Asian Journal of Innovation and Policy (2018) 7.3:489-510
DOI: http//dx.doi.org/10.7545/ajip.2018.7.3.489

New Venture Incubation Framework: An Indian Academic Model

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Abstract Institution-based Technology Business Incubators are on the rise in India, as a means of promoting innovation-based tech start-up ecosystems, due to increased policy initiatives. Against this background, we have traced the origin and process of building a start-up ecosystem in IIT Madras, Chennai of India, based on semi-structured interviews held with the stakeholders of the ecosystem. Subsequently, we have ascertained the key components of IIT Madras start-up ecosystem, and the process of incubation comprising pre-incubation, incubation and post-incubation phases. Finally, we have derived the key lessons from the ecosystem development experience and incubation process which enable generation of start-ups from both students and faculty, apart from alumni and ex-industry executives. Though this ecosystem model has emerged over a period of time through learning and experience, the ecosystem is able to generate more than 100 start-ups, majority of them being from students and faculty. Thus, the evolved start-up ecosystem of IIT Madras is able to generate faculty-supported and student-led entrepreneurship successfully.

Keywords Incubators, start-ups, institution, IIT, Chennai, India

I. Introduction

Start-ups have the potential to generate employment, new products/services and income through their widespread growth and thereby contribute to the transformation of an economy (Song et al., 2008; OECD, 2013). But start-ups, often seen as a source as well as an outcome of innovation, are prone to failure, prior to the stage of emergence as much as in the subsequent stages after emergence. Therefore, they are attracting considerable attention from policy

Submitted, November 2, 2018; 1st Revised, December 19, 2018; Accepted, December 23, 2018

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makers for strengthening the ecosystem for their emergence and growth (Salamzadeh and Kirby, 2017).

Accordingly, novel forms of support for start-ups are emerging (Albort-Morant and Oghazi, 2016). Of them all, incubators assume significance as a support environment for start-up and fledgling companies (Peters et al., 2004). Conceptually, incubators bring together science, technology, education, knowledge, entrepreneurial talent, and capital (Smilor and Gill, 1986; Mian et al., 2016). Incubators are a wide range of organizations that, in one way or another, help entrepreneurs develop their ideas from inception through to commercialization and the launching of a new venture (Caiazza, 2014). Incubators enable knowledge transfer and provide access to a wide range of services and resources to prospective entrepreneurs, which otherwise, they would often find it hard to obtain on their own (Albort-Morant and Oghazi, 2016). Thereby, incubators support new venture emergence, stability, growth and its long-term survival (Schwartz and Hornych, 2008).

Therefore, incubators are found to be able to produce successful companies (Mas-Verdu et al., 2015). Incubators in general have a diverse set of sponsors and stakeholders such as governments, local development agencies, universities, science parks and non-profit organizations, but they all provide a mechanism for technology transfer and commercialization. The incubation programmes help start-ups to emerge, survive and grow through the provision of supportive environments (Wonglimpiyarat, 2014). Interactions with academic institutions and public research are almost always a substantive element of the incubation process in such incubators (Centre for Internet Society, 2015). Among the diverse sponsors of incubators, academic institutions assume unique significance, as they generate and accumulate knowledge, offer scope for ideation, innovation and commercialization for venture creation through their incubators. Obviously, this is done involving their students, faculty, and alumni, among others. Thus, among the various kinds of incubators, academic incubators stand apart.

Given the above, it is important to examine the role of an academic institution in the promotion of start-ups through the creation of an incubation framework, involving students, faculty and alumni of the institution itself, on the one hand, and its own incubator, on the other. We propose to probe this issue with the help of a case study in the context of India as an emerging economy, with reference to an institute of higher learning and research.

II. Role of Universities in New Venture Creation

For a long time, universities have been considered to be central to the innovative process through generating, codifying and communicating basic knowledge. Since the middle of 20th century, they have played an increasingly important role in developing and using applied knowledge, particularly in scientific and technical fields. This is because Universities or Institutes of higher learning and research are constantly engaged in the generation and accumulation of knowledge. Knowledge is the base for ideas which in turn are the sources of innovations. Therefore, it is observed that higher levels of education make powerful contributions to technology creation and diffusion through innovation (UNDP, 2001). Academic literature depicts universities and related activities as the source and catalyst for new technologies as well as the source for talented and qualified employees (Markusen, 1996).

Of late, in new venture creation, universities or institutes of higher learning assume increasing visibility and significance as they have the potential to create entrepreneurial environments that facilitate connections and speed innovative ideas from concept to reality involving both students and faculty (US Department of Commerce, 2013). Thus, Universities or Institutes of higher education and research are important sources of many new ideas in science and technology that contribute to innovations. By producing new knowledge, and exposing students to that knowledge, universities not only generate new ideas but also prepare knowledgeable, inventive, and motivated graduates who can carry those ideas into businesses (National Academy of Sciences, 2018). Universities continuously generate and accumulate knowledge, and such knowledge accumulation results in knowledge spillovers, and there is a strong positive relationship between knowledge spillovers and entrepreneurship (Acs et al., 2009). As a result, it is argued that for a university, successfully engaging in academic entrepreneurship is likely to lead to many financial, reputational, and societal benefits (Wood, 2011).

However, though universities/institutes of higher learning hold immense potential for ideation, innovation, and commercialization for new venture creation, this process within universities is neither smooth nor spontaneous. Therefore, it is observed that academic entrepreneurship through venture creation is not very common, even among the 100 most active research universities in the United States (Asterbro et al., 2012). Many universities have not necessarily championed this form of entrepreneurial activity (Mendes and Kehoe, 2009; Wright et al., 2004). This can partly explain why venture creation is found to be the least compatible with the role of the university scientist.

Siegel et al. (2003) illustrate that the actions, strategies and motives of university scientists differ significantly from the university technology transfer officer as well as a typical venture entrepreneur. An entrepreneur's primary motive is financial gain, facilitated through commercialization of a new

technology. In comparison, the university scientist's main ambition when commercializing research is to diffuse the discovery of new knowledge in order to gain recognition within the scientific community through publications and patents, with financial gain as a secondary objective as a means to securing more funding for research. The University Technology Transfer (UTT) officer's prime objective is to protect university IP, and reap benefits out of it while mediating deals between university scientists and external commercial entities (Jain and George, 2007). The UTT officer's role has been found to have only a marginal influence in persuading university scientists to start new ventures (Clarysse et al., 2011).

It is in this context that incubators, science parks or research parks assume significant relevance in university environments. It is found that successful venture-creating universities in the U.K have clear strategies towards the spinning out of new ventures through the use of surrogate entrepreneurs (Lockett and Wright, 2005). Some universities have established or created stronger links to incubators and science parks (Rasmussen and Borch 2010; Phan et al., 2005). Others have linked technology transfer activities to entrepreneurship education, in order to build up on student capacity to champion the entrepreneurial process (Berggren, 2011; Lundqvist and Williams-Middleton, 2008). University based incubators are generally seen as a mechanism to translate academic output into commercially useful innovations and value-adding start-up companies (Kolympiris and Klein, 2017).

Given this, universities are increasingly assigned the responsibility of fostering entrepreneurship and innovation, encouraged to generate revenues from the research output generated within, and contribute to regional economic growth (Goldstein and Renault, 2004). This strategy of universities for entrepreneurship promotion indicates two recent trends. First, universities lay increasing emphasis on patenting research with commercial potential seeking to increase their licensing revenues (Bulut and Moschini, 2009). Second, universities are setting up incubators to assist faculty members, students, their alumni, or external entities to initiative start-ups that not only contribute to local economic growth, but also generate income for the university, which often holds equity positions in the incubator's tenant firms.

In fact, more and more countries are undertaking steps with a view towards increased commercialization of the results of public research output emerging from their universities. Accordingly, universities in these countries are increasingly focusing on the commercialization of knowledge and research findings (Roessner et al., 2013). To facilitate this, universities are setting up institutional arrangements such as technology transfer offices, incubators, entrepreneurship centres, and internal seed funds to increase the commercialization of research (Rasmussen et al., 2006). As a result, there has

been a significant increase in technology-based economic development initiatives, focused mainly on stimulating university-based technology entrepreneurship via patenting, licensing, start-up creation, and university-industry partnerships (Grimaldi et al., 2011).

Despite all these, however, the results in most contexts are disappointing, even in the context of the USA (Harrison and Leitch, 2009). With the exception of MIT and Stanford, which are considered the true seedbeds of new ventures, the majority of the institutions in the US have not proven to be effective when it comes to new venture creation (O'Shea et al., 2005). Even in Europe, though the number of new ventures is increasing, they are highly skewed in favour of a few institutions (Wright et al., 2007). This brings out that there are variations in the performance of technology creation, commercialization and venture creation between universities as much as between nations. The reasons could be multifaceted, varying from country to country, and even from sector to sector. Given this, it is important to ascertain how universities could encourage technology creation and commercialization for new venture creation in the context of a nation. Such an understanding would be valuable for designing policies and infrastructure to promote entrepreneurship in academic settings (Rao and Mulloth, 2017).

This assumes significance because universities or institutes of higher learning are complex institutions performing multiple responsibilities such as teaching of undergraduate and graduate students, guiding students for research degrees, providing consultancy for industries, government and non-government organizations, carrying out research projects leading to patents and publications, conducting training and faculty development programmes, etc. Thus, they would differ in terms of nature and intensity of several different dimensions. Empirical studies have revealed that faculty quality, intellectual eminence and scientific productivity of universities are all related to its new venture creations (Rao and Mullath, 2017).

But at the same time, Aldridge and Audretsch (2011) have brought out that a large share of university spin-offs does not involve intellectual property formally developed at the university. However, the overall university context and its characteristics could still be valuable for creating new technology ventures. The university system which provides access to technology, networks, business knowledge, finance, human resources, tax incentives, and that reduces administrative burdens could be perceived as useful for venture creation by many prospective entrepreneurs, within as well as outside.

Given this, there is limited literature or understating on how a university or an institution of higher learning and research, in fact, builds up a system of incubation comprising ideation, innovation and commercialization for new venture creation. A conceptualization of this process and understanding of its features will be useful as a base model for its replication elsewhere. Unless and

until this process is conceptualized adequately, neither start-ups would emerge increasingly nor the emerged start-ups would be able to grow successfully thereafter from academic institutions, even if policy support is extended for new venture creation. Such an attempt is made in this paper, focusing on an institute of eminence in India, which is an emerging economy and is considered to have the third largest start-up ecosystem globally (NASSCOM, 2018).

III. Research Objectives, Scope and Methodology

The specific research objectives of the study are as follows:

- How does a university build a start-up ecosystem for new venture creation involving students, faculty and alumni, among others?
- What are the structure and characteristics of such a university based start-up ecosystem?
- What are the key lessons that can be derived out of such an experience?

These research objectives are studied with respect to IIT Madras in India. A description on the selection of IIT Madras for our study is in order. Of late, policymakers in India have been laying a greater emphasis on TBIs (Technology Business Incubators) as a means of promoting tech entrepreneurship for tech start-ups, through industry-institute partnerships. Accordingly, Government of India has proposed to establish seven Research Parks (modeled based on the Research Park set up of IIT Madras) in the following institutions: (i) IIT Delhi, (ii) IIT Gandhinagar, (iii) IIT Guwahati, (iv) IIT Hyderabad, (v) IIT Kanpur, (vi) IIT Kharagpur, and (vii) IISc, Bangalore. The objective of establishing these Research Parks is to promote successful innovation through incubation and joint R&D efforts between academia and industry (Department of Industrial Policy and Promotion, 2016). It is against this backdrop that we propose to analyze our research objectives focusing on IIT Madras including ascertaining the diversity and comprehensiveness of IIT Madras Research Park model, to examine its sufficiency for replication elsewhere in the country.

IIT Madras located at Chennai is one of the institutes of national importance in higher education, in science and engineering, basic and applied research. IIT Madras was established, with German technical assistance, in 1959. The IIT system has 23 Institutes of Technology in India today. The origin of IIT system can be traced back to the vision of former Indian Prime Minister, Jawaharlal Nehru, who pioneered establishing of the Indian Institutes of Technology to provide trained technical personnel of international class to the nation who

would act as leaders in technology for the newly born independent India. The institutions were to be designed with the necessary dynamism, flexibility of organization and capacity to adapt in the light of expanding knowledge and changes in the socio-economic requirements of modern society. IITs not only impart world class science and engineering education but also provide an excellent ecosystem for research in diverse disciplines. With vibrant Industry-Academia Collaborations, they develop cost effective technological solutions, which strengthen indigenous manufacturing and spur economic growth (Press Information Bureau, 2018).

IIT Madras today has more than 12,000 students and about 600 faculty members in science and engineering, with about 700 support staff. It obtained 54 patents and published 395 patents during 2014-2016. It has a strong alumni network of about 45,000 spread all over the world, mostly in high-profile executive positions of industry, apart from academia and other professions, predominantly in the USA (IITMAA, 2018).

IIT Madras Research Park is an independent company promoted by IIT Madras and its alumni and was incorporated under Section 25 of the Indian Companies Act 1956 in 2010. The IIT Madras Research Park facilitates the promotion of research and development by the institute in partnership with industry, assisting in the growth of new ventures, and promoting economic development. The IIT Madras Research Park assists companies with a research focus to set up a base in the park and leverage the expertise available at IIT Madras. IIT Madras Research Park is aimed at promoting research and development in partnership with the industry, nurturing innovation. While IIT Madras Research Park is modeled along the lines of successful research parks elsewhere in the world (particularly based on those in the US), it has a larger agenda that focuses not just on incubation efforts, but also on propelling successful innovation in established R&D focused companies (IITM Research Park, 2018).

Today, IITM Research Park has 29 Corporate clients operating out of the Research Park, engaged in collaborative R&D with IITM faculty. The Research Park houses the already established RTBI, but soon included the newly-created Incubation Cell in 2013, followed by a Biotech TBI in 2015 and a Medical Tech TBI in 2016. Thus, IIT Madras Research Park hosts four TBIs among other research centers, apart from 29 Corporate clients who carry out collaborative R&D with the IITM faculty involving various departments. Thus, out of the four TBIs, RTBI has a history of more than a decade whereas Incubation Cell is more than half a decade old, while the remaining two TBIs are at their infancy. In addition, the IIT Madras Research Park assists companies with a research focus to set up a base in the park and leverage the expertise available at IIT Madras (IITM Research Park, 2018). The Research Park of IIT Madras is India's first university-driven Research Park for

incubation in rural, social and industrial technologies (IITM Incubation Cell, 2018).

To understand the system and process of start-up incubation and generation at IIT Madras, we personally interviewed and interacted with the key executives of the Research Park as well as with the Professors and students of IIT Madras who are directly involved in the start-up incubation ecosystem, during 11-12 September 2017. The personal interviews and interaction were conducted based on a case study protocol. Table 1 summarizes the number of semi-structured interviews conducted.

Table 1 Number of semi-structured interviews

Persons Interviewed	Number of Interviews	Date & Year
Dean, Industrial Consultancy & Sponsored Research, IIT Madras (Academic entrepreneur)	1	September 12, 2017
CEO, IITM Incubation Centre (IC) and Rural Technology Business Incubator (RTBI), Research Park	2	September 11 & 12, 2017
Associate Faculty-in-charge, Nirmaan, IIT Madras	1	September 11, 2017
Student office bearers of CFI & their faculty mentor, IIT Madras	1	September 11, 2017
Two founders each of two start-ups undergoing incubation at IC, Research Park	2	September 11 & 12, 2017

The interaction and discussions enabled notes writing, which was supplemented by appropriate secondary sources of information for case analysis.

IV. Start-up Ecosystem in IIT Madras: Origin, Growth and Performance

The process of emergence of start-up incubation formally began in IIT Madras in 2006 with the establishment of Rural Technology Business Incubator (RTBI). In the same year, the institution established a sandbox known as Centre for Innovation (CFI), as a seedbed to promote student entrepreneurship in IIT Madras. This was followed by the creation of a Research Park as an exclusive company in 2010, located on the outskirts of the institution, which housed the already established RTBI.

Thereafter, an Incubation Cell was formed in the Research Park in 2013, followed by a pre-incubation cell known as Nirmaan, which was created in IIT Madras in 2014 (within the institute but outside the Research Park). Further, a

Biotech TBI was established in 2015 followed by a Med Tech TBI in 2016, both within the Research Park. The sequence of emergence of different entities involved in the incubation of start-ups in IIT Madras is given in Table 2. All these entities together formed the start-up incubation framework of IIT Madras.

Table 2 Chronology of the emergence of start-up ecosystem entities in IIT Madras

Serial No.	Name of the Entity	Year of Establishment
1	Rural Technology & Business Incubator (RTBI)	2006
2	Centre for Innovation (CFI) [Sandbox]	2006
3	Research Park (RP)	2010
4	Incubation Cell (IC)	2013
5	Nirmaan [Pre-Incubation Cell]	2014
6	Biotech TBI	2015
7	Med Tech TBI	2016

The start-up incubation framework of IIT Madras, thus, comprises a sandbox and a pre-incubation cell, both of which are located within IIT Madras, but outside the Research Park, whereas the latter consists of four TBIs, each of them specializing in one specific sector, apart from 29 client companies. While the RTBI aims at nurturing start-ups with a focus on rural/underserved societal segments, leveraging ICT (Information and Communication Technologies), Incubation Cell coordinates and leverages the synergies in various strands of excellence driving innovation and entrepreneurship at IIT Madras, consisting of cutting edge research, and industrial interactions. It aims at empowering innovation and deep tech driven entrepreneurship to address national challenges through successful, self-sustaining companies that are redefining markets (IITM Incubation Cell, 2018). Both biotech and medical-tech incubators are still in the process of establishing themselves.

Further, though the RTBI was the earliest established incubator, the Incubation Cell (hereafter IC) appeared to be at the forefront of the Research Park, in terms of linkages with the sandbox (CFI) and the pre-incubation cell (Nirmaan) within the institute as well as with the external networks comprising alumni, industry, venture capitalists and angel investors as the sources of finance, among others. The relationship between the various entities that constitute the start-up incubation framework of IIT Madras is presented in Figure 1.

IC incubated spin-off start-ups largely in the product space involving deep tech, emerging from the faculty labs. In addition, it incubated CFI originated Proof of Concept (POC) based start-ups which graduated through Nirmaan. Further, IC also incubated start-ups involving individuals with industry work experience. IC supports students, faculty, staff & alumni of IIT-Madras and

external entrepreneurs (or R&D partners to IITM) in creating successful tech startups, disrupting industries and translating benefits to the society at large.

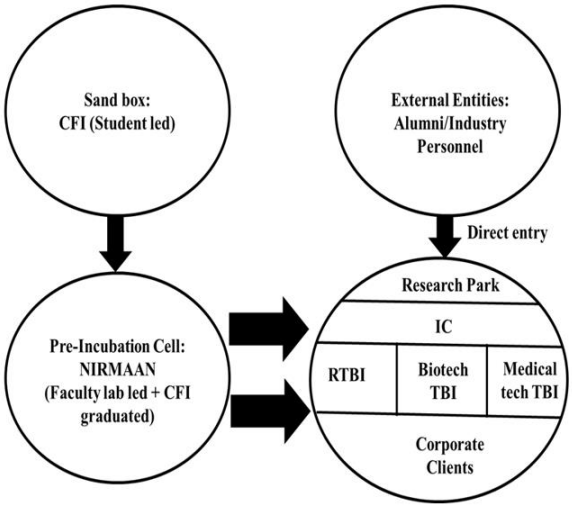

Figure 1 Start-up incubation framework at IIT Madras

Thus, the entry route for IC is three-fold: (i) Student led start-ups through CFI and Nirmaan, (ii) Spin-offs from the faculty labs of IITM directly from Nirmaan, and (iii) from outside individuals/groups including IITM alumni, which enter IC directly. The overall incubation framework consists of three stages: (i) Pre-incubation stage involving the selection of incubatees, (ii) Incubation stage where all kinds of support are provided to the admitted incubatees, and (iii) Post-incubation stage involving the determination and facilitation of start-up graduation for stability and growth.

(i) Pre-incubation stage of incubatee selection

As stated earlier, there are three sources of entry for IC. The first of them is through CFI and Nirmaan involving student led projects, the second one is from Nirmaan consisting of faculty led projects, supported by students and staff, whereas the third one is from the external world of IIT Madras comprising alumni and/or ex-industry personnel, among others. How each of these three sources of entry functions enabling the admission of prospective start-up founders into IC requires an elaboration.

Entry source No. 1: Centre for Innovation (CFI): Sandbox to promote student led entrepreneurship

The origin of CFI as a sandbox in 2006 can be traced back to the operation of various informal clubs formed by the undergraduate students (from diverse disciplines of engineering and science) to discuss and develop their technology based ideas in different hostels of IIT Madras in the previous years. Hostels are 'fertile grounds' where students from diverse engineering/science disciplines and regional/income backgrounds converge and form groups based on mutual complementarity to share and discuss their ideas. This has gradually and steadily led them to form informal clubs in the hostels to nurture their ideas.

The sustained informal club activities of students led to their gradual and steady visibility thereby prompting the institute authorities to formally create CFI in 2006, by bringing all the student hostel based multiple clubs under one single umbrella with a faculty member as an advisor. CFI is aimed at encouraging younger undergraduate engineering/science students to give shape to their ideas to work in the form of projects for developing a POC towards product development. It is a 'student lab', set up with the funds donated by the batch of 1981, and it is set in the building that houses the central workshop, in the middle of the academic zone of IIT Madras campus. Its objective is to enable a student group to 'walk in with an idea and walk out with a product'.

CFI has primarily remained as a student focused and student managed set up, where faculty members play only an advisory role, as and when required. In CFI, initial two year undergraduate students are mentored by third and fourth year undergraduate students as well as post-graduate and research students. Thus, CFI is purely a student focused entity and a tech playground for them, where they have opportunities to give shape to their ideas for development in the form of projects. Therefore, their business skills are hardly examined here. To meet the cost of student project experiments, a part of the students' fee contribution is diverted to CFI as the source of seed funds. Students who successfully complete their projects have the opportunity to earn 4 credits (towards completing their graduate program), based on due evaluation done by IIT Madras faculty. On average, about 1200 students forming about 300 to 400 teams operate out of CFI, in any year. Those student groups who are able to successfully complete their projects, as evaluated by the faculty, will graduate into Nirmaan, the pre-incubation cell, for their subsequent entry into IC (from 2014 onwards).

Entry source No.2: Nirmaan: A Pre-Incubation Cell for nurturing Faculty lab led Entrepreneurship (supported by staff and students)

Nirmaan is the nursery of start-up dreams among the students and faculty of IIT Madras. It is a pre-incubator where ideas mature towards incubation. The rich talent pool of IIT Madras serves as the fountain spring of ideas, and the end goal of teams accepted into Nirmaan is to obtain entry into the Incubation Cell at IIT Madras Research Park for start-up formation (Nirmaan, 2018).

Soon after the creation of Incubation Cell (IC) in 2013, IIT Madras felt the need for a pre-incubation cell which resulted in the establishment of Nirmaan in 2014. This is because, the ideation and POC of CFI graduated teams, which got entry into IC, were found to be inadequate in maturity for venture creation. Therefore, Nirmaan was developed as a feeder to the TBIs of IIT Madras Research Park, and a link from CFI. All the successfully completed student projects in the CFI are encouraged to move to Nirmaan from where it would graduate further into IC of IITM Research Park. About 30 to 40 projects out of the projects of 300 to 400 teams from CFI graduate into Nirmaan. These are typically 3rd year students moving into the 4th year. Such students are allowed to have deferred placements (for 2 years) to encourage their risk-taking and entrepreneurial bent of mind (without worrying about losing the opportunity of getting a placement forever). The deferred placement option acts as a source of security. About three to four out of the 30 to 40 CFI generated projects graduate further into one of the four TBIs of IIT Madras Research Park, mostly IC.

But, there is a provision for a direct entry into Nirmaan bypassing CFI, if a student group has a viable idea for product development and has a market value, and nurtured in a faculty lab at IITM. In addition, faculty members along with their students also work on ideation and innovation for product development towards venture creation. In Nirmaan, IITM alumni and 3 to 4 IITM faculty members play an advisory role.

Recently, IITM has introduced a new programme known as Entrepreneur-in-Residence (EIR) for its faculty members, to promote entrepreneurship among them. In such a programme, a faculty member who has developed a technology for a prospective start-up, may remain as a Chief Technology Officer (CTO) or as a technology mentor of such a start-up. The objective of EIR is to promote systemically driven start-ups. The start-ups so promoted need not be run by the faculty members (who have developed the technologies) but can be run by their students or even outside experts. The role of the faculty members is to bring together a bunch of talented students and drive them for venture creation with the help of the technology developed. Faculty labs with risk-taking students are encouraged to generate tech start-ups. A faculty member who has developed the technology may continue to involve with the new venture as a CTO.

Nirmaan provides various kinds of infrastructure and services to encourage start-up formation among students and faculty (Table 3). These services and facilities aim at ensuring a matured start-up plan to graduate into IC of the Research Park for incubation. Currently, 25 projects are under pre-incubation at Nirmaan.

Table 3 Services/Facilities provided at Nirmaan

No.	Services/Facilities	Objective
1	A workspace to think and work on ideas	Ideation
2	Access to Tools and Resources	Product development
3	Mentoring	Product - Market fit
4	Pre-seed funding	Finance
5	Workshops/Trainings	Exposure to legal and business issues
6	Other services including counseling, support for IP filing and guidance for PLC formation, etc.	Company formation

Source: Nirmaan (2018)

Entry source No.3: Direct entry of External individuals/groups involving alumni and ex-industry personnel into IC

There is a well-defined pre-incubation process for the selection of incubatees for IITM-IC. While the entry through CFI and Nirmaan is well regulated, the applications from outside individuals are received regularly, and it amounts to about 15 per week whereas informal enquiries are many more. If any application does not appear to be relevant for the existing expertise available in the IITM Research Park, such applications are out rightly rejected. Internal team screens all the applications received, periodically. While technology evaluation is done by the faculty of IITM, business prospects are evaluated by an internal team, aided by its network of business mentors including alumni and industry experts. The admitted incubatees are provided with furnished space at a discounted rate of 20% to 30% of the commercial rate.

If technology is good but market is not yet identified, such proposals are still accepted for mentoring. Therefore, there are prospective start-up founders who have joined IC with moderate maturity (after product-market validation). Generally, IC encourages a team of founders rather than individuals. An average size of incubating start-ups is four founders.

(ii) Incubation stage of providing support

IC plays a major role in bringing together all the stakeholders of the start-up ecosystem for nurturing tech start-ups. First of all, IC provides space and infrastructure at a concessional rent in the Research Park. In addition, IC provides technology mentoring from the faculty of IITM and business mentoring from IITM alumni and network. Retired faculty of IITM and industry partners provided the third line of mentorship, the latter mostly business mentorship and enable network development, and thereby facilitated the identification of early product adopters from industry.

The IC primarily focuses on commercialization of innovation. Therefore, an innovation which has a commercial value and which can generate revenue at

the earliest, is given preference for admission. Thus those who have ideated and developed POC are admitted into the IC generally. IC enables development of a business model along with technology development, resulting in product development, product testing and validation along with market identification, for product launching thereafter. The task is usually simpler for CFI-cum-Nirmaan led start-up founders, as their projects have already been tested for their product viability and market acceptability.

A good number of alumni, who are either serial entrepreneurs or occupied high profile executive roles in industry or have worked as Angels/VC investors and, thus, have a strong business experience, work as mentors, provide resources and facilitate early product testing. In addition, many retired IIT Madras faculty members work as technology mentors. Mentoring clinics for incubating firms are held regularly in the Research Park. The overall support provided during incubation for start-up generation in the incubators of Research Park is summarized in Table 4.

Table 4 Dimensions of incubation support for entrepreneurship & start-up generation

Nature of support	Source	Objective
Technology Mentoring	IITM faculty & retired faculty	Entrepreneurship for start-up generation
Business Mentoring	IITM alumni and industry experts	
Finance	Seed grants, Angels & VCs	
Human resources	IITM graduates	
Production	Infrastructure of Research Park	
Marketing	Early product adopters through industry & alumni	

Given the rigor maintained in the selection of incubatees, the TBIs of IIT Madras Research Park had only 140 incubatees [as against a total capacity to accommodate 200 incubatees] as of 2017, out of which 50 were in RTBI, 80 were in IC, 8 were in Biotech TBI and just 2 in Medical tech TBI. This substantiates the earlier observation that IC is at the forefront of venture incubation at IIT Madras Research Park, though it had a history of just about four years by 2017 and thereby reaffirming its role as the umbrella body for nurturing technology entrepreneurship at IITM.

(iii) Post-incubation stage for graduation

The stage where a start-up has emerged independent of the TBI support is a signal for graduation. At this stage, they would have started generating revenue to support their operations, take care of their costs, obtained institutional follow-on funding and market stability, with a proven business model. Those start-ups which have taken unduly long-time to achieve product-market fit do

fail and exit from the incubators. Mere market identification is not sufficient, rather what is crucial is agility to capture the market before some competitor emerges and moves in. In some cases of failures, the ideas were considered too early for Indian market or they turned out to be mere copy cats (usually from the US). Such failed start-up founders have either joined large companies or other start-ups as employees or moved out for higher studies. Many graduated start-up founders have become mentors to other incubatees within the Research Park as well as outside. Till 2017, the TBIs of IITM Research Park have graduated about 130 start-ups overall, majority of them obviously from the IC. The overall start-up generation process followed (consisting of sources, process and outcomes) at IIT Madras is summarized in Table 5.

Table 4 Start-up generation at IIT Madras - sources, process and outcomes

Background of entrepreneurship	Source of origin	Criteria for selection	Facilities provided	Criteria for graduation	Process of graduation	Causes of failure
Undergraduate students	A Sandbox (CFI)	Nil. Undergraduate students form groups based on mutual understanding and complementarity for ideation	Technology mentoring to juniors by seniors, advisory role by faculty, and project funds	Successful ideation in the form of projects	From Sandbox to Pre-Incubation Cell	Not able to ideate
Students, and Faculty with students	A Pre-incubation cell (Nirmaan)	Selected student projects from CFI, and faculty led lab based projects	Work space, Technology mentoring by faculty and alumni; pre-seed funds, training and soft services	Successful development of POC to PD, and ready for MVP, with market potential	From Pre-Incubation Cell to one of the four TBIs of Research Park	Not able to develop a POC and move to PD
Students, Faculty and External entities (alumni/others)	TBIs of Research Park: RTBI, IC, Biotech TBI, and Med Tech TBI	Selected projects from Nirmaan; and Proposals evaluated by faculty for technology content and by in-house experts, alumni and industry experts for business potential.	Tech mentoring by IITM faculty and retired faculty for MVP and product testing; business mentoring by alumni and industry experts for market identification and obtaining early market adopters; human resources; finance from Angels or VCs, space & infrastructure on rent at a concession	Self-sustainability in the form of revenue generation, obtaining external funds, initial market penetration	Formation of a PLC, and exit from the TBI concerned with a proven business model for growth	Not able to develop a MVP and achieve product-market fit, and generate revenue

V. Discussion and Implications

IIT Madras is an important case study, as it is one of the well-established premier technological institutions in India. IIT Madras has made a considerable progress in terms of setting up and offering incubation services to prospective start-up founders/entrepreneurs for start-up generation, to tap the knowledge-based entrepreneurial potential of students and faculty, along with alumni and industry networks. Accordingly, it has developed a well-defined model for start-up incubation linking students, faculty, institute alumni and industry all together to knit an ecosystem for start-ups. Thus it has demonstrated how an institute of higher learning and research can become a strategic player in influencing progressive building up of a start-up ecosystem.

The ecosystem for nurturing start-ups in IIT Madras evolved over a period of about a decade, i.e., during 2006-2016. This is experiential learning, as this has not emerged due to any pre-planned strategy. Thus it is a case of incremental building of start-up ecosystem in the institute, similar to the experience of University of Strasbourg, as observed by Matt and Schaeffer (2018). While RTBI and CFI were set up in the same year as far back as in 2006, the start-up ecosystem development got the real boost only in 2010, with the formation of a Research Park (with an exclusive building infrastructure and personnel in the outskirts of IIT Madras).

To begin with, Research Park comprised the already set up RTBI. But the ecosystem development got further fillip with the creation of its second incubator, that is, Incubation Cell in 2013. The initial link provided from CFI to IC in the Research Park made the latter to realize that projects graduated from the CFI were not matured enough for incubation in the IC. Thereby the need for a pre-incubation cell was felt, leading to the formation of Nirmaan, as a pre-incubation cell in 2014. In the subsequent two years (in 2015 and 2016), two more sector specific TBIs emerged in the Research Park. Thus, by 2016, the start-up ecosystem of IIT Madras has taken a definite shape.

Today, the IIT Madras start-up ecosystem broadly comprises (i) a Sandbox, (ii) a Pre-Incubation Cell, and (iii) four TBIs of IIT Research Park, apart from internally located Corporate Clients. Though the Research Park comprises four TBIs, clearly IC is at the forefront. This is understandable given the fact that IIT Madras is predominantly an engineering education and research centre. The feeder routes to the other three TBIs are not pronounced and therefore may not be adequate. The gradual and steady connections built among the various ecosystem components through conscious efforts involving students, faculty, alumni and industry led to the development of a unique start-up ecosystem. As Wright et al. (2017) have suggested, it is not possible to build an expanded ecosystem from scratch in a short period of time. However, IIT

Madras is able to put in place a vibrant start-up ecosystem within a period of about half a decade (from the emergence of Research Park in 2010 to the emergence of Nirmaan in 201).

Ideation is done in the CFI, leading to POC and thereby making an entry to Nirmaan where prototype development is done. The prospective start-up founders with developed and tested technologies for product development get admission to one of the TBIs of Research Park, for generating Minimum Viable Product (MVP) and early market identification for venture creation. In addition, Nirmaan directly encourages faculty members along with their students to experiment their ideas for product development and venture creation. Further, talented "alumni and external individuals" can directly enter into any of the TBIs with potential ideas for product development and venture creation, through accessing the technical expertise available in IITM and business mentoring from alumni/industry experts. Many of the under graduate students get opportunities for doing internship with the incubating start-ups in the Research Park. Some of the IITM graduates join incubating or graduated start-ups subsequently. Thus, a well-knit system is put-in place for the generation of student entrepreneurship independently or aided by technology developed in the labs of faculty.

The graduation system from a Sandbox to a Pre-Incubation Cell and further to an Incubator is well drawn in the form of CFI to Nirmaan to TBIs of Research Park. The system is ably supported by the faculty and retired faculty (for technology mentoring) on the one hand, and by alumni and industry (for business mentoring), on the other. But so far success is largely confined to graduation of start-ups, and rapid growth of start-ups is not yet visible widely. Even here, statistics found wanting on the number of jobs created, new products/services innovated, patents and income generated, among others. However, the very formation of an explicit start-up ecosystem (within a short period of about half a decade) itself is a remarkable beginning, and in course of time, with gaining maturity, IITM start-up ecosystem will be able to produce more success stories, particularly in terms of scaling up and growth.

Given the above, the key lessons that can be derived from the start-up ecosystem development experience of IIT Madras are as follows:

(i) Start-up ecosystem development is a process, and it can be achieved over a period of time, to suit the research-cum-knowledge-base and tap the entrepreneurship potential of an institution's students and faculty as much as the community in the neighborhood.

(ii) The start-up ecosystem development itself is a learning process, as there is no universally applicable pre-defined ecosystem model for academic institutions.

(iii) An already developed network of alumni and industry will prove beneficial for an institution in the building of a start-up ecosystem in multiple ways, as the sources for technology and business mentoring, finance, and market, among others.
(iv) A strong research base of faculty and their labs will be an asset for generating entrepreneurship (from students as well as faculty) as much as for providing technology mentoring in all the phases of start-up incubation.
(v) The retired faculty of an institution of higher learning and research is a valuable asset, for providing technology mentoring in the ecosystem.
(vi) An institution with a sandbox as part of its start-up ecosystem will be able to encourage its students to experiment with their ideas, for nurturing them towards start-up creation.
(vii) A pre-incubation cell can be a good mediator between a sandbox and an incubator in a start-up ecosystem for an effective graduation of successfully ideated student projects to undergo incubation in the incubator subsequently.
(viii) The quality of an ideated student project is likely to be strengthened steadily when it progresses from a sandbox to a pre-incubation cell and further to an incubator in an institution-based start-up ecosystem, and thereby it can ensure the emergence of a high-quality start-up at the end.
(ix) The success rate of start-ups emerging from a well-defined institution based start-up ecosystem can possibly be higher relative to start-ups which have emerged outside such an ecosystem.

VI. Conclusions

We have traced the origin and the process of building a start-up ecosystem in IIT Madras, Chennai of India, based on semi-structured interviews held with the stakeholders of the ecosystem. Subsequently, we have ascertained the key components of IIT Madras start-up ecosystem, and the process of incubation comprising pre-incubation, incubation and post-incubation phases. Finally, we have derived the key lessons from the ecosystem development experience and ecosystem incubation process which enable generation of start-ups from both students and faculty, apart from alumni and ex-industry executives. The start-up ecosystem as it prevails is vibrant enabling the following:

- Undergraduate students engage with their ideas for development in multiple groups through projects in a sandbox for POC and prototype development, move towards a MVP and market identification for start-up formation,
- Faculty members involve undergraduate/research students and staff to develop their research lab based technologies for product development and market identification for start-up formation supported by a pre-incubation cell, and
- Alumni and ex-industry executives enter one of the incubators in the ecosystem for undergoing incubation for start-up formation.

Though this ecosystem model has emerged over a period of time through learning and experience, the ecosystem is able to generate more than 100 start-ups, majority of them being from students and faculty. Thus, the evolved start-up ecosystem of IIT Madras is able to generate faculty supported and student led entrepreneurship successfully. However, the ecosystem will take some more time to mature and produce results in the form of scaled up ventures, thereby contributing to regional development through substantial employment creation, new product development and income generation.

Acknowledgement

This article forms part of the Research Project titled, "Technology Business Incubators in India: An Exploratory Study on their contribution to National R&D Efforts", carried out by the first author with the sponsorship from the National Science and Technology Management Information System, Department of Science and Technology, Government of India, New Delhi. An earlier version of this article was presented by the first author in the ICSSR-JSPS Joint Seminar on "Ecosystem for Technology Start-ups in India and Japan: Gaining Deeper Insights", conducted at Toyohashi University of Technology, Toyohashi, Japan during 21-25 August 2018. The authors are grateful to DST for the project sponsorship and to ICSSR and JSPS for the sponsorship provided to the Joint Seminar. Further, they are grateful to Prof. Sung-Soo Seol, Editor-in-chief, AJIP for bringing out a special issue on the ICSSR-JSPS Joint Seminar, containing this article. However, the views expressed in the article are exclusively those of the authors and not that of the sponsor, nor the institutions, which the authors represent.

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