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Supporting Tech Founders—A Needs-Must Approach to the Delivery of Acceleration Programmes for a Post-Pandemic World

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Abstract: Along with most economic sectors, the COVID-19 crisis has had a strong impact on start-up accelerators, forcing them to seek urgent and imaginative solutions to quickly adapt to a new environment. The enforced change brought challenges that have been exacerbated by the sudden slowdown in economic activity. Despite these difficulties, it has become clear that the accelerated digital transformation that emerged through a needs-must approach to engage with start-ups through remote means has also presented new opportunities for accelerators to improve their programmes. This article analyses the impact of the COVID crisis on the organisation and results obtained by a European accelerator, which delivers programmes for growth stage technology start-ups. For this purpose, two very similar programmes have been analysed and compared: one focused on industrial technologies (delivered in 2019–2020) and another one focused on products and services built on space technologies (2020–2021). The research has been undertaken using observational techniques, reinforced through the collection of primary and secondary data throughout the study duration. The result of the analysis point to a possible post-COVID accelerator model that blends online and remote delivery as a new way of improving the experience of start-ups and optimising the use of scarce resources.

Keywords: COVID-19; accelerator; start-up; digital transformation; qualitative data analysis; technology

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1. Introduction

Three years into the COVID crisis, Europe's economic future is still unclear as it faces new threats fuelled by the war in the Ukraine and the global instability it has generated. Despite the considerable reduction in COVID-19 mortality following successive vaccination campaigns, countries may still be susceptible to new waves of infection, and it is difficult to predict when the pandemic will end. After global economic growth rebounded to 5.5% in 2021, it is now expected to fall once again to 4.1% in 2022 and 3.2% in 2023 [1].

Against this backdrop, COVID-19 has accelerated digital transformation as many countries turn to technology to address economic and social challenges [2–4], and has demonstrated the capacity of some societies to adapt to what has become known as the new normal. Overall, the coronavirus crisis has served to accelerate the speed of digital transformation of organisations across all sectors of the economy [5,6]. The role of technology as a key driver of economic growth has been reaffirmed with new solutions that have enabled businesses and workers to continue working during the pandemic. Businesses that had gone digital before the COVID crisis have coped much better than those that had not, resulting in a significant increase in digital business activities, despite the more general economic slowdown [5,7].

Some authors claim that technological entrepreneurship has flourished in these circumstances [8], with extraordinary new business opportunities emerging based on innovative products, services and business models [9]. According to Crunchbase [10], US start-

ups raised USD 643 billion in venture investments in 2021, nearly doubling the previous annual record of USD 335 billion set in 2020. The total VC deal count also increased significantly, to an estimated 17,054 deals in 2021, up from 12,173 in 2020, demonstrating that innovation and entrepreneurship play a key role in any economic recovery.

As before the pandemic, start-up accelerators remain key players in entrepreneurship ecosystems. Within days of the onset of the crisis, accelerators were forced to adapt their programmes to a new environment to continue to provide support for their start-ups. The lockdowns and travel bans imposed across most of the world forced accelerators to rapidly transform delivery to virtual models, offering remote training, workshops, networking events, demo days, etc. [11]. Accelerator managers, start-up founders, mentors and investors were forced to make significant changes overnight. After an initial period of adjustment, certain advantages started to become apparent [12]. The possibility of organising events online allowed start-up founders to attend events more easily, and to adjust their schedules [13]. Training or participation in workshops became much more flexible without the rigidities imposed by face-to-face attendance. In the case of international accelerator programmes, non-domestic start-ups and mentors found it easier to participate.

Despite some undisputed advantages, there have also been drawbacks as discussed in other works related to other areas [14,15]. The lack of personal contact has had an impact on the ability to develop trusted relationships between founders and investors, the exchange of experiences between founders and peer learning, while the ease of participation has sometimes led to less commitment and engagement with content. It is therefore not entirely clear that completely virtual models, as were necessary during the worst of the pandemic, will remain the preferred accelerator delivery model in the future. Due to the unprecedented nature of the pandemic and the fact that these transformations are still very recent, there is a dearth of evidence describing how accelerators have adjusted, what results are being achieved compared to the previous delivery models and whether or not these changes will be reversed in a post-COVID world.

This research work was carried out in a start-up accelerator that works regularly at a global level throughout the European Union plus the United Kingdom, with the objective of systematizing the performance evaluation processes of start-up acceleration programmes in the growth phase and based on the analysis of their progress through a set of indicators grouped into different key areas: technology, product, market, team, property rights, communications and finances. Having a set of standardized indicators to measure the progress of the different start-ups could not only allow the internal evaluation of the results of a given programme, but also facilitate the comparison of results between different programmes and even the accountability to the administrations that financed our acceleration programmes with European funds. With the unexpected COVID crisis and the necessary methodological changes that had to be carried out quickly to respond to the new situation, it was also considered relevant to use the indicators already defined to carry out a study of the impact of this global and unprecedented crisis on our start-up acceleration programmes.

Thus, in this article, we analyse the results obtained in two European acceleration programmes with two cohorts each, which were carried out before and during the pandemic. We discuss the impact of the pandemic on the contents of the organised programmes, the support tools used and the results obtained. Finally, a post-COVID accelerator model is proposed with a new way to organise and improve the experience of start-ups and provide them with maximum value in the most efficient way. Therefore, this paper contributes to the growing literature on accelerators [16–19] that has been published since 2011, proposing a systematic approach for the evaluation of the progress of start-ups in accelerator programmes in the growth phase and has been applied to carry out a study of the impact of COVID in its accelerator programmes.

The results obtained will help shape future accelerator programmes for growth-stage start-ups with an international reach, whether they are public sector or corporate-driven initiatives. In particular, they will help to understand where face-to-face resources, actions and activities can have the most impact and make a substantial difference and how the

organisation of some virtual activities can and should be maintained to reduce barriers to participation and increase the efficiency of many activities.

The paper is organised in six sections. Section 2 covers the theoretical framework and introduces the background literature on accelerators, an update on the European mapping of accelerator programmes and how the emergence of COVID-19 has impacted accelerators and their programmes. Section 3 presents the methodological framework of the research conducted based on qualitative and quantitative data analysis. Section 4 outlines the findings obtained through the performance of the analysis process. Section 5 discusses the findings and suggests the recommendations that would be the most suitable hybrid accelerator model for a post-pandemic world. Finally, Section 6 concludes by highlighting the theoretical and practical implications of the study.

2. Theoretical Framework

2.1. Start-Up Accelerators

The concept of start-up acceleration emerged in the US with the creation of the well-known Y Combinator (2005) and Techstars (2006). They proposed what has become a very successful model for identifying innovative start-ups, supporting their rapid growth by providing seed capital in exchange for equity stakes in the companies, training, mentoring and advice on key aspects over a very short period of time, ranging from 3 to 6 months. As a result, internationally known companies such as Airbnb and Dropbox emerged and started to draw attention from more traditional venture capitalists. Almost as soon as the first accelerators appeared, first in the United States and then in Europe, many researchers began to study this new phenomenon. Miller [20], and later Cohen [21], were among the first researchers to point out the defining characteristics of the accelerators:

1. They offer programmes that are in principle open to all, but are nevertheless highly selective [22].
2. They provide training and mentoring for a limited time (typically 3–6 months) [23] to connect start-ups with investment, unlike incubators that provide offices, workspaces, training services, mentoring and funding in the form of public subsidies during the first years of the companies' life [19].
3. They provide seed capital (typically between $18,000 and $25,000) usually in exchange for equity (typically 4–8%) [24].
4. They support start-ups grouped in cohorts or batches to provide training in an efficient way, promote peer learning and generate a competitive and high-demanding environment.
5. The programme finishes with a graduation event or demo day [17].

From an investor perspective, early acceleration programmes were funded by venture capitalists who provided seed capital, debt or convertible notes in exchange for non-controlling minority stakes in the start-ups [16,25]. This implied that the accelerators' main source of revenue came from the sale of these stakes in subsequent investment rounds, with some accelerators also charging back a fee for participating in the acceleration programme from the capital provided. For this reason, accelerators were very selective and only accepted start-ups with high growth potential that could scale or fail quickly, thereby minimising the risks of the investment made.

This first model, driven by venture capitalists and business angels, whose objective was to make profits quickly spread around the world, reaching more than 2000 programmes globally with a wide variety of interests as many organisations felt that the accelerator format could be adapted to their own purposes [21,26]. So other types of accelerators emerged with different aims: (1) accelerators driven by governments and public institutions seeking to strengthen entrepreneurial activity in their regions or solve social and environmental challenges; (2) corporations seeking to attract knowledge and innovative solutions; (3) not-for-profits interested in supporting companies with a social impact or working in a particular sector related to their social purpose; and (4) accelerators that organise acceleration programmes financed by external funds (public or private) and are therefore free of charge for the participating start-ups. In these cases, the accelerators do not invest in their portfo-

lio of start-ups or are relatively interested in the possible income that can be obtained from the sales of their shares, because they prioritise other types of objectives, such as attracting talent, corporate image, transferring knowledge to society, improving certain social objectives, etc. [27]. Bańka [28] presents an updated review of the state of the art on start-up accelerators available in the Scopus base and suggests future research lines.

The accelerator observed during the course of this research, IoT Tribe, is equity-free, typically funding its accelerator programmes through a blend of public and corporate sources.

2.2. The Accelerator Ecosystem in Europe

It is not easy to find reliable data on start-up accelerators in Europe that would allow us to obtain an up-to-date and accurate picture of the current ecosystem. One of the first efforts to map accelerators in Europe was carried out by Martin Bryant for the European Commission in 2012 [29], who identified 16 unique accelerator brands across the European Union, some of which had a presence in more than one country, resulting in a total of 39 accelerators. Most of these were to be found in London, Berlin and Dublin, and the remainder in Copenhagen, Amsterdam, Stockholm, Paris, Tallinn and Helsinki. The same study also identified other emerging cities where new accelerators were being set up: Bucharest, Riga, Barcelona, Madrid, Lisbon and Zurich.

Shortly afterwards, Telefónica carried out another study [30] with a similar objective, to obtain as complete a picture as possible of the different entrepreneurial ecosystems in Europe. To this end, they mapped the accelerators, incubators and company builders of the seven largest countries in the European Union (Germany, France, United Kingdom, Italy, Spain, the Netherlands and Sweden) by Gross Domestic Product (GDP). According to the study, which covered the period between 2007 and 2013, the number of accelerators and incubators in Europe had grown by nearly 400%, reaching a number of programmes per capita that was very similar to that of the United States. In 10 EU countries with a combined population of c.361 million, 260 accelerator programmes were identified, while the USA with a population of c.316 million, had 200 programmes.

The following year, 2014, marked a turning point in European policy on the start-up ecosystem, with the launch of the Startup Europe (SE) programme, launched under the European Commission's Horizon 2020 EU Research and Innovation programme [31]. Six European projects were funded (Digistart, Welcome, ePlus, Startup Scaleup, Twist and Startup Europe Partnership), involving approximately 700 European start-ups. The SE mission was to connect stakeholders of local start-up ecosystems in EU member countries, including entrepreneurs, start-ups, researchers, investors, mentors, local authorities and also accelerators. Under this initiative, a European network of accelerators was also created under the name of Accelerators Assembly. One of its first actions was to obtain a map of European accelerators based on the data collected by SeeD-DB [32]. The study concluded that the overall European accelerator ecosystem consisted of some 57 accelerators that had already graduated 738 start-ups.

More recently, the Global Accelerator Learning Initiative [33] conducted a similar study, but with a global scope based on data collected during the period 2013–2019. For this, accelerators were initially identified through internet searches, as well as by consulting various secondary sources such as Crunchbase, Seed-BD, Nesta, Global Accelerator Network and F6S. Subsequently, the veracity of the data was verified through interviews with the heads of the accelerators or by reviewing their websites. Finally, a global map was obtained showing that some 72 accelerators were deployed in Europe, compared to 101 in the USA and Canada, 49 in South Asia, 35 in East Asia and the Pacific, 41 in the Middle East and Africa and 33 in Latin America. In line with this, the authors of [34] studied the relationship existing between the level of economic development (considering the global competitiveness index and the gross domestic product per capita growth) of each of the 27 EU countries with the performance of their entrepreneurial activity.

To update and complete the previous studies, we have used a similar technique and created our own map from the data available on Crunchbase and F6S. To do so, we checked

the activity of the accelerators through their websites and social networks. The UK was also included in the study due to its relevance in the European start-up ecosystem.

As can be seen in Table 1, the data vary according to the source used. For example, in the case of the United Kingdom, only 135 accelerator programmes appeared in F6S, while 238 appeared in Crunchbase. This is possibly due to F6S being a social network, in which the accelerators themselves register in the network, while in Crunchbase, it is the company itself that searches for and includes the accelerators in its databases. When we studied the data in detail, we also observed that sometimes the accelerator programmes are confused with accelerators, resulting in an overestimation of the number of accelerators or an underestimation of the number of programmes. Similarly, we detected accelerators that were inactive but were listed in the databases as active. Despite the effort we made to identify and filter these cases, it is possible that the data still include some accelerators that are technically no longer operational.

Table 1. Main European Hubs ranked by number of start-ups accelerators programmes.

Country	F6S	Crunchbase	Country	F6S	Crunchbase
Austria	7	14	Italy	58	58
Belgium	41	25	Latvia	2	3
Bulgaria	11	4	Lithuania	3	9
Czech Republic	5	7	The Netherlands	31	54
Croatia	5	3	Malta	3	0
Cyprus	4	2	Poland	12	19
Denmark	7	16	Portugal	22	37
Estonia	12	10	Romania	24	13
Finland	13	23	Slovakia	1	5
France	47	87	Slovenia	4	3
Germany	84	113	Spain	57	103
Greece	9	5	Sweden	11	17
Hungary	12	14	Luxembourg	4	6
Ireland	11	26	UK	135	238

Once the data were filtered, we further focused the study on the 10 EU countries with the highest GDP and the UK and obtained the following general conclusions (see Table 2):

1. There is no direct correlation between the number of accelerators in a country and its GDP. For example, Spain has a high number of accelerator programmes compared to some larger countries, such as France and Italy.
2. Most accelerators in the EU are cross-sectoral and when there is a specific focus, it is usually based on the application of technologies in a given sector, such as Fintech, Agritech, Edtech, Cybersecurity or Smart cities.
3. In the UK and France, most accelerators are concentrated in their capital cities, while in other countries (e.g., Spain and Sweden), programmes tend to be more distributed across the territory, although still anchored to large cities.
4. Most of the accelerators focus on the following fields: Fintech, Agritech, Edtech, Cybersecurity or Smart cities.

Table 2. Top ten European countries ranking by total GDP (2022 estimation).

Concept	DE	UK	FR	IT	ES	NL	PL	SE	BE	IE
Total GDP (USD billion)	4223.11	3186.85	2937.47	2099.88	1425.28	1018	674.08	627.43	599.87	498.55
Population (M people)	83.129	67.326	67.499	59.066	47.326	17.533	37.781	10.415	11.59	5.028
GDP per capita (USD)	50,801	47,334	43,518	35,551	30,115	58,061	17,840	60,239	51,767	99,152

Table 2. *Cont.*

Concept	DE	UK	FR	IT	ES	NL	PL	SE	BE	IE
Acceleration programmes (F6S)	84	135	47	58	57	31	12	11	41	11
Acceleration programmes rate per 1 K inhabitants (F6S)	10.1	20.1	7	9.8	12	17.7	3.2	10.6	35.4	21.9
Share according to F6S	17.25%	27.72%	9.65%	11.91%	11.70%	6.37%	2.46%	2.26%	8.42%	2.26%
Acceleration programmes (Crunchbase)	113	238	87	58	103	54	19	17	25	26
Acceleration programmes rate per 1 K inhabitants (Crunchbase)	13.6	35.4	12.9	9.8	21.8	30.8	5	16.3	21.6	51.7
Share according to Crunchbase	15.30%	32.20%	11.80%	7.80%	13.90%	7.30%	2.60%	2.30%	3.40%	3.50%

2.3. Impact of the COVID-19 on Accelerators

So far, very few studies have addressed the question of the effects of the COVID-19 crisis on accelerator programmes, and the role of digital technologies in their activities. Chowdhury et al. [35] have provided the first analysis of the effect of the pandemic on accelerator and incubator programmes, albeit only at the UK level. They found that the pandemic affected many different aspects, such as the source of funding, use of space, programme offerings, staffing and safety of both members and teams. A related contribution is that of [11], where the authors propose a new accelerator model for a post-COVID world, or the contribution of [12], where the authors describe a case study of digital-enabled redesign of entrepreneurship education. In this section, we contribute to this growing body of literature by providing a first-hand observation of the cohorts that participated in four acceleration programmes in Europe, two of them pre-COVID, two during COVID.

From the beginning of the COVID-19 crisis, the accelerators were subject to the restrictions imposed by the health authorities [36], which included social distancing [37,38], limiting opening hours, confinement, disinfection of their facilities and COVID-19 testing. The authors in [39] describe how companies could reshape results and plan for a COVID-19 recovery. Accelerators also had to adapt traditional programmes to the new situation, discovering and increasing the use of new digital technologies [40]. Meeting restrictions and social distancing requirements made it impossible to hold workshops, networking events and face-to-face demonstration days, which led to the urgent need to select virtual platforms [12] that would allow for a rapid adaptation of programmes. In effect, the pandemic made it necessary to design and implement new ways [41] of doing things in the acceleration programmes.

Whereas before COVID-19, accelerators tended to include face-to-face selection as part of their recruitment, this recruitment process became fully virtual, increasing the use of social media, alumni referrals and online networking events [42]. In the case of the accelerator under study, as in others, the delivery of the programme content also had to be adapted, moving to online channels that replaced face-to-face meetings. Workshops, lunch breaks, coffee breaks and other activities had to become virtual, forcing the exploration of innovative platforms that allowed meeting in a virtual space to stimulate interaction between all participants in the programme.

In some cases, this transformation was an obstacle for accelerators working at a local or regional level, who were less used to working in digital environments. All of them had to transform their programming and contents to the new situation in a very short period. In the case of our accelerator, the transition was less difficult, as the acceleration programmes had already catered to founders sourced globally and had therefore already experimented with certain online elements, including recruitment and onboarding.

Amongst the most important challenges was the need to find ways to facilitate team-building and interaction amongst cohort founders. New digital tools, such as Slack, were explored, tested and introduced permanently or discarded. Many of these tools have continued to be used post-COVID as a way to facilitate ongoing communication and knowledge-exchange at founder, cohort, and inter-cohort levels.

From a financial perspective, the cost of the new technologies was lower than that of the physical premises that had previously been required to host the founders, deliver workshops, and host events.

A summary of what has been described in these three sections on the state of the art of accelerators is shown in Table 3. The table shows and classifies the most relevant research works we have identified in the field of accelerators and COVID's impact on them. The papers have been classified according to five categories with respect to their content. Thus, we have identified papers analysing the start-up phenomenon, proposals for new acceleration models, experiences on the implementation of acceleration models, definition of metrics to assess their performance and finally the study of the impact of COVID on accelerators and future models. This paper contributes to the literature on accelerators in the categories 'Acceleration model in practice', 'Performance metrics' and 'Impact of COVID on accelerators'.

Table 3. Literature review on start-ups accelerators.

Research Article	Acceleration Phenomenon Analysis	Acceleration Model Proposal	Acceleration Model in Practice	Performance Metrics	Impact of COVID on Accelerators	Region	Keywords
Isabelle and Del Sarto (2020) [11]	☑	☑			☑	South America	Accelerators, COVID world, Start-ups, Entrepreneurship, Accelerator model, South America
Batistella et al. (2017) [16]	☑					Europe	Case studies, Open innovation, Business failures, Accelerators, Start-ups
Cohen et al. (2019) [17]	☑					USA	Entrepreneurship, Startups, Startup programmes
Goswami et al. (2018) [18]	☑					India	Accelerators, entrepreneurial ecosystems, entrepreneurial expertise, ecosystem intermediation
Pauwels et al. (2016) [19]	☑					Europe	Incubation models, Accelerators, Activity system perspective, Design
Cohen and Hochberg (2014) [21]	☑					USA	
Bone et al. (2017) [25]	☑					UK	
Chowdhury and Bone (2021) [35]					☑	UK	Accelerators, Incubators, UK, COVID, Pandemic, Brexit
McIver-Harris and Tatum (2020) [38]	☑			☑	☑	USA	Business incubator, COVID, Performance, Entrepreneur, Metrics

Table 3. *Cont.*

Research Article	Acceleration Phenomenon Analysis	Acceleration Model Proposal	Acceleration Model in Practice	Performance Metrics	Impact of COVID on Accelerators	Region	Keywords
Järvi et al. (2013) [43]		☑	☑			Canada	Game business, Lean start-up, Start-up accelerator, Game development
Clarysse et al. (2016) [22]	☑					UK	Incubators, Accelerators, High-tech startups, Microfinance

3. Research Methodology

The purpose of this research has been to explore how the COVID crisis has impacted the delivery model of an accelerator by comparing the results obtained by cohorts of technology start-ups that participated in the accelerator's programmes before and during the pandemic. The research has been conducted using a combination of qualitative and quantitative techniques, sourcing initial data through interviews and then structuring that information under a common framework (Assessment matrix in Appendix A). This framework has been developed and used by the accelerator since 2017 to assess the stage of development of the start-ups and adjust the content of the programme. Figure 1 shows a graphical representation of the research methodology described in this section. As can be seen, it consists of four fundamental steps: selection of the cohorts to be accelerated, qualitative and quantitative assessment of the maturity of each start-up at entry and exit of the programme, and statistical analysis of the progress of the participants. Further details of these steps are provided in the following subsections.

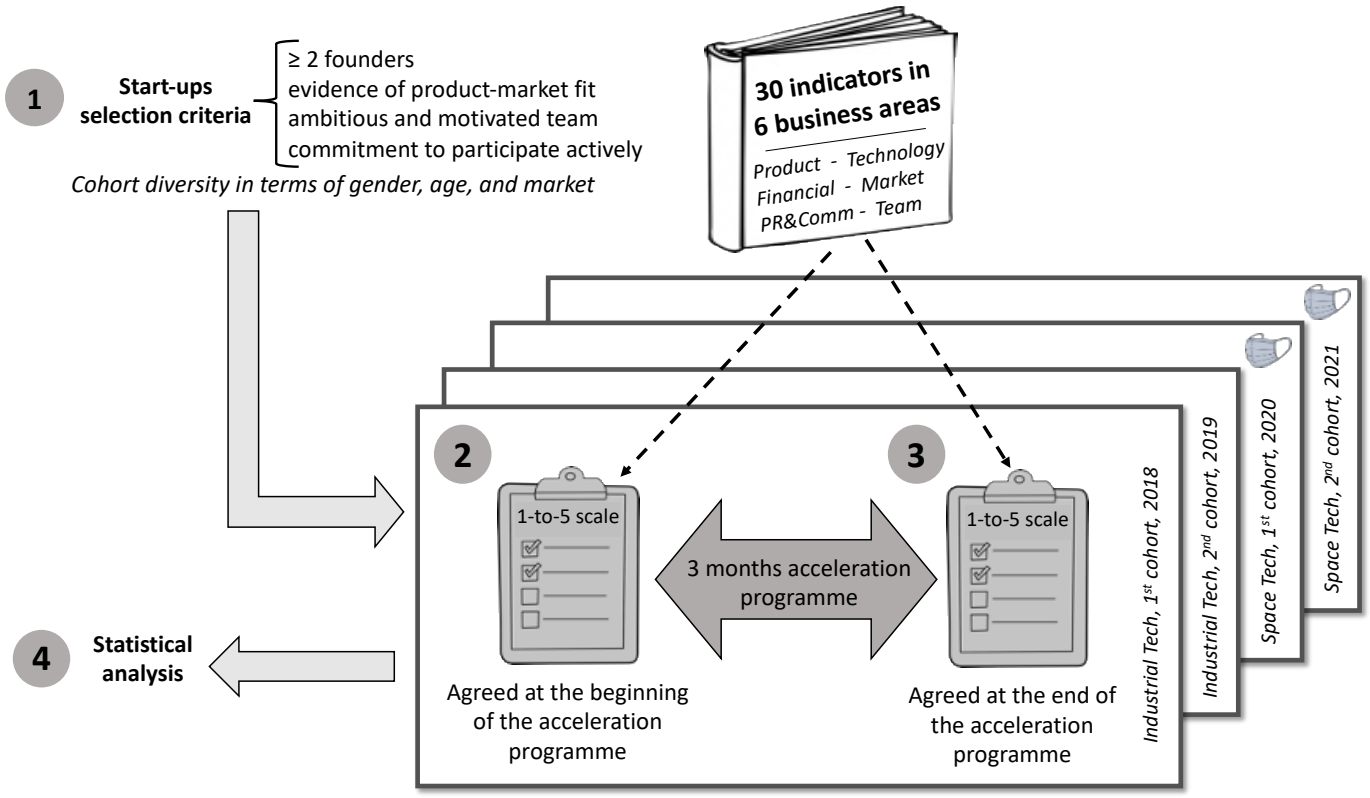


Figure 1. Graphical representation of the research methodology.

Although the cohorts themselves have been heterogenous in terms of technology, market and growth stage of the participating start-ups, the use of qualitative methods [44] has

allowed the interviewers to explore the start-ups' responses and ensure that they could be categorised, abstracted and compared. These data have then been used to draw conclusions on the impact of the acceleration delivery models and best practices for start-up accelerators in the new post-COVID era.

The method for conducting the interviews differed depending on whether they were performed before or during COVID. Prior to COVID, most interviews were conducted face-to-face, thereby allowing the interviewer to not only record the interviewee's verbal response, but also the degree to which the question was understood and probe for nuances. During the pandemic, interviews were conducted online, which required interviewers to spend more time explaining the concepts in the assessment matrix and clarifying responses.

3.1. Empirical Context and Source of Data

The data provided for this research were supplied by an accelerator that focuses on start-ups working on Internet of Things (IoT) technologies, named IoT Tribe. It is a London-headquartered accelerator operating in Europe and Singapore whose mission is to "accelerate the adoption of disruptive technologies globally and connect the wider technology ecosystem".

The company was created in 2017 as a result of an EU-funded innovation action that sought to build a European entrepreneurship ecosystem (Startup Scaleup, 2017) around four established regional ecosystems, Cloud Incubator HUB in Spain, Ryan Academy in Ireland, Crosspring in the Netherlands and Open Club Coffee in Lithuania, together with the then largest social network for Start-ups in the European Union (F6S). The aim was to provide a broad range of services to European start-ups that wanted to launch and grow companies focused on IoT technologies.

The experience and knowledge gained through the Startup Scaleup accelerator, which supported 120 IoT start-ups, was the basis for the launch of IoT Tribe's first commercial accelerator programme in 2018, supported by the Innovate UK programme and Barnsley's Digital Media Centre. IoT Tribe has since delivered a total of eleven accelerators programmes, in addition to other initiatives.

This study has taken the data gathered from four of these programmes, two Industrial technology accelerators delivered in 2018 and 2019 (Industrial Tech I and Industrial Tech II, respectively) and two Space technology accelerators, delivered in 2020 and 2021 (Space Tech I and Space Tech II). The anonymised data of the participating start-ups are provided in Appendix B. These programmes were selected because they provide reliable data on activities held before and during the pandemic. Although there are slight variations in the way the four accelerator programmes were conducted, they were all equity- and founder fee-free and all followed a common three-stage format: (1) cohort search and selection, (2) implementation of the acceleration programme, and (3) consolidation and follow-up of the start-ups.

The start-up selection process was also common to all acceleration programmes. It lasted three months, starting with the opening of the application period, announced through general social networks (i.e., LinkedIn and Twitter), start-up-specific social networks and other global digital media (blogs, general and entrepreneurial press). The outreach aimed to attract start-ups that were at the right stage of development (early-stage and pre-scale) with products and services based on the technologies relevant to the programme, rather than mass market recruitment.

The criteria used for the selection of the start-ups were the following: (1) start-ups with at least two founders; (2) with some evidence of product market-fit; (3) commitment to participate actively in the programme; and (4) founding team with the ambition and the will to succeed at a global level. Cohort diversity in terms of gender, age, and market were considerations for the final selection to ensure complementarity, rather than direct competition, and facilitate enriching exchanges of experiences and opinions through peer support. In order to understand the context of the IoT Tribe accelerator, some data relating to the four programmes are shown in Table 4.

Table 4. Main European Hubs ranked by number of start-up accelerator programmes.

Programme	Year	Cohort Size	Graduated	Median Age of Company at Start	Av. No. of Founder	Target Markets	Technologies
Industrial Tech I	2018	10	9	1.5	1.9	Real Estate ǀ Health ǀ	Artificial Intelligence ǀ IoT ǀ Augmented Reality/Virtual
						Consumer Electronics ǀ Utilities ǀ Transport & Logistics ǀ Maritime Industry	Reality
Industrial Tech II	2019	9	9	3	1.8	Transport & Logistics ǀ Smart Manufacturing ǀ Real Estate	Artificial Intelligence ǀ IoT ǀ
							3D printing ǀ Cybersecurity ǀ Digital Twins ǀ Drones
Space Tech I	2020	13	12	3	1.9	Smart Cities ǀ Aerospace ǀ	Artificial Intelligence ǀ IoT ǀ Augmented Reality/Virtual
						Critical Infrastructure ǀ	Reality ǀ Earth Observation ǀ
						Real Estate ǀ Healthcare ǀ Financial Services	Satellites
Space Tech II	2021	8	8	2	1.6	Industry ǀ Smart Cities ǀTransport ǀ Smart Cities ǀ Agriculture ǀ Aerospace	Artificial Intelligence ǀ IoT ǀ Earth Observation ǀ Satellites ǀ Advanced materials ǀ
							Cybersecurity ǀQuantum

3.2. Data Description

The data used for the research were gathered from a total of 41 start-ups who participated in four acceleration programmes (Table 4). Two of these acceleration programmes were delivered in person, pre-COVID and two were delivered during COVID.

With respect to the sample size, only those participants of the acceleration programmes who completed the programmes and were active at the time of the interviews were considered. As a result, the data analysis is based on 18 of 19 participants for the first two pre-COVID and 20 out of 21 participants for those participating in acceleration programmes during the pandemic. These sizes are adequate to understand and contextualise the data obtained and correspond to the sample sizes commonly used in qualitative interviews [45].

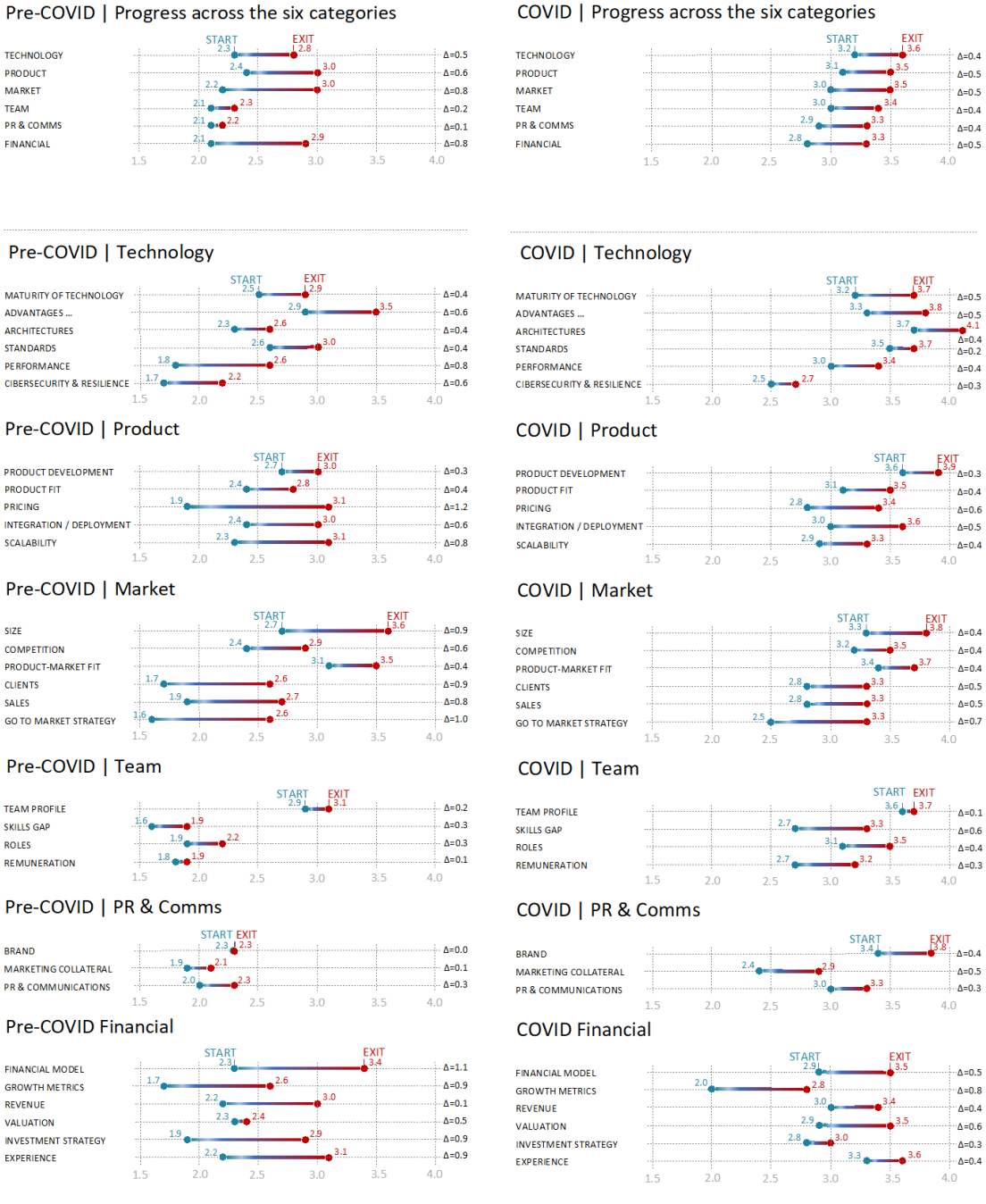
The data on the start-ups were collected against a total of thirty indicators described in Appendix A. These indicators refer to the start-ups' maturity in relation to six key business areas: Technology, Product, Market, Team, PR & Communications, and Financial. These criteria were first used in Europe's first IoT start-up accelerator programme (Startup-Scaleup) during 2015–2017 and have been refined and adjusted to meet the needs of IoT Tribe accelerators.

3.3. Data Collection

The data have been collected through primary sources. Individual interviews were conducted with participants on each of the programmes at the beginning and at the end of each acceleration programme. Each start-up's maturity was assessed qualitatively against the indicators. The maturity assessment was jointly agreed between the start-up founders and the IoT Tribe team, during an in-depth discussion of where the start-up stood in relation to each indicator. Interviews were conducted in person or virtually for the first two accelerator programmes, and virtually for the last two. The scores agreed upon at the start of the start-ups' participation in the accelerator programme were used to adjust the content of the accelerator

programme and for the allocation of mentors. Each qualitative statement was assigned a score from 1 to 5, which subsequently enabled the relative progress to be determined.

The graphs in Figure 2 show the values collected for the two periods considered: (a) pre-COVID or in-person (2018–2019) and (b) COVID or online (2020–2021). Each of the indicators has a single bar graph with a START and EXIT value. The values for each indicator have been calculated on the basis of the average values for all the start-ups in a given cohort. The length of the bars (Δ) indicates the absolute progress achieved by each cohort.



(**a**) (**b**)

Figure 2. Average scores obtained by participants in each of the 30 indicators for the 6 categories considered at the beginning and at the end of the acceleration programme, together with the absolute increase in score achieved. (**a**) Pre-COVID acceleration programmes (2018–2019, Industrial Tech). (**b**) Into-COVID acceleration programmes (2020–2021, Space Tech).

3.4. Data Validity Analysis

The validity of the results was checked through a statistical analysis of the data gathered for both cohorts. This provides the foundation and the justification for the qualitative analysis that will be presented in the next section. The results of two hypothesis tests comparing the two cohorts and their evolution through the acceleration programmes are: the Levene test [46], which assesses the equality of the variances of the indicators gathered for the in-person and online cohorts, and two versions of the Mann–Whitney test [47], paired and not paired, to assess the equality of the means of those 30 indicators between the cohorts.

On the one hand, the null hypothesis verified through the Levene test is that the population variances are equal in both cohorts. That is, the test seeks to confirm the property of homoscedasticity of the samples to be compared. On the other hand, the null hypothesis tested by the Mann–Whitney U nonparametric test is that, for randomly selected values from two populations, the probability of the first value being greater than the second one is equal to the probability of the second value being greater than the first one. That is, it checks if the two samples were drawn from two different populations with equal means. We performed two versions of the Mann–Whitney test: paired and non-paired data. The first one allowed us to check the impact that the acceleration programme has had on the participant indicators, while the second allowed us to compare if the indicators for both cohorts followed a similar distribution. The Mann–Whitney test does not require normality and equal variances, which are hard to demonstrate, but rather that the observations are independent and that the samples are randomly selected.

We require a significance value (α) of 0.05 or less in order to reject the null hypothesis defended by each of the statistical tests performed. Since there are 30 indicators for characterizing the status of each participant, we show the results of the tests through histograms of the significance level, grouped by interval. The red bars on the histograms that are shown in this section correspond to p-values that are lower than the selected significance value ($\alpha \leq 0.05$). We also identify significance levels in the range from 0 to 0.005 and from 0.005 to 0.01.

We first present, in Figure 3, the results of the Levene tests comparing the equality of the variances of the two cohorts, both just before entering and after exiting the programme. The first row in Figure 3 corresponds to the comparison between cohorts before entering the acceleration programme, while the second row in Figure 3 corresponds to the cohorts just after exiting it. Only four indicators ('PR & Communications', 'Growth metrics', 'Investment strategy' and 'Experience') scored lower than the required significance level at the entry point, while none did so at programme exit. This means that the variance of the companies/start-ups that participated in the programmes was similar in 87%/100% of the indicators measured at the entry/exit points. This allows us to conclude that we had a similar variability, with respect to the indicators, in the participants of both cohorts.

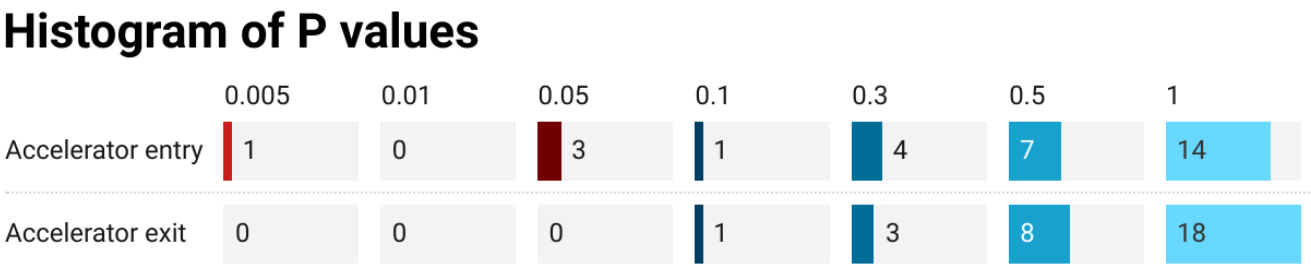


Figure 3. Histograms of Levene test results comparing for equality the variance of the 30 indicators for the COVID and pre-COVID cohorts at programme entry and exit.

Figure 4 shows the histograms of the results of the Mann–Whitney unpaired two-tails tests that compare the 30 indicators at programme entry and exit, for equality of the means of the populations. As can be seen, at programme entry there were 11 indicators for which

the Mann–Whitney tests provide a p-value that is higher than the required one (0.05), meaning that we can estimate that the participants of both cohorts had a similar level on only 37% of the selected indicators. After their participation in the programme, 17 indicators passed the test threshold, meaning that the cohorts completed the programmes with similar levels on 57% of the indicators. These new indicators were 'Standards', 'Cybersecurity & Resilience', 'Pricing', 'Competition', 'Clients', 'Sales', 'Go to market strategy', 'Experience', two from the Technology category (33%), one from the Product category (20%), four form the Market category (67%) and one from Financial (17%). There were, however, two indicators which p-values decreased and did not pass the significance level, 'Team profile' and 'Marketing collateral'. Therefore, it is possible to conclude that there have been some differences in the evolution of both cohorts, since approximately one third of the measured indicators have changed their status (p-value over/under the required significance level) between programme entry and exit.

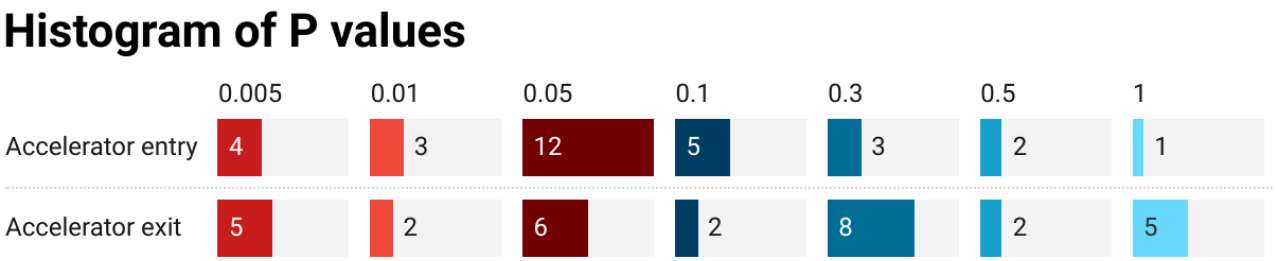


Figure 4. Histograms of Mann–Whitney test results comparing for equality of the 30 indicators of the COVID and pre-COVID cohorts at programme entry and exit.

In order to evaluate the evolution of the cohorts during the online and in-person programmes, we performed another set of Mann–Whitney two-tail tests, but now applied the paired version of the test to each cohort, contrasting the values of the indicators before and after the acceleration programmes. Figure 5 shows a couple of histograms of the p-values obtained after applying this test to check whether the evolution of the indicators for both populations was similar or not. As the histograms show, there were differences on the number of indicators that are under the significance level when comparing the COVID (two indicators) vs. the pre-COVID (nine indicators) programmes. These indicators were 'Performance', 'Pricing', 'Scalability', 'Size', 'Clients', 'Financial Model', 'Investment Strategy', 'Growth Metrics' and 'Go to Market Strategy', with the last two indicators being common in the evolution of both cohorts. It is possible to conclude that the evolution of the indicators for both cohorts has been similar for 77% of them.

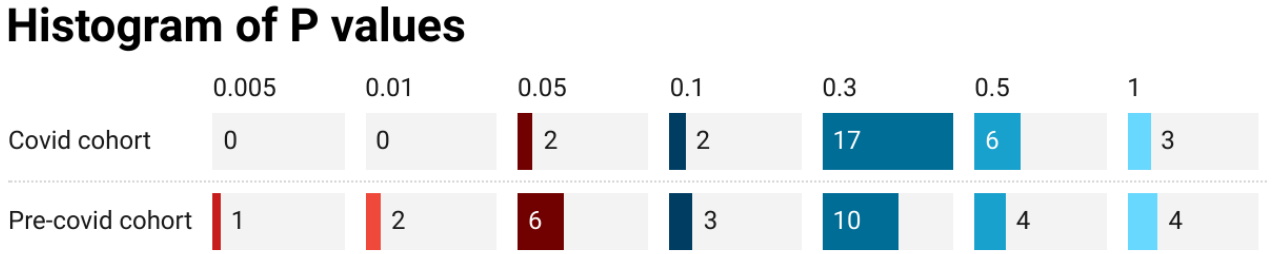


Figure 5. Histograms of Mann–Whitney paired test results comparing for equality of the evolution of the 30 indicators of the COVID and pre-COVID cohorts.

Some conclusions that can be drawn from the tests performed in this section are:

- The cohorts' composition, in terms of the means of the values of the indicators and their variance, was similar in pre-COVID an into-COVID programmes.
- At programme entry, Technology was the category with the highest difference between cohorts, while Financial was the lowest.

- At programme exit, the differences between the indicators were reduced across all categories except Team and PR & Comms, in which all indicators differed.
- The evolution of the pre-COVID cohort (paired test) exceled over that of the COVID one in all categories.

3.5. Threats to the Validity of the Experiment

Regarding the analysis of threats to the validity of the study, the experiment conducted corresponds to four instances of the 'Pretest and posttest with one experimental group only' typology [48]. The experiment does not consider a control group because this would have required involving a set of start-ups that would not have participated in any of the activities organised in the acceleration programme but would have been subsequently evaluated to check their evolution. The acceleration programmes did not consider this option. Next, we describe the main threats to the validity of this type of experiment according to Sekaran and Bougie [48] and comment on the impact they may have had on the results and conclusions of the study:

- The *History* effect refers to those events or factors that occur while the experiment is in progress and that are beyond the control of the experiment designer. Given the complexity of the objective of the experiment (to test the impact of COVID on the performance of start-ups participating in acceleration programmes) and the heterogeneity of the participants (business experience, level of education and network of contacts of the founders, technology used, level of income and maturity of the start-ups, etc.), it is very difficult to assess the impact of this effect on the validity of the results. This is precisely the objective of the statistical tests described in the previous section: to verify that the evolution of the indicators of the start-ups has been similar in all cases and that, therefore, regardless of the events that may have taken place while the experiment was underway, all participants have experienced a similar evolution after their passage through the acceleration programme.
- *Maturation* refers to how the passage of time and the experience participants gained in the programme can affect the outcome of the experiment. Since there is no control group, it is not possible to assess the effect of this threat directly. Again, the objective of the statistical tests is to check that the evolution of the indicators is independent of what has happened during the acceleration programme and is similar for all start-ups, in order to mitigate the effect of this threat. In addition, almost all start-ups had already participated in previous acceleration programmes, where they started the development of their business idea. Therefore, they had already acquired some of the knowledge that can be gained as part as their participation in an acceleration programme, so it is possible to assume that the maturation effect had already occurred to a large extent for almost all of them.
- *Main testing* and *interactive testing* effects occur as a result of participants being tested on entry and exit from the acceleration programme and affect participants' posttest scores. This may be due to factors such as participants not understanding the questions well or not having experience with the scale used, wanting progress to be visible after the programme, paying more attention or trying harder knowing that they are being assessed, etc. In this sense, it has to be clarified that, from the beginning of the acceleration programme, it was indicated to participants that the purpose of the evaluation was to make them aware of their current status, of what goals they would have to achieve to improve in each of the 30 business-oriented indicators and of the progress they had experienced after their passage through the programme. In any case, to mitigate this effect, the scores given both at the beginning and at the end of the acceleration programme were agreed between the start-up and the IoT Tribe team. In this way, an attempt was made to maintain homogeneity in the evaluation.
- *Mortality* refers to the impact of participants dropping out of an experiment. In the case of the two acceleration programmes studied, only one start-up did not complete each of the programmes, which represents 5.26% in the pre-COVID programme and

4.76% in the into-COVID programme. The impact of these drop-outs was small as the samples were still of adequate size and there were no dependencies between participants that could reduce the performance of the start-ups that remained in the programme. Data from the start-ups that dropped out of the accelerator programmes have not been taken into account in this study.

4. Findings

Comparing the graphs in Figure 2a,b, it can be seen that the indicators of the pre-COVID start-ups obtained lower average scores at the start of the programmes (between 1.6 and 3.1) compared to the COVID start-ups (2.0 and 3.7). The averages for the six categories considered were between 2.1 and 2.4 for pre-COVID programmes and between 2.8 and 3.2 for COVID programmes. This can be attributed to the fact that the maturity of the start-ups that participated in the Space technology accelerators was higher, as subsequently demonstrated throughout the acceleration programme.

There was also greater variability in the progress of the pre-COVID start-ups compared to the COVID start-ups. Thus, the delta of the pre-COVID categories varied between 0.1 and 0.8, while the delta of the COVID categories remained between 0.4 and 0.5. This behaviour is justified by the difference in maturity of the start-ups observed across the four programmes. While more mature start-ups may need to progress across in all categories and may start from a more advanced position, the less mature start-ups must focus on product development, market analysis and acquiring funding, while branding and marketing as less determinant of their survival. On the other hand, the progress of pre-COVID start-ups in the other categories (Technology, Product, PR & Comms and Financing) was higher in all of them and in two of them almost twice as high (PR & Comms and Financing). This was because the progress of the COVID start-ups was lower than expected under normal circumstances, not reaching 0.8 points in any of the categories.

This can be attributed to a wide variety of factors stemming from the constraints imposed by the pandemic, including:

- The intensity of the acceleration programmes, where founders are not fully immersed in an accelerator environment and cannot as easily draw on the accelerator team and resources as needed.
- The lack of face-to-face workshops limits the acquisition of knowledge as it is more difficult to interact to clarify or expand on themes of particular interest.
- On-line environments hindering the informal learning, socialising and support that accompany the founders who are part of the face-to-face cohort.
- The difficulty of effective networking where people engage in conversations that allow relationships to develop and where contacts made are better contextualised and more memorable than their virtual equivalents.
- The temporary moratorium on corporate budgets that emerged during the early stages of the pandemic, in which non-essential spending was frozen in many companies, essentially delaying any possibility of piloting new technologies.
- Zoom fatigue [49], a recognised phenomenon that has confirmed that burnout occurs after exposure to long periods of videoconferencing.
- The following sections describe the findings in each of the categories.

4.1. Technology

The degree of technological maturity of the start-ups at the beginning and end of the programme was assessed according to the criteria shown in Appendix A for each of the following indicators: (1) degree of maturity of the technology employed by the start-up, (2) advantages of the proposed technology over other technologies proposed by competitors, (3) existence and degree of development of an architecture defining the structure, operation and interaction between the parts of the product/service, (4) consideration of standards for the development of the product/service, (5) degree of realisation of the product/service and availability of metrics for its verification, and (6) degree of consideration

of cybersecurity aspects of the product/service from the design phase and existence of risk mitigation plans.

In relation to the Technology category, Figure 2a,b shows that the most significant progress was achieved in the pre-COVID programmes, specifically in aspects related to the degree of product development (performance indicator, $\Delta = 0.8$), followed by addressing cybersecurity and resilience issues ($\Delta = 0.6$) and identifying the advantages of the technology supporting the products over the competition ($\Delta = 0.6$). In contrast, in the programmes delivered during the first two years of the pandemic, the progress achieved was not as high (between 0.2 and 0.5), despite the fact that start-ups started the programme with considerably higher levels of maturity in each of the categories considered. This may seem surprising at first glance but may be due to the fact that progression in the early stages is easier and/or faster, while the effort, experience and resources required to progress in the later stages are much greater. For example, less mature start-ups have to prioritise areas such as product development and core technology performance over standards development, cybersecurity and performance indicators, which are often left for later stages.

4.2. Product

In relation to Product, Figure 2a,b again shows greater progress in the pre-COVID programmes, and especially in aspects related to the methods and strategies used for pricing ($\Delta = 1.2$) and product scalability ($\Delta = 0.8$). This could be attributed to the fact that start-ups were moving from earlier stages where sales volumes were non-existent, low or based on a consultancy revenue model, to more system- and value-based pricing structures.

4.3. Market

Six indicators have been assessed to establish Market progress: (1) size of the start-up's addressable market, access to market and priority segments; (2) depth of knowledge on the competition, whether a market intelligence process has been carried out, how often, in what way and whether the data obtained match those of the target market; (3) degree of product–market fit, clear value proposition differentiated from competitors' propositions; (4) the existence of paying customers and the commercial terms established with them; (5) the degree of knowledge of the customer's purchasing criteria and the procurement process; and (6) the existence of a go-to-market strategy and its level of development.

Start-ups in the face-to-face acceleration programmes made more progress in the Market category than those in the virtual programmes. In both situations, the methodologies of the business coaches were similar, and the time allocated to work on market development was also similar. Presumably, the in-person networking events provided teams with more opportunities to talk to potential customers and business partners and get first-hand information about their markets and their needs.

The greatest progress across all indicators in this category was made in relation to go-to-market strategy ($\Delta = 1.0$), followed by customer understanding ($\Delta = 0.9$), market size ($\Delta = 0.9$) and sales ($\Delta = 0.8$).

4.4. Team

The maturity level of each of the teams participating in the accelerator programmes was assessed against four indicators: (1) team profile in terms of single or multiple founders, track record, technological expertise, and target domain; (2) existence of a formal procedure for detecting skill gaps within the team; (3) documented existence of a role distribution among team members; and (4) existence of a formal remuneration structure.

For this category, more progress has been made in the COVID programme than in the pre-COVID programme. In particular, the greatest progress was achieved in the indicators related to the detection of skill gaps in the team ($\Delta = 0.6$) and in the definition of a remuneration structure for staff ($\Delta = 0.3$). One possible explanation is that, given the limitations imposed by face-to-face meetings and the lack of networking opportunities, participating start-ups were (i) forced to spend more time on internal matters that required less reliance

on external contact and (ii) were able to benefit from the proliferation of communication tools and channels that became available during the pandemic.

4.5. PR & Communications

This category generally refers to the ability of a start-up to communicate its differentiated value proposition to the outside world. In order to determine the maturity level of the start-ups in relation to this aspect, three indicators were used: (1) brand, namely whether or not the logo had been professionally developed, whether it was recognisable with clear messages and values, whether or not guidelines for the use of the brand had been established and if so, whether these were applied consistently; (2) marketing collateral, assessing whether the start-ups had already developed any marketing materials (e.g., > brochures, social media campaigns), the existence of a marketing strategy and budget, and the existence or otherwise of a dedicated team (internal or external); (3) maturity of PR and communication activities and the degree to which these were aligned to a clear communications, strategy with a budget, channels and metrics.

Start-ups from the face-to-face acceleration in the pre-COVID stage made little progress in the first of these sub-categories, possibly due to the fact that UK start-ups, which formed a larger percentage of the two face-to-face cohorts, tend to be quite developed.

Relative to the COVID acceleration programme, improvements in the marketing subcategory were significant ($\Delta = 0.5$), possibly because they were more mature at the outset, but they also benefited from support in preparing materials with native English reviewers. This led to a higher quality text, with a clearer and more concise message. However, in this category there were significant differences between the cohorts, depending on the assets, language and design skills of the teams at the point of entry to the programme. Some had advanced marketing materials and therefore progressed little because their existing assets were already adequate.

4.6. Financial

Financial maturity was assessed with the help of six indicators: (1) the existence of a clear and appropriate financial model, including an analysis of whether the model was based on verified assumptions, supported by clear assumptions and forecasts; (2) the quality and relevance of metrics to track growth and the degree to which they were used to monitor progress; (3) for revenue, considering pre- and post-revenue statuses, the existence of a defined monetisation strategy and the assumption on which monetisation was based were assessed; (4) the valuation of start-up, carried out independently, and on the basis of a recognised methodology; (5) the existence of an investment strategy, with a defined plan and a clear timetable for implementation; and (6) an assessment of the financial acumen of the founders, and their experience of securing investment from angel investors or VCs, successfully or otherwise.

As with most of the other categories, most indicators showed greater progress in the pre-COVID programmes than in the COVID programmes. As can be seen in Figure 2a,b, progress in four of the six indicators (financial model, growth metrics, investment strategy and experience) was above 0.9 points; the next indicator (valuation) scored a $\Delta = 0.5$, followed by revenue with a $\Delta = 0.1$. In the case of the COVID accelerator programmes, very similar growth was observed in almost all indicators (between 0.3 and 0.5), except in the case of growth metrics, whose $\Delta = 0.8$, due to the fact that all start-ups started from a low baseline. The experience in raising funds was also consistent with the fundraising journey of more mature start-ups.

5. Discussion

This section discusses the main findings of the research described in this paper and their implications from both theoretical and practical points of view. It also describes some of the limitations of the study that must be taken into account when extending the findings and recommendations to other scenarios.

5.1. Theoretical Implications

Since the first scientific paper on start-up accelerators published in 2013 [43], there has been a growing interest in the topic until today. Bańka [28] recently identified 76 scientific publications in the Scopus database from the years 2011–2021 and classified them into six thematic areas ordered chronologically: academic accelerators (10), corporate accelerators (27), general approach to start-up accelerators (22), seed accelerators (9), reviews and attempts to systematise knowledge (6) and other types of accelerators (3).

To the best of our knowledge, our study is the first work that attempts to systematize the outcome evaluation process of a growth-phase accelerator programme by analysing the progress of start-ups in six key areas. Moreover, the application of such a systematic approach to different acceleration programmes before and during the COVID has allowed us to study the impact of the COVID crisis on two programmes that started in a pre-pandemic situation and had to adapt quickly to the new situation. Therefore, the results obtained enrich the existing literature on start-up accelerators in growth phases for a post-pandemic world.

5.2. Implications for Practice

The observation of the four cohorts over a four-year period has led to some interesting findings on where accelerators can add more value to start-ups (content), as well as which formats may be more effective for each type of content (delivery). The results of our study suggest that accelerators can adapt their models permanently to allow for more flexible programmes that combine online and in-person activities to deliver more targeted support for founders.

In relation to the content, our recommendations follow on the six key areas that determine the rate and extent of the start-ups growth or scaling progress (Technology, Product, Market, Team, PR & Comms, and Financial). These categories have remained stable over the four-year period of the study and have provided the yardstick to assess start-ups needs on entry to the programme and their progress on exit.

Regardless of the initial maturity level of the start-ups, the accelerator must offer a balanced programme with content covering most categories, but it is the founders themselves that decide where and when they need to focus their attention and resources. A hybrid model allows this choice to be made without a significant impact on the overall results of the cohort or the relationships with co-founders, mentors and investors.

With regard to the content that aims to support the development of Technology, in-person delivery means that the product development, particularly in the case of hardware, can benefit from access to lab and physical infrastructure and tooling. Working on standards, cybersecurity and product performance can be done individually, to processes and principles that are codified and structured.

For Product, the possibility of face-to-face networking meetings open up opportunities to talk to potential customers and business partners and work on product–market fit and understanding value-based pricing. When these activities are in-person, conversations are deeper and more lasting than when initiated through online channels. This is also true for progress in Market development, particularly in understanding market needs and achieving sales.

Conversely, work on the Team does not in itself require in-person activity. Workshops on compensation, developing career plans and reviewing performance can be held online with the founders then working independently on the internal processes and tools that support good human resource management.

With reference to PR & Communications, the results are more mixed. Verbal communication improved more noticeably with in-person coaching and workshops that allowed for founders to gather non-verbal feedback in the practice sessions. For other areas, such as branding, remote working was as effective as the in-person work.

Finally, in relation to the Financial content, founders once again seem to progress more with in-person content. One possible explanation is that they are able to adjust pitches to the non-verbal signals they are receiving from potential investors and differ-

entiate their value proposition more clearly, particularly if they are pitching to investors in a non-native language.

In terms of the delivery model, the most significant conclusions that can be drawn from our observation are:

- Virtual acceleration programmes attract more mature start-ups, as they can combine their day-to-day work with participation in the accelerator and even assign different members of the team to different parts of the programme.
- The barrier for participation from non-domestic start-ups is also lowered.
- Virtual programmes are also able to provide access to a broader range of mentors with specific technology or market expertise, reducing the friction inherent in finding free time and matching founders with the know-how they need.
- While during the pandemic founders were able to benefit from remote peer support and relationships with their fellow cohort members were established, these relationships lasted longer and run deeper when they are established in an in-person accelerator.
- While events designed to showcase the start-ups' capability succeeded in attracting relatively large numbers of attendees during the pandemic, fatigue soon set in. The value of the contacts and connections made through in-person events was significantly higher.
- Market engagement can also be more effective in the early stages through remote channels (e.g., to establish whether the contact is the right person within the organisation and to obtain initial, high-level feedback) but more valuable information and longer-lasting contacts are obtained through in-person meetings.
- Similarly, in-person demo days resulted in better delivery of pitches, particularly for non-native English speakers, and engagement with investors more fruitful.
- Across both types of programmes, progress in the early stages is quicker than that in later stages, which may point to a need to deliver accelerators for scale-ups with a different cadence to the standard linear three months.

Finally, we distinguish between the findings that relate to formats that were followed because there was no choice (circumstantial or needs-must), and those which may indeed lead to more or less permanent changes in the delivery model in both the pandemic and business as usual (BAU) scenarios (see Figure 6).

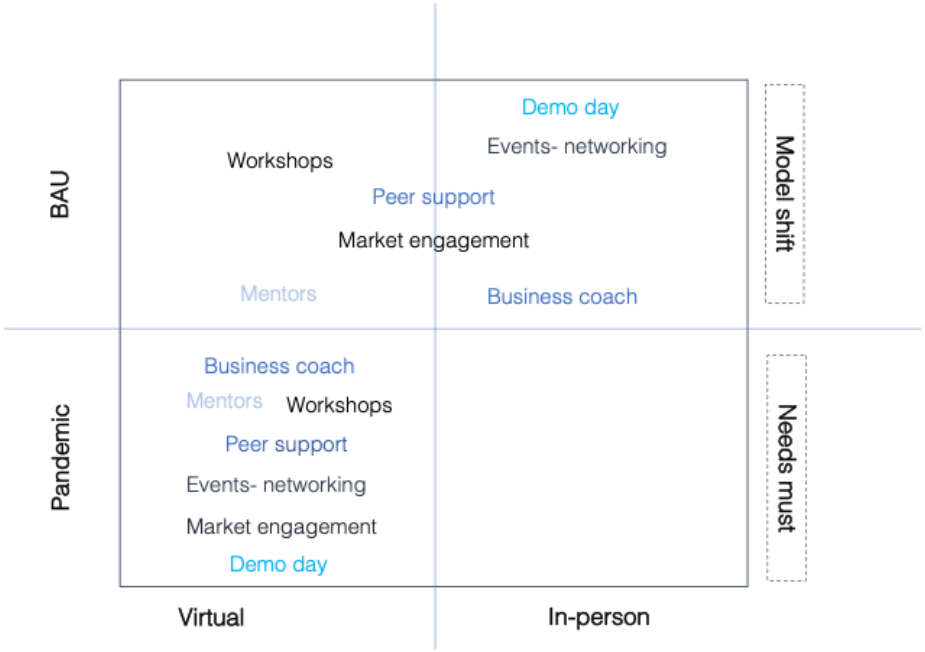


Figure 6. From Needs-Must to BAU Accelerator Model.

5.3. Limitations of the Study

This paper has analysed and compared the performance of mature start-ups, which already had a developed product when they entered the accelerator programmes mentioned above, and whose products made use of innovative technologies such as Artificial Intelligence or Internet of Things. Therefore, the conclusions drawn may not be directly extensible or applicable to other environments, such as incubators that support early-stage start-ups, or may need to be nuanced if extrapolated to accelerators that work with start-ups developing products/services in other application domains, such as circular economy or social entrepreneurship.

6. Conclusions

Although the pandemic has had a tremendous impact on society, it has also brought opportunities to introduce operational improvements in many sectors. This paper contributes to the growing literature on accelerators by studying the impact of COVID in a start-up accelerator working globally across the European Union plus the United Kingdom. For this purpose, two accelerator programmes, each with two cohorts, have been analysed and compared. The first one for the period 2018–2020 focused on businesses using IoT in the industrial sector, and the second one for the period 2020–2021 focused on the use of IoT in the aerospace sector.

The research has employed qualitative and quantitative methods, gathering data from primary sources. The data obtained were structured using a common framework (Assessment matrix in Appendix A) that has been developed and used by the accelerator since 2017 to assess the stage of development of the start-ups and adjust the content of the programme.

Despite all the difficulties and restrictions imposed by the pandemic, the accelerator and the start-ups participating in them have been able to adapt and make the most of the challenging environment. As described in this article, the data collected in the programmes executed before and during COVID show that the evolution of the cohorts has been similar, despite the significant differences in circumstances and context.

Particularly, in the case of the acceleration programmes, it has surprised us to find that the impact of certain online activities has been similar or greater than that of those same activities carried out in the in-person period. These findings have led to our proposal for a post-COVID accelerator model with a new way of organising and improving the experience of start-ups and supporting their growth while increasing efficiency in delivery.

The results can support accelerators to select which parts of an acceleration programme offer the most value when delivered in person, and which can achieve the same or even better results when they are delivered remotely.

Policy makers can also take note of the findings to develop effective entrepreneurship programmes that make better use of resources. The findings can also be used to understand the value of "place" and context in creating new innovation and technology hubs that draw on newly created, high-growth potential businesses.

Further research could also investigate the links between the in-person and remote models and the start-ups' subsequent growth, in terms of revenue, employees and/or investment raised.

Regarding other research lines, we intend to validate the acceleration model described in Figure 6 and the distribution of the activities that are usually carried out in an acceleration programme between a face-to-face and an online delivery model. On the other hand, we also intend to refine and validate the indicators proposed in this article by expanding the number and variety of accelerator programmes and start-ups analysed. For example, including accelerator programmes: (i) focused on circular economy or social entrepreneurship, (ii) focused on certain types of populations, such as female entrepreneurship, rural entrepreneurship or in disadvantaged environments, and (iii) aimed at early-stage start-ups. This will allow the applicability of the proposed indicators to be broadened.

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Appendix A

Criteria for scoring (from 1 to 5) a key business sub-category, depending on the degree of achievement by the start-up.

Table A1. Assessment matrix.

Business Category	Key Business Sub-Category	Criteria for Score = 1	Criteria for Score = 2	Criteria for Core = 3	Criteria for Score = 4	Criteria for Score = 5
1. TECHNOLOGY	1.1 Maturity of Technology	Tech. in initial experimental phase	Tech. successful on a laboratory scale	Technology successful in live environment	Tech. commercially deployed (small scale)	Tech. commercially deployed (large scale)
	1.2 Advantages Compared to Competitive Technologies	No concrete advantages defined	Advantages identified but not quantified	Advantages identified and quantified	Advantages identified and quantified and evidence is available	Significant advantages identified and quantified and evidence is available
	1.3 Architecture	No architecture identified or associated with design process	Basic architecture with part of the functionality at a high level of abstraction	High-level architecture of the design of the system	High and detailed level architecture for the whole system	Scalable and fully identifiable architecture adopted following well-known industry practice
	1.4 Standards	No standards	Few standards have been considered in development phases	Standards have been considered occasionally in development phases and quality assurance	Standards have been considered in development phases and quality assurance	Standards have been considered in development phases and quality assurance in a systematic way

Table A1. *Cont.*

Business Category	Key Business Sub-Category	Criteria for Score = 1	Criteria for Score = 2	Criteria for Core = 3	Criteria for Score = 4	Criteria for Score = 5
1. TECHNOLOGY	1.5 Performance	No metrics	Basic metrics for performance	Basic metrics for performance and scalability	Well-defined metrics for performance and scalability	Systematic consideration of well-defined metrics for performance and scalability
	1.6 Cybersecurity & Resilience	No risk assessment	Ad hoc risk assessment	Basic risk assessment and mitigation plan available	Full risk assessment and mitigation plan available	Full and systematic risk assessment and mitigation plan available with resources assigned
2. PRODUCT	2.1 Product Development	No methods, no process. Product developed ad hoc	Methodologies or process applied in some phases of development	Methodologies or processes applied in many phases of development	Use of well-known methods and processes to specify and design the whole system	Documentation available for all tech development and itera-tion/updating of processes for all phases
	2.2 Product	Characteristics developed on a tech first basis	Some characteristics developed with user needs loosely identified	Some characteristics developed with user needs identified on the basis of data	Most/all characteristics developed with user needs on the basis of data	Most/all characteristics developed with user needs on the basis of data and tested
	2.3 Pricing	No consistent pricing parameters or consultancy pricing	Initial pricing strategy and parameters available	Pricing strategy and parameters associated with product attributes	Pricing strategy and parameters associated with product attributes and market segments	Pricing strategy and parameters associated with product attributes and market segments and cross or upselling strategies clear
	2.4 Integra-tion/Deployment	Do not yet understand the issues related to integration and/or deployment	Some understanding of the issues related to integration and/or deployment	Clear understanding of the issues related to integration and/or deployment	Clear understanding of the issues related to integration and/or deployment and some experience in dealing with them	Clear understanding and experience of the issues surrounding integration with legacy environments and existence of a methodology for identifying and addressing them

Table A1. *Cont.*

Business Category	Key Business Sub-Category	Criteria for Score = 1	Criteria for Score = 2	Criteria for Core = 3	Criteria for Score = 4	Criteria for Score = 5
2. PRODUCT	2.5 Scalability	No scalability	Potentially scalable but no plans defined	Route to scalability defined	Route to scalability defined and clear metrics established	Route to scalability defined and clear metrics established and are being met
3. MARKET	3.1 Size	No clear real idea of the size of the addressable market size	Initial rough assessment of addressable market	Clear idea of addressable market	Clear idea of addressable market and the routes to the market	Clear idea of addressable market, the routes to the market and the priority segments
	3.2 Competition	No market intelligence performed	Some market intelligence performed but no clear or only partial advantages defined over competitors	Market intelligence performed ad hoc with advantages over competitors clearly defined	Market intelligence performed regularly with advantages over competitors clearly defined	Full market intelligence performed on a regular basis and response to competitors offerings is adjusted
	3.3 Product–Market Fit	Unclear product–market fit	Initial product–market fit established	Product–market fit established and initial value proposition has been defined	Product–market fit established and value proposition is clear and strong	Product–market fit established and value proposition is clear and strong and differentiated from existing solutions on the market
	3.4 Clients	No clients, paid or unpaid	Some contracts signed with clients for non-paying pilots	Some revenue-generating contracts signed with clients	Increasing number of revenue-generating contracts signed with clients	Increasing number of revenue-generating contracts signed with clients and full customer pipeline
	3.5 Sales	No clear idea of client purchasing criteria and procurement process	Initial contact with clients and with insights into purchasing criteria and/or procurement process	Clear idea of client purchasing criteria and procurement process	Clear idea of client purchasing criteria and procurement process and at least one successful sale completed	Clear idea of client purchasing criteria and procurement process integrated into sales strategy and successful sales with several clients

Table A1. *Cont.*

Business Category	Key Business Sub-Category	Criteria for Score = 1	Criteria for Score = 2	Criteria for Core = 3	Criteria for Score = 4	Criteria for Score = 5
3. MARKET	3.6 Go-To-Market Strategy	Opportunistic approach to go-to-market	Proactive but ad hoc approach to go-to-market by core team	Go-to-market strategy has been developed	Go-to-market strategy has been developed and has a budget	Go-to-market strategy has been developed, has a budget and is being implemented by a dedicated person/team
4. TEAM	4.1 Team Profile	Single founder	Several founders	Several founders will skills that address core business functions	Complete team with track record and technological expertise	Strong team with proven track record and technological and relevant domain expertise
	4.2 Skills Gap	Skill gap analysis has not been performed	A basic skill gap analysis has been performed	A full skill gap analysis has been performed	A full skill gap analysis has been performed and used to inform recruitment	Full skill gap analyses are performed systematically and are used to inform recruitment
	4.3 Roles	No job descriptions are available	Job descriptions are available for some profiles	Job descriptions are available for all profiles	Job descriptions are available for all profiles and there is a formal recruitment process	Job descriptions are available for all profiles and there is a formal recruitment and evaluation process
	4.4 Remuneration	No formal remuneration structure available	Basic remuneration structure available	Comprehensive remuneration structure available	Remuneration and career development plan for employees	Remuneration and development plan with a range of incentives to retain and reward employees
5. PR & COMMS	5.1 Brand	The logo has not been professionally developed	The logo has been professionally developed but there are no brand guidelines	The logo has been professionally developed and there are brand guidelines	The logo has been professionally developed and there are brand guidelines that are consistently applied	The logo has been professionally developed and there is a recognisable brand with clear messages and values

Table A1. *Cont.*

Business Category	Key Business Sub-Category	Criteria for Score = 1	Criteria for Score = 2	Criteria for Core = 3	Criteria for Score = 4	Criteria for Score = 5
5. PR & COMMS	5.2 Marketing Collateral	There is no marketing collateral	Some marketing collateral (e.g., leaflets, social media campaigns)	Clearly defined marketing collateral and a marketing strategy	Clearly defined marketing collateral and a marketing strategy and budget	Clearly defined marketing collateral and a marketing budget implemented by a dedicated team (internal or external)
	5.3 PR & Communications	No communication activities are carried out	Communication activities carried out on an ad hoc basis (e.g., press releases, blog posts)	Basic communication activities according to general guidelines online and off-line including presence at trade fairs	Full communication strategy available with budget assigned	There is a full communication strategy available linked to clear channels for brand awareness and comms metrics
6. FINANCIAL	6.1 Financial Model	No financial model	Calculations are backed with simple, unverified assumptions	Calculations are backed with clear assumptions and forecasts	Calculations are backed with clear assumptions and forecasts and clear milestones linking income and/or expenditure	Calculations are backed with clear assumptions and forecasts and clear milestones linking income and/or expenditure and there is a track record of achievement
	6.2 Growth Metrics	No growth metrics have been defined	Basic growth metrics have been defined	Comprehensive body of growth metrics available	Comprehensive body of growth metrics available and regularly tracked	Comprehensive body of growth metrics available and regularly tracked and acted upon
	6.3 Revenue	Pre-revenue with no monetization strategy	Pre- or post-revenue with a monetization strategy with no defined targets	Pre-revenue or consultancy revenue with a basic monetization strategy and/or targets that are not based on tested assumptions	Pre- or post-revenue with a clear monetization strategy with defined targets based on tested assumptions	Pre- or post-revenue with a clear monetization strategy that has been implemented and meeting targets

Table A1. *Cont.*

Business Category	Key Business Sub-Category	Criteria for Score = 1	Criteria for Score = 2	Criteria for Core = 3	Criteria for Score = 4	Criteria for Score = 5
6. FINANCIAL	6.4 Valuation	Company has not been valued	Company has been valued without applying a recognized valuation methodology	Company has been valued internally applying a recognized valuation methodology	Company has been valued externally applying a recognized valuation methodology	Company valuation is clear and is backed by pre-money term sheets
	6.5 Investment Strategy	No investment plan	Basic investment plan available	Comprehensive investment plan available	Comprehensive investment plan available with clear implementation timetable	Comprehensive investment plan available with clear implementation timetable regularly tracked and acted upon
	6.6 Experience	Does not know what a term sheet is and has no experience in securing investment	Has limited experience in trying to secure investment	Has experience in trying to secure investment unsuccessfully	Has secured angel investment	Has secured VC investment
7. QUALITATIVE ASSESSMENT OF THE FOUNDING TEAM	7.1 Domain Knowledge	No knowledge of the target market	Some indirect knowledge of the target market or experience <2 years	Direct experience of target market 2–5 years	Direct experience of target market >5 years	Recognised expert in the field
	7.2 Entrepreneurial Spirit	Does not appear to possess the basic qualities of a founder	Demonstrates some entrepreneurial behaviour	Demonstrates entrepreneurial behaviour	Demonstrates entrepreneurial behaviour although not fully aware of risks and opportunities	Highly entrepreneurial mindset and spirit. Aware of risks and opportunities but still confident of success
	7.3 Coachability	Does not appear to be able to take advice or criticism	Takes on external advice or criticism sporadically	Takes on external advice or criticism most of the time	Takes on external advice or criticism and analyses impact on company and takes action	Takes on external advice or criticism, contrasts with other inputs, analyses impact on company and takes action
	7.4 Passion	Does not communicate with conviction or passion	Communicates with some conviction or passion	Communicates with conviction or passion inconsistently	Always communicates with conviction or passion	Capable of transmitting passion and generating interest in others

Appendix B

List of the IoT Tribe start-ups accelerated during the four programmes (2018–2021).

Table A2. Anonymised data of the participating start-ups.

Acceleration Programme	Start-Up Code	Foundation Year	Start-Up Age (Years)	# of Founders	Nationality of Founders	Country of Incorporation	Technological Sector of Start-Up Focus
A (2018)	A1	2015	3	1	Italian	UK	Utilities
	A2	2017	1	3	Turkish	USA	Real Estate
	A3	2016	2	1	Scottish	UK	
	A4	2017	1	2	British	UK	Health
	A5	2016	2	2	Brazilian, German	USA	Consumer Electronics
	A6	2017	1	2	Colombian	UK	Utilities
	A7	2017	1	2	British	UK	Industry
	A8	2016	2	4	Polish, North American	PL	Transport & Logistics
	A9	2014	4	1	Spanish	ES	Maritime
	A10	2017	1	1	British	UK	Industry
B (2019)	B1	2018	1	1	Russian	NL	
	B2	2018	1	1	Polish	PL	Transport & Logistics
	B3	2018	1	2	Pakistani	UK	Smart Manufacturing
	B4	2016	3	3	British, Canadian	UK	Real Estate
	B5	2015	4	2	British	UK	Smart Manufacturing
	B6	2015	4	1	Finish	FI	Manufacturing
	B7	2013	6	1	Russian	UK	Transport & Logistics
	B8	2018	1	2	British, Portuguese	UK	Smart Manufacturing
	B9	2016	3	3	Spanish	ES	Smart Manufacturing
C (2020)	C1	2015	5	1	Spanish	ES	Industry
	C2	2018	2	3	Spanish	ES	Aerospace
	C3	2017	3	2	Romanian	RO	Financial Services
	C4	2015	5	1	British	UK	Smart Cities
	C5	2019	1	2	Russian	DE	Aerospace
	C6	2007	13	2	Cypriot British	CY	Critical Infrastructure
	C7	2014	6	4	Spanish	ES	Smart Cities
	C8	2019	1	1	Irish	UK	Real Estate
	C9	2018	2	2	French	FR	Healthcare
	C10	2019	1	2	Spanish	ES	Aerospace
	C11	2013	7	2	French	FR	Financial Services
	C12	2019	1	2	Uruguayan	Uruguay	Aerospace
	C13	2016	4	1	French	FR	Aerospace
D (2021)	D1	2019	1	1	British	UK	Industry
	D2	2018	2	1	German	DE	Industry
	D3	2018	2	2	Spanish	ES	Industry
	D4	2013	7	2	Belgian	BE	Smart Cities
	D5	2019	1	1	French	FR	Transport
	D6	2017	3	4	Italian	IT	Smart Cities/Agriculture
	D7	2016	4	1	Spanish	ES	Aerospace
	D8	2020	0	1	French	FR	Aerospace

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