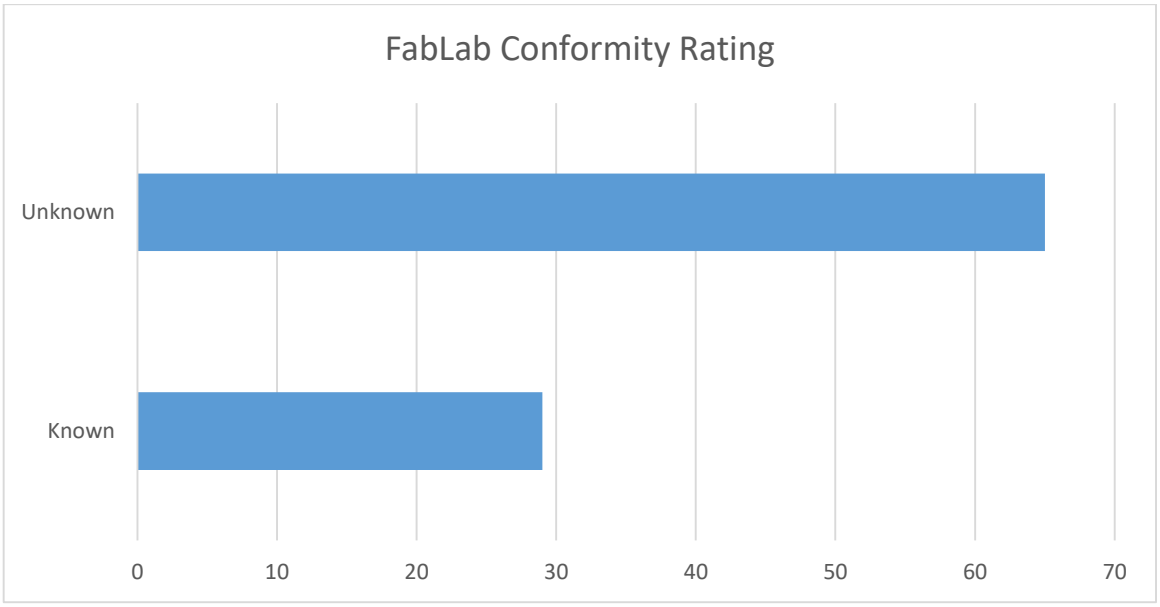

Figure 22: FabLab conformity rating

Results

Reviewing the information presented in this section indicates that, in certain forms the FabLab initiative is contributing to the empowerment capacity/human development capabilities, and technological capabilities of the environment it is established. Though the facilities indicated huge success and creation of entrepreneurial opportunities, just as stated in previous categories, there is an urgent need for the development of a standardized structure which existing and new facilities can use in developing a formidable workshop, thereby maximizing the potentialities of the FabLab initiative.

8. FabLabs in developed vs developing economies

This section aims to provide an in-depth comparison of FabLabs in developed countries to that in the developing economies based on the information gathered during the survey process. The goal of this comparison is to facilitate learning between the two economic segments, which involves the implementation/growth rates, mode of operation, collaboration, the impediments to the FabLab facilities in the two economic segments, and their devised plan/model to ensure the sustainability of their facilities.

As highlighted in the earlier section on the FabLab's growth rate, as of April 2015, there were 490 workshops in total within the global network, 379 of these workshops are in the developed country, while there are 111 FabLabs in the developing countries. During the research survey process, a total number of 94 participants responded to the online survey we conducted. Out of which 75 are from the developed countries, this is statistically analogous to approximately 20% of the total numbers FabLabs in the developed countries. The remaining 19 participants are from developing countries, which is analogous to approximately 17% of the total numbers of FabLabs in the developing.

From the slight differences of the statistical analogies, we can confidently make comparative analysis between the two different economies, irrespective of the difference between the responses gathered from the two economic segments.

8.1. Focus of FabLabs in Developed vs Developing countries

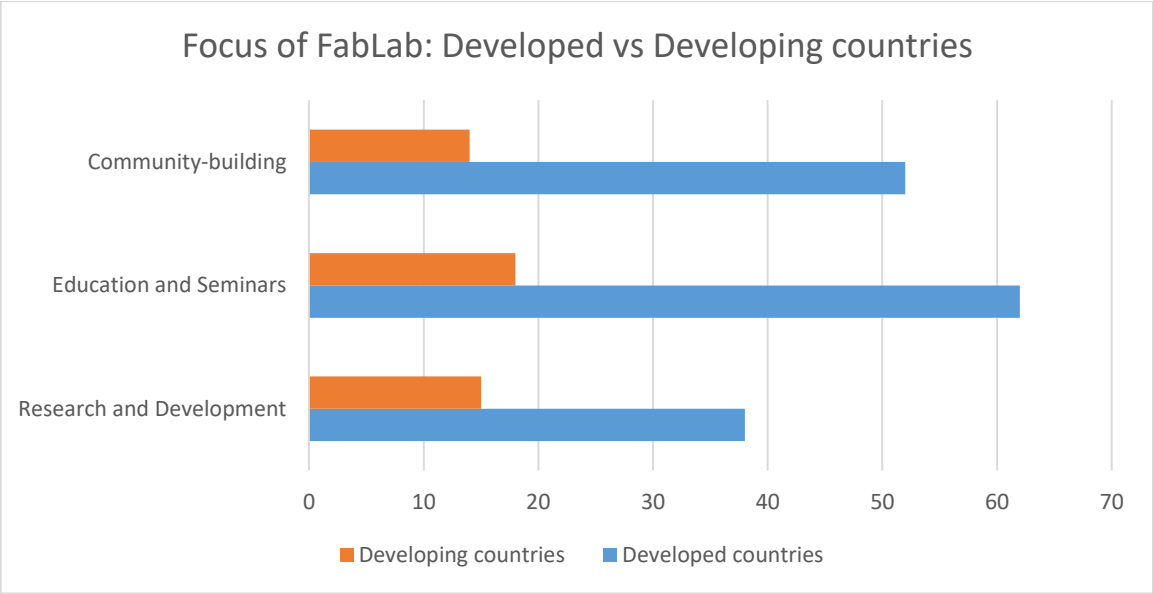

Figure 23: Focus of FabLab – Developed vs Developing countries

Research and development: - From figure 23, 15 (approximately 79%) of the respondents in developing countries are focused on research and development, while 38 (approximately 51%) are focused on R&D in the developed countries. Due to the percentage difference, it can be deduced that FabLabs in the developing economies are more focused in R&D than FabLabs in the developed countries.

Education and Seminars: - Mikhak *et al* (2002) stated in their article that education will continue to be an important and integral part of the FabLab ecosystems. From figure 23 above, we identified that FabLabs in developing countries are also more focused on providing educational activities and seminars than the FabLabs in the developed countries. 95% (18) of the FabLabs in developing countries are focused on education and seminars, while the percentage of the FabLabs focused on education and seminars in developed countries is 83% (62).

Community-building: - Lastly, from the survey (figure 23 above), it can be gathered that FabLabs in developing countries are slightly more focused on community development than FabLabs in developed countries. 14 (74%) of the FabLabs are focused on community building while 52 (69%) of the FabLabs in developed countries are focused on community building.

8.2. Equipment in Developed vs Developing countries

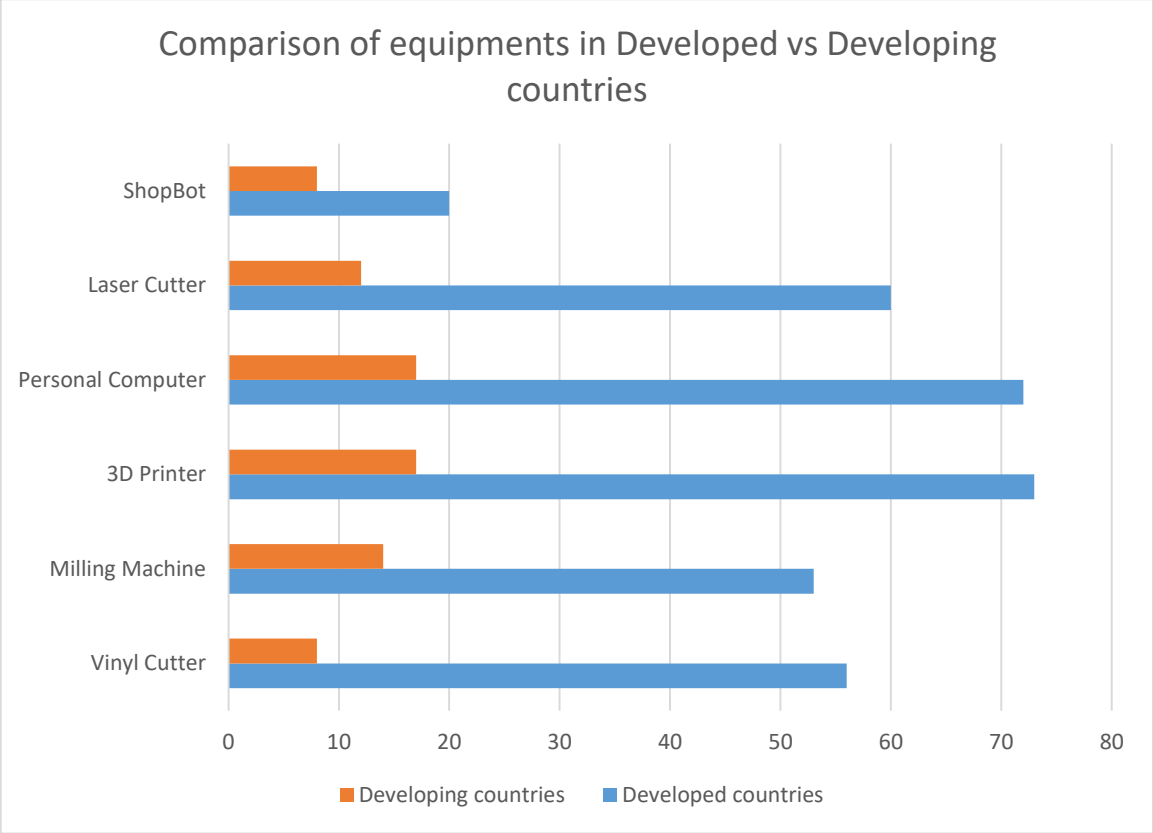

Figure 24: Equipment in developed vs developing countries

From figure 24, we gathered that FabLabs in developed countries slightly possesses more equipment than the FabLabs developing countries. In respect of the 3D printer, 73 (97%) out of the 75 FabLabs in developed countries acknowledged the possession of the machine, while 17 (90%) of the FabLabs in developing countries acknowledged the possession of the 3D printing machine. This statement also holds for the personal computers, vinyl cutter and the laser cutter. However, from the information represented in figure 24, the developing countries utilizes more milling machine and shopBot machine, with the percentages of 74% and 42% respectively, compared to 71% and 27% of the same machines in the developed economies.

8.3. Types of Users: Developed countries vs Developing countries

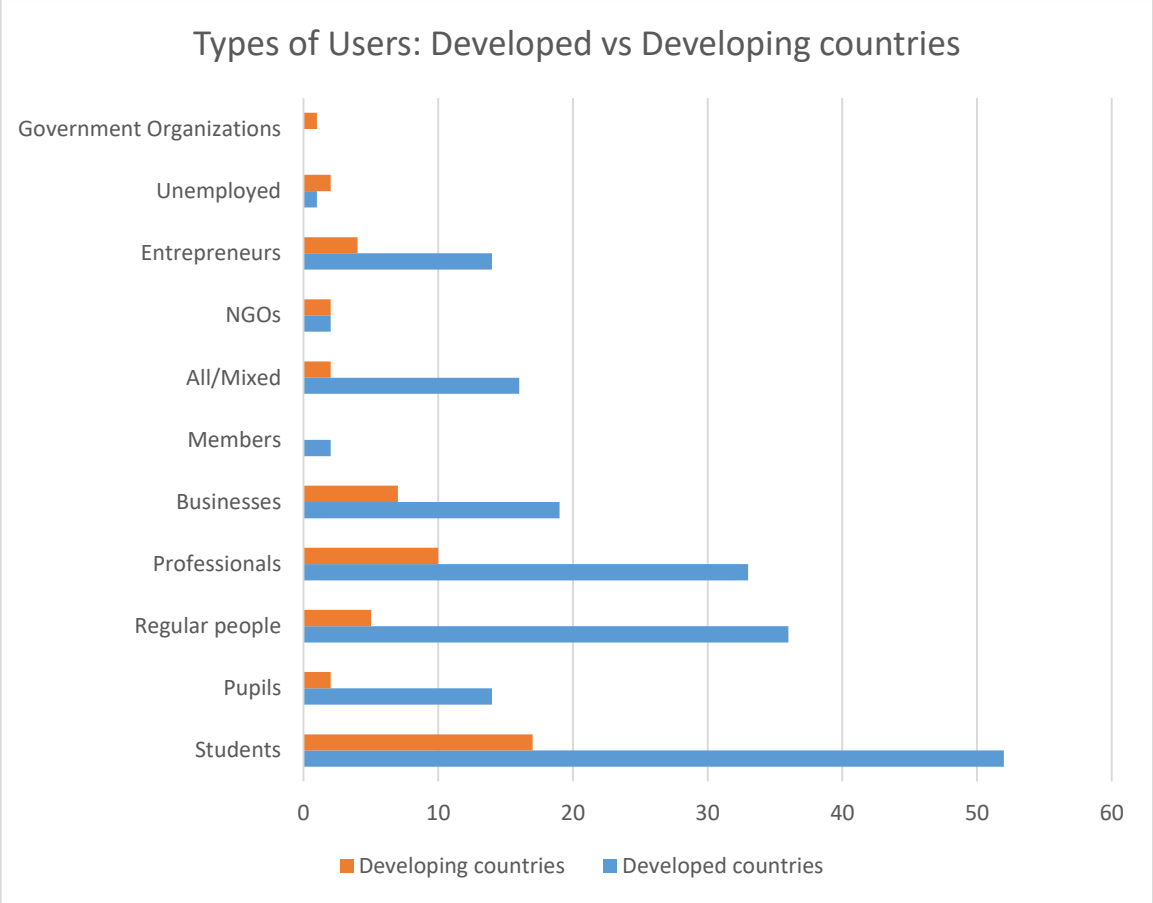

Figure 25: Types of users – Developed countries vs Developing countries

In doing a comparison of the types of users that visits the FabLab facilities in the two economic segment, it was discovered that the percentage of students that visits the FabLab facilities in the developing countries are higher than in the developed countries. From the analysis, 17 out of the 19 (approximately 90%) respondents from the developing countries indicated that the typical users of their facilities are students, while 52 (approximately 69%) confirmed the same in the developed country.

Also, the further comparison of the analysis indicated that, developing countries gets more visits from professionals (i.e. 53% compared 44% in the developed countries), business organizations (i.e. 37% compared to 25% in the developed countries), entrepreneurs (i.e. 21% compared to 19% in the developed countries), unemployed people (i.e. 11% compared to 1% in the developed countries), and government organizations (i.e. 5% compared to none in the developed countries).

However, the developed countries get more visits from pupils (i.e. 19% compared to 11% in the developing countries), regular people (i.e. 48% compared to 26% in the developing countries), regular members (i.e. 3% compared to 0 from developing countries), and lastly from mixed set of people (i.e. 21% compared to 11% from developing countries).

8.4. Collaboration: Developed countries vs Developing countries

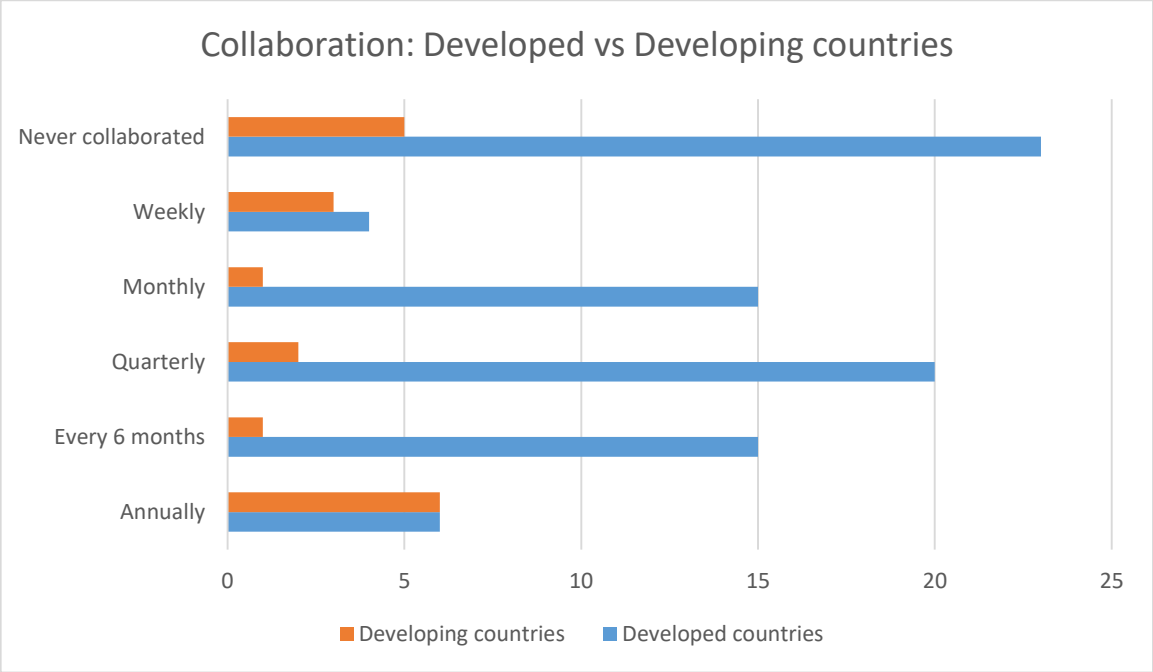

Figure 26: Collaboration – Developed countries vs Developing countries

In terms of collaboration, comparing the percentage analysis of the respondents from the two economic sectors reveals that more FabLab facilities in the developed countries collaborate with other FabLabs on a monthly basis (i.e. 20% compared to the 5% from developing countries), quarterly basis (i.e. 27% compared to 11% from developing countries), and semi-annually (i.e. 20% compared to 5% in developing countries). Moreover, more respondents from the developed countries also indicated that they have never collaborated with any other FabLab facilities, the percentage of respondents in the developed countries that are yet to collaborate with other FabLabs is 31% while the percentage of respondents in the developing countries is 26%.

However, more respondents in the developing countries indicates that they collaborate with other FabLabs on a weekly basis (i.e. 16% compared to 5% in the developed countries), and also annually (i.e. 32% compared to the 8% from the developed countries).

8.5. Mode of operation: Developed vs Developing countries

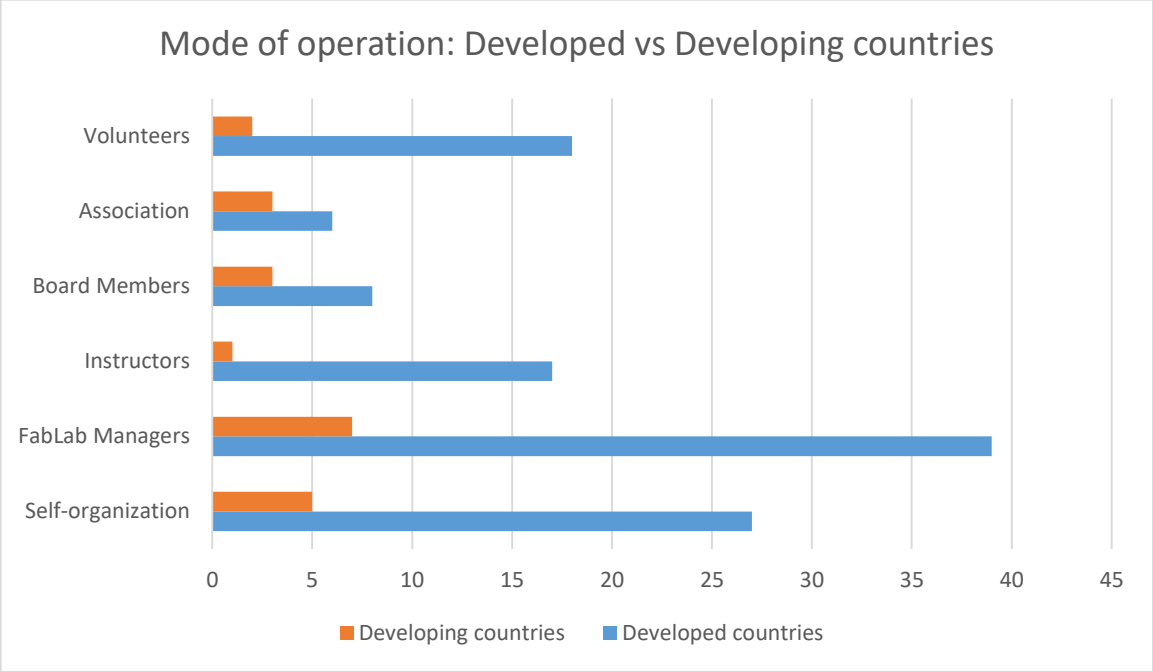

Figure 27: Mode of operations – Developed vs Developing countries

In comparing the mode of operation of FabLabs in developed countries to the developing countries, it was discovered that FabLabs in developed countries operates more by self-organization, volunteers, instructors, and FabLab managers than the FabLabs in the developing countries. The percentage comparison are as follows: Self-organization, 27 (approximately 36%) respondents from FabLabs in developed countries operate by self-organization, unlike the 5 (i.e. approximately 26%) in the developing countries. FabLab managers, 39 (i.e. 52%) respondents from the developed countries indicated that they operate with the guidance of a workshop manager, while 7 (i.e. approximately 37%) in the developing countries are operated with the assistance of a FabLab manager. Moreover, 17 (i.e. 23%) and 18 (i.e. 24%) respondents from the developed countries indicated that their mode of operation is by instructors and volunteers respectively, compared to 1 (i.e. 5%) and 2 (i.e. 11%) respondents from the developing countries on the same methods of operation.

However, the analysis revealed that more of the developing countries are operated by association and board members than in the developed countries. In terms of these two mode of operation, 3 (i.e. 16%) respondents each from the developing countries indicated that they use these modes of operations, while 8 (i.e. 11%) respondents from the developed countries indicated that they operate by board members, and 6 (i.e. 8%) indicated that they operate by association.

8.6. FabLab Sustainability in Developed Countries vs Developing countries

The aim of this section is to provide comparative on how FabLabs in both economic segments are sustained, what methods are preponderant, and which methods differs. This is done so as to promote learning, knowledge sharing, and replication of proven sustainability methods between the Fab ecosystems despite their location.

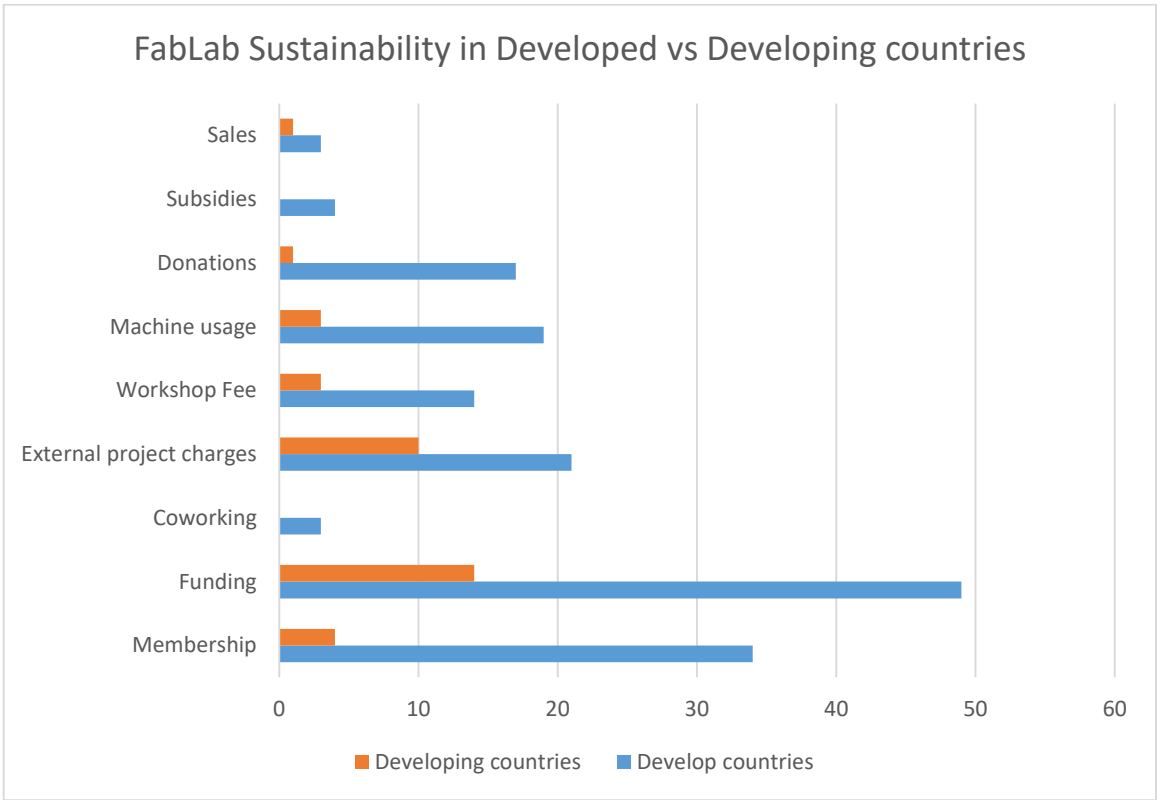

Figure 28: FabLab sustainability in developed vs developing countries

Membership: - From figure 28 above, 4 out of 19 (21%) FabLabs in developing countries are sustained by membership fee, while 34 out of 75 (45%) in the developed countries does the

same. Looking at the percentage difference, it is pertinent that FabLabs in the developed countries are generating more income from their members than in the developing countries.

Funding: - In terms of funding, 14 (74%) FabLabs in developing countries were either started or sustained by funds and grants, while 49 (65%) FabLabs are sustained by funds in the developed countries. Considering the minimal percentage difference, we deduce that both economic segments are almost on par in respect of funds.

Involvement in External Projects: - Also from figure 28, we discovered that FabLabs in developing countries are more involved in external projects than the developed countries, 10 (approximately 53%) of the 19 developing FabLabs generates incomes by engaging in external projects, while 21 (approximately 28%) engages in external projects in developed countries.

Workshop and Machine Fee: - in terms of workshop fee, 16% of the respondents from the developing countries are partly sustained by incomes generated from organizing workshops, while 19% of the FabLabs from the developed countries are partly sustained by workshop fee. Also, 16% of the FabLabs from the developing countries are also sustained by income generated from the machine usage charges, while 25% of FabLabs in the developed countries are sustained by the income generated from the machine usage.

Product Sales: - in terms of the product sales, 1 (approximately 5%) of the FabLabs in the developing countries and 3 (4%) in the developed countries are sustained by incomes generated from the sales of innovative products and designs.

Donations: - from figure 28, 1 (approximately 5%) out of the 19 FabLabs in the developing countries is sustained by donations from the community or business organizations, while 17 (approximately 23%) are sustained by donations.

Coworking and Subsidies: - as represented in figure 28 above, FabLabs in the developed countries are further sustained by subsidies on the cost of equipment and materials, and also by engaging in a coworking communities, while no FabLabs in the developing countries uses such initiative.

8.7. Impediments to FabLab: Developed countries vs Developing countries

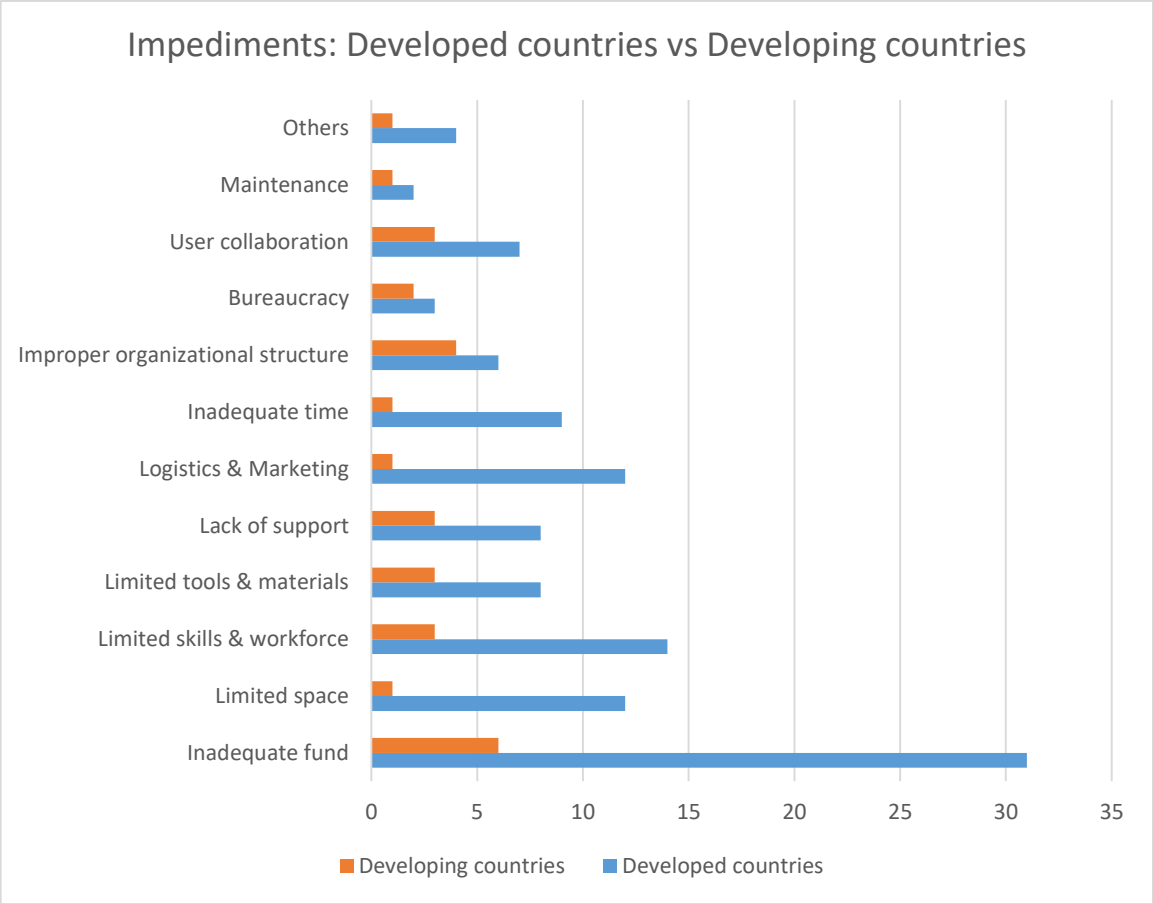

Figure 29: Impediments – Developed vs Developing countries

In terms of the barriers to the FabLab facilities from the different economic segments, it was discovered that more respondents from the developed countries identified insufficient funds, limited space, limited skills and workforce, logistics and marketing, and inadequate time as the major barriers to the sustainability of their facilities. While respondents from the developing countries identified limited tools and materials, lack of support, improper organizational structure, institutional bureaucracy, lack of user collaboration, and high cost of maintenance as their major impediments. The percentage analysis of the identified impediments are given below:

Inadequate Funds: - 31 (i.e. approximately 41%) respondents from the developed countries identified insufficient fund as one of the major barriers to their facilities, while 6 (i.e.

approximately 32%) of the respondents from the developing countries indicated insufficient funds as one of the constraints to their facilities.

Limited Space and limited skills: - as identified from the survey, 12 (16%) and 14 (19%) respondents from the FabLabs in the developed countries indicated that limited working space and shortage of skills are some of the impediments encountered within their facilities, while 1 (5%) and 3 (16%) respondents from the developing countries identified limited working space and shortage of skilful workforce as their impediments.

Logistics/marketing and inadequate time: - Also, 12 (16%) and 9 (12%) of the respondents from the developed countries identified logistics/marketing and inadequate time as some of the constraints faced within their FabLab facilities, while 1 (i.e. 5%) respondent each from FabLabs in the developing countries identified logistics/marketing and inadequate time as some of the impediments encountered within their FabLab facilities.

Lack of Support and Limited tools/materials: - comparing the analysis of FabLabs in developed countries to developing countries, it was uncovered that 3 (i.e. 16% each) responding FabLabs in developing countries encounters barriers such as lack of support and limited tools and materials than respondents from the developed countries, whose percentages are 11% (i.e. 8 respondents) each.

Improper organizational structure and Bureaucracy: - 4 (i.e. 21%) respondents from FabLabs in the developing countries identified the inadequate and improper organizational structure of the FabLab facilities as a major barrier to their facilities, while 6 (i.e. 8%) respondents from the FabLab in developed countries indicated the lack of organizational structure as one of their constraints. Also, 2 (i.e. 11%) respondents from FabLab in the developing countries indicated the existence of institutional bureaucracy as an impediment, while 3 respondents (i.e. 4%) indicated the existence of bureaucracy as a barrier in the developed countries.

User collaboration and maintenance: - from the analysis, it was uncovered that respondents from the developing countries encounters more barriers in terms of inadequate user collaboration and high maintenance cost than FabLabs in developed countries. The

percentage analysis are as follows: 3 (i.e. 16%) respondents from the developing countries indicated inadequate user collaboration, and 1 (5%) respondent indicated high maintenance cost as one of the impediments to their FabLab facilities. Meanwhile, in the developed countries, 7 (i.e. 9%) identified user collaboration and 2 (i.e. 3%) respondents identified the high cost of maintenance as an impediment to their sustainability.

From the analysis given in this section, it can be concluded that there are slight percentile differences between the types of users, the level of collaboration, the mode of operation, types of equipment and focus areas of the FabLabs in the different economic segments of the FabLab ecosystems. However, sustainability in both economic segments can be strengthened by eliminating the identified impediments and also by replicating proven sustainable methods, for example, the FabLabs in the developing countries could look into imbibing sustainable concepts such as subsidies and coworking, while FabLabs in the developed countries could focus more on generating additional incomes by engaging more in external business projects. Also, the FabLab nodes within the ecosystems could also focus on generating income by internal product development and sales activities.

9. Contributions to Emerging economies

The basic goals of FabLab is to solve the global problems from its local origin, by providing means for developing technological solutions that assists in conceptualizing, designing, developing, fabricating and testing almost anything, thereby facilitating unique products developments in small batches. The variety of projects developed within the FabLab ecosystems are endless, and these ranges from solar and wind-powered turbines, thin-client computers and wireless data networks, analytical instrumentation for agriculture and healthcare, custom housing, and rapid-prototyping of rapid-prototyping machines (Kovats 2013)

Moreover, FabLab is the birth place of affordable and quality indigenous technologies that are designed according to user's specificities, hence creating adequate values that meets the specific needs of the community. Apart from its technological development capabilities, it

also contributes to the human development capacities, by providing adequate learning/educational channels that promotes rapid skill development between people of all ages. The cases below illustrates the signicant impact the FabLab initiative have had in some developing countries up to date.

9.1. Case Review: India

Two FabLab facilities were introduced to India within 2002 and 2003, and right from the introduction of the FabLab initiative to India, FabLab have been immensely contributing to the grassroots community development of the community it serves. According to reports (Mikhak *et al* 2002; Stacey 2014), in the early inception phase of the FabLab in India, two indigenous technologies were birthed, one was the development of timing boards to do more accurate timing of diesel engines, and the other was a device used in determining and monitoring the quality of milks. These solutions were developed using the bottom-up economy approach, and also by the use a reliable low cost and low maintenance device that were abundant and otherwise dormant within Indian community.

Up till date, there are 11 FabLab facilities across India, this represents the second largest development of the initiative in a developing country after Russia which presently has 15 workshops within its borders. During the survey analysis, the respondent from India indicated that they collaborate with various nodes on the FabLab ecosystems every 6 months, and they were able to create 17 startups, and have developed various unique artifacts and technologies, some of which includes:

Automated Chess for visually impaired, Pollution mapping on Google maps (Ecomappers), Bio-Degumming of silk, Musical Staircase, Hybrid Bike, Backlight Project, Holographic projector, Brain Controlled wheel chair etc.

9.2. Case Review: Afghanistan

The first FabLab was installed in Bagrami village in Afghanistan in 2008, despite the emergence of war which has grossly overshadowed the existence of the initiative within its

borders. Since its inception, FabLab Afghanistan have conducted various educational trainings, which has highly empowered the users and community members in terms of basic machine usage and development.

One of the major local technological breakthrough developed within the FabLab Afghanistan is the FabFi Ethernet connectivity. FabFi is an open-source, extensible point-to-point long range wireless broadband transmission infrastructure, which operates on the principle that by focusing the weak energy from a basic Wi-Fi transmitter into a narrow beam, communication can be made to span a wider geographical space. The indigenous FabFi technology can be built from affordable common building materials, thereby enabling access to online educational, medical, and other useful information and resources (Sun 2009).

9.3. Case Review: Kenya

In the case of Kenya, the first FabLab was launched in 2009, and there are 2 FabLabs within the Kenyan border with the third under development and scheduled to be opened in the outskirts of the country's capital city (Nairobi). Up till date, the existence of the initiative has led to the development of various indigenous technologies and breakthroughs especially with its impact felt in the confines of the medical and the energy sector. These are innovations that would have been inconceivable or undeveloped without the existence of the FabLab movement. Some of which includes:

- A 'Vein finder' – which is a children venepuncture aid device that assists doctors in administering intravenous needles to infants. According to report, this technology is almost through the prototype phase (Ruvaga 2014).

- A 'Bit Harvester' – which is an electronic monitoring device designed to remotely assess (using SMS) the status and installations of basic renewable energy sources (wind turbines and solar). This invention was reported to have won the People's Choice award at the NASA Space Applications Challenge (Ruvaga 2014).

Also, the respondent from Kenya further corroborated and expatiated on the above stated inventions, by highlighting that FabLab Kenya are the *"makers of devices for maternal and new-borns health under concern worldwide"*, and that their network also focus on the creation of other agro-based entrepreneurship opportunities.

In conclusion, it is obvious from these reviews that the emancipation of the FabLab concept is highly beneficiary to the developing countries. The initiative provides an opportunity to connect with outside facilities to work on common projects which are otherwise too expensive or complex for an individual organization to venture in (for example, the low cost prosthesis project which was produced through collaboration between FabLab Amsterdam and the Netaji Subhas Institute of Technology (New Delhi, India) (Eychenne 2013)). Also the invention of the indigenous FabFi wireless connectivity which was a project conceived as a radio signal reflector in Norway, extended and developed in Afghanistan, by utilising locally available materials to keep costs down, and was also subsequently tested and launched in rural parts of Kenya (Eychenne 2013, Stacey 2014). In addition, the FabLab initiative also serves as an idea incubating platform, thereby encouraging a paradigm shift in the value creation process and system, by reducing the developmental constraints that formerly existed in the previous industrial eras, which leaves much of the work to the human conceptual abilities.

10. Conclusions

The present overall impact of the FabLab initiative is tremendous, with its usefulness cutting across different economic sectors, from the agriculture sector, energy sector, and to the health sector etc. Though the lack of a formalized structure, the lack of well-developed unified communication platform, and pending issues such as sustainability seems to be impeding the broad effectiveness of the initiative.

Mikhak *et al* (2002) stated that support will be provided within the Fab ecosystem through collaboration between the FabLabs via Think Cycle and the FabLab website. However, the Think Cycle seems to be out of service, and also from further literature survey, it was gathered

that the global FabLab foundation initiative indeed have developed or are developing other forums to assist in attending to the pending issues or challenges encountered by an average FabLab facility, such as Knowledge Exchange (under development), Fab Share (working, but under-developed and not well publicized), Fab Economy (working but not well publicized), Fab Connect (working but not well publicized), and the Fab Markets (under development). These platforms are briefly explained below:

Knowledge Exchange: - this platform is aimed at facilitating knowledge sharing within the ecosystems.

Fab Share (fabshare.org): - this is a web space to facilitate collaboration and project sharing within the FabLab ecosystems. It also provides a linked, searchable catalogue of published projects in the fab lab network.

Fab Markets: - The Fab market is a platform where machines/tools, production materials, products, and services can be exchanged from one FabLab facility to another, and also to connect the FabLab's products and services to the rest of the world.

Fab Economy (fabeconomy.com): - This is another collaboration platform where companies, FabLabs and individuals can potentially source for resources, funding, collaborations and expertise. The Fab economy is a community business platform that creates new economy for everybody, where local fulfilment and customization take the place of mass production and global distribution.

Fab Connect (fablabconnect.com): - The aim of the fab connect is to bring resources to the Fab Lab network through a project platform. Fab Lab Connect runs awards and challenges to get projects funded and mentored by sponsors to benefit the individual, the team and the community.

The discovery while reviewing these support platforms are that some of these platforms are either under-developed or still under construction, while the awareness of the well-developed ones are either unknown or not properly publicized. Therefore it is an important

venture for the global FabLab systems to devise plans in bringing these platform to the knowledge of the individual networks within the ecosystems.

11. Recommendations

From the literature and survey analysis, it can be gathered that the global FabLab system should endeavour to develop a formalized organizational structure and method which governs the affairs of the nodes within the FabLab ecosystems. Therefore, we recommend the broad promotion and development of a formidable regional network, like the United States Fab Lab Network (USFLN) and the FabLabAsia regional network. Testaments from the USFLN shows the potential significance of having such regional networks, these includes: providing assistance for new FabLab start-ups, adequate networking and communication for idea and information exchange, national and international visibility of each facilities, and building credibility in terms of marketing and funding (Davis 2012).

Also, according to our survey analysis, most respondents indicated an urgent need for a unified communication platform to aid easy distribution of information, knowledge, establishing and creating collaborative network, and also serve as unique information database which pools together existing scattered and conflicting information about the FabLab initiative.

Moreover, whether in the developed or developing country, the sustainability of an average FabLab facilities can be further enhanced by also engaging in the reusability of depreciated or recycled objects, which also has the potentials to further improve creativity and learning among all users. Like in the cases of FabLab Genk that organized a workshop to specifically promote reusability (De Weyer 2013), or the FabLab Togo (Woelab) that created a 3D printer out of recycled computer parts (van der Hijden & Juarez 2014). Therefore, all these highlighted concepts should be constantly elaborated, and concretely developed within the within the FabLab ecosystem so the initiative can accomplish its maximum potentials.

In summary, from the versed literatures and case study reviews, and research survey conducted. We therefore conclude that the FabLab initiative is not just a success, but is of great importance in ensuring the innovative and sustainable development of both the developed and developing countries. Therefore, FabLab and other digital/personal fabrication initiatives are unique avenues in facilitating adequate value creation.

With FabLab “IF YOU CAN CONCEIVE IT, YOU CAN ACHIEVE IT”. So let curiosity lead the way.

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Appendix 1 – references used for plotting the growth graph

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Appendix 2 – Outline of the online Survey

Survey Questionnaire for FabLab Project

The aim of this survey is to measure the impact and success rate of the FabLab movement. The survey was grouped into four (4) segments, these segments encompasses the aim and scope of FabLab using the Fab Charter.

1. Where is your FabLab workshop/laboratory located? ……..
2. When was your FabLab workshop/laboratory established? ……
3. What is the focus of your FabLab workshop?

☐ Research and workshop ☐ 3D Printing

☐ Academy and seminars ☐ others

4. Which equipment do you have in your laboratory:

☐ Vinyl cutter ☐ 3D Printer ☐ Laser cutter

☐ Milling machine ☐ Personal computers ☐ ShopBot

☐ Others, please list……

5. Which of the following best describes your association?

☐ Community-based FabLab ☐ Education-based FabLab

☐ Business-based FabLab ☐ Others, ……

6. What are your opening hours?
   ……..

……

7. How accessible is the workshop for the users (i.e transportation)? ……

……

8. How many visitors/users do you have on a weekly basis? ……
9. What kind of users attend your FabLab (e.g. Students, regular people, business organizations etc)? ……
10. What is the age group of the user?

☐ 7 – 12 ☐ 13 – 20

☐ 21 – 35 ☐ >35

11. How do you operate (e.g. self-organization, designated supervisor etc)? ……..
12. How is your workshop sustained (e.g. funding, membership fee etc)? ……

……
……
……
……

13. Have you collaborated with other FabLab workshop? If yes, how often?……..

……

14. How easy and helpful did you find collaborating with the other FabLab workshops?

……
……

15. Any suggestion on how communication and interaction among FabLabs can be strengthened? ……..

……
……
……
……
……

16. Would you say FabLab has been successful in your area? Explain ……

……
……

17. What projects have you worked on? Please list

……
……

18. How many entrepreneurship opportunities has your workshop created? List some

……
……

19. Do you organize training programmes or seminar? If yes, how often? ……..

……

20. What is your FabLab workshop's rating (e.g. AAAA, ABAC)? ……..

21. What would you describe as the greatest accomplishments of your workshop to date?

……
……
……
……

22. What are the impediments to FabLab's success in your area? ……

……
……
……
……
……

Thank you for completing the survey.