POLITECNICO DI MILANO

School of Industrial and Information Engineering

Master of Science in Management Engineering

Internet of Things startup: state of the art of the international ecosystem

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RINGRAZIAMENTI

Con questo lavoro di Tesi si conclude la mia carriera universitaria, un percorso lungo e tortuoso e che mi ha permesso di crescere e imparare tanto.

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SUMMARY

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ABSTRACT (ITA)

L'Internet of Things è una tecnologia che sta rivoluzionando il modo di vivere e di operare dell'essere umano, in diversi ambiti della sua esistenza, massimizzando e ottimizzando la raccolta e l'utilizzo dei dati. La sua peculiarità è quella di creare una rete di oggetti connessi in grado di scambiarsi dati e informazioni, creando in questo modo nuove possibilità e scenari. L'elaborato si occupa di analizzare ed approfondire questa nuova tecnologia in tutti i suoi ambiti, in modo da estrapolare quali sono le principali direzioni di sviluppo. Questa analisi viene condotta attraverso il punto di vista delle startup, promotrici per definizione di innovazione, agenti nell'ambito dell'Internet of Things. Dopo aver analizzato approfonditamente il panorama globale delle IoT, si passa all'analisi dello stato di avanzamento delle startup analizzate attraverso un modello creato appositamente che permette di classificare le varie aziende nei diversi stadi del ciclo di vita. In particolare, lo scopo è quello di andare a constatare quali sono i campi applicativi dell'Internet of Things di maggior successo, ovvero quelli nei quali le startup riescono a raggiungere con maggior facilità le fasi finali del proprio ciclo di vita.

ABSTRACT (ENG)

The Internet of Things is a technology that is revolutionizing the way humans live and operate, in different areas of their existence, maximizing and optimizing the collection and use of data. Its peculiarity is to create a network of connected objects capable of exchanging data and information, thus creating new possibilities and scenarios. The thesis work deals with analyzing and deepening this new technology in all its areas, in order to extrapolate which are the main directions of development. This analysis is conducted through the point of view of startups, promoters by definition of innovation, agents in the Internet of Things. After having thoroughly analyzed the global IoT landscape, the focus shifts on to the analysis of the progress of the startups analyzed through a specifically created model that allows us to classify the various companies in the different stages of the life cycle. In particular, the aim is to ascertain which are the most successful Internet of Things application fields, that is, those in which startups are able to reach the final stages of their life cycle more easily.

EXECUTIVE SUMMARY

INTRODUCTION

The Internet of Things technology is one of the most emerging trends of recent years. This technology makes it possible to connect smart objects to each other and to receive and exchange information, through wireless networks. Its use is increasingly widespread and present in many areas that characterize the life of the human being and today's society more in general. In particular, the main application fields of this technology are:

- eHealth: use of technology with the goal to benefit human health, creating new life-saving solutions to improve the quality of life;
- Multi-Application platform: it connects different kinds of objects and sensors, enabling them to collect data from different sources;
- Networks and Infrastructures: large IoT networks that give the possibility to smart connected objects to transmit and process data;
- Smart Agriculture: monitoring of parameters related to the agriculture with the intent to increase the quality of products and to optimize the resources used;
- Smart Asset Management: it allows to remotely manage, track and trace assets
- Smart Building/Home: solutions to manage automatically objects connected to the home/building, in order to reduce energy consumptions, improve the comfort and increase the security;
- Smart Car: application of the IoT technology which gives the possibility to communicate real time information about car to the customer;
- Smart City: monitoring and management elements characterizing cities such as security, transport, parking, in order to improve the life of citizens;
- Smart Factory: it is basically a question of optimizing productivity and connectivity between machines, making processes more flexible and efficient;
- Smart Grid: solutions concerning electrical networks that allow the smart distribution of energy;
- Smart Logistics: it consists in the use of the IoT for the management of company fleets, useful for improving the quality of delivery;
- Smart Metering: connected meters that allow the monitoring of consumption;
- Smart Objects: all the physical objects augmented with computation capabilities, and which are therefore capable of communicating through the internet with remote services or other objects;
- Smart Retail: it helps the customer during its purchasing journey, making the purchasing processes faster and more functional;
- Wearable Objects: they represent smart objects which people can directly worn and allows to collect and transfer data about the users.

In order to better explore the characteristics of the reference market, the point of view of startups operating in the IoT field was considered. in particular, through the definition provided by the IoT Observatory, all those startups founded no later than 5 years ago or which have received funding in the last two years are considered.
Startups by definition usually take advantage of new technological currents to develop their business. It is for this reason that studying its behavior and ecosystem can be important in order to identify the main trends of this new technology.

RESEARCH QUESTIONS AND METHODOLOGIES

The thesis work is based mainly on two research questions.
The first is the following: "*What is the state of the art of IoT startups at international level?"*. It aims to deepen some details of the internet of things such as the diffusion of this technology, what kind of solutions the analyzed startups offer most, up to the analysis of financial aspects considering in particular the funding received by companies. In this way, it is possible to have a global overview regarding the development of the Internet of Things. The starting point for this kind of analysis is a database containing information about 1079 startups provided by the Internet of Things Observatory of the Politecnico di Milano, and subsequently updated.

The second research question, on the other hand, has the main objective of measuring the level of success of the different application fields of the internet of things. The question is "*What is the level of success of the IoT startups belonging to the different application fields?"*. The starting point, this time, is a classification framework built considering the last funding round received by startups. In fact, by analyzing these data it is possible to extract information about the progress of startups, and therefore understand at what stage of their life cycle they are.

GLOBAL LANDSCAPE OF THE IOT STARTUPS

The first aspect considered in this analysis is the evolution of IoT startups over years, that is, for each year the new startups born in the internet of things field are considered. There is a growing trend in which it reaches its peak in 2016, then there is a slight decrease compared to the peak. These numbers are mainly due to the conditions set by the definitio of IoT startups that were adopted during the project.
Then, the geographical distribution of the IoT startups was analyzed.

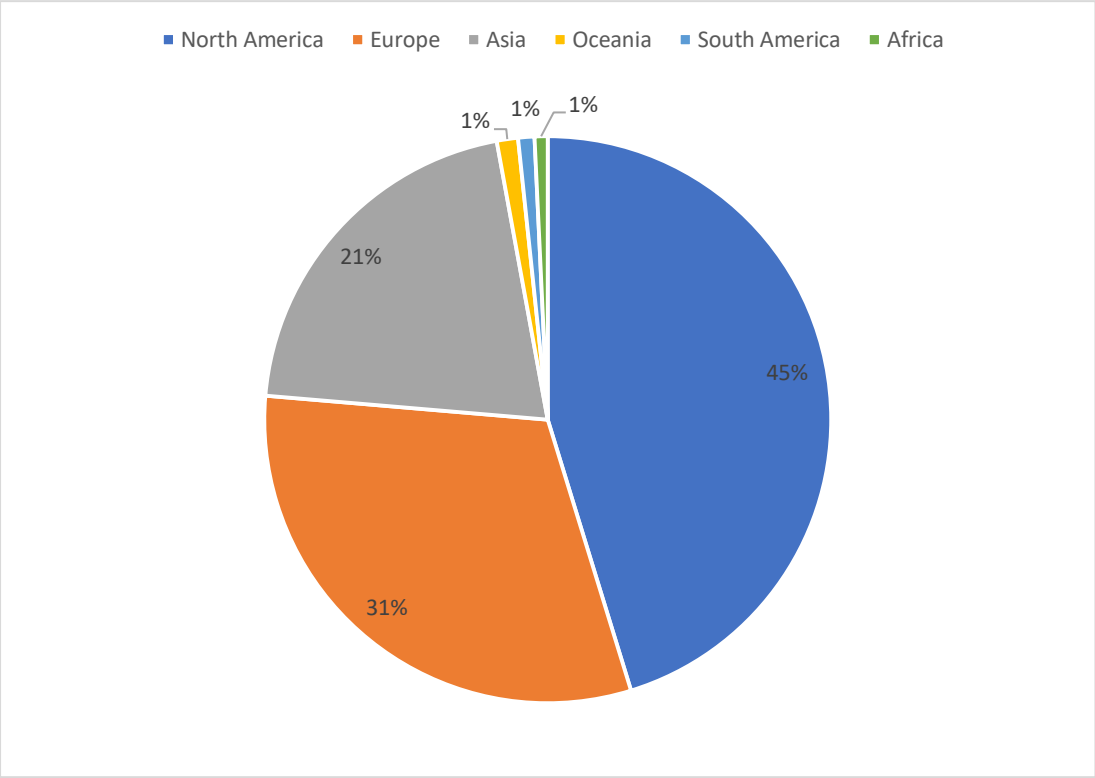

Figure 1: Geographical distribution of the 1074 startups

As can be seen from the figure, 97% of IoT startups are located in the 3 most developed areas of the planet, namely North America, Europe and Asia. In particular, the 45% of the 1079 startups analyzed are located in North America, the 31% in Europe and the 21% of the total in Asia. There is a consideration regarding the Asian numbers, valid from here to the end of the thesis: some Asian countries' policies impose severe limitations on information sharing, which make it more difficult to find information or even entire companies on the Web. These restrictions may affect the veracity of the data concerning Asia. Making a more detailed analysis on the 3 main areas, as far as North America is concerned, almost all startups are concentrated in the USA. In Europe, instead, about 57% of the 332 IoT startups are concentrated in Italy, United Kingdom, Germany and France. Finally, in Asia, India, Israel and China count together 159 out of 226 Asian Internet of Things startups.
Instead, from the distribution of companies within the different application areas of Internet of Things, it was possible to highlight the presence of concentrations, especially in one field compared to another.

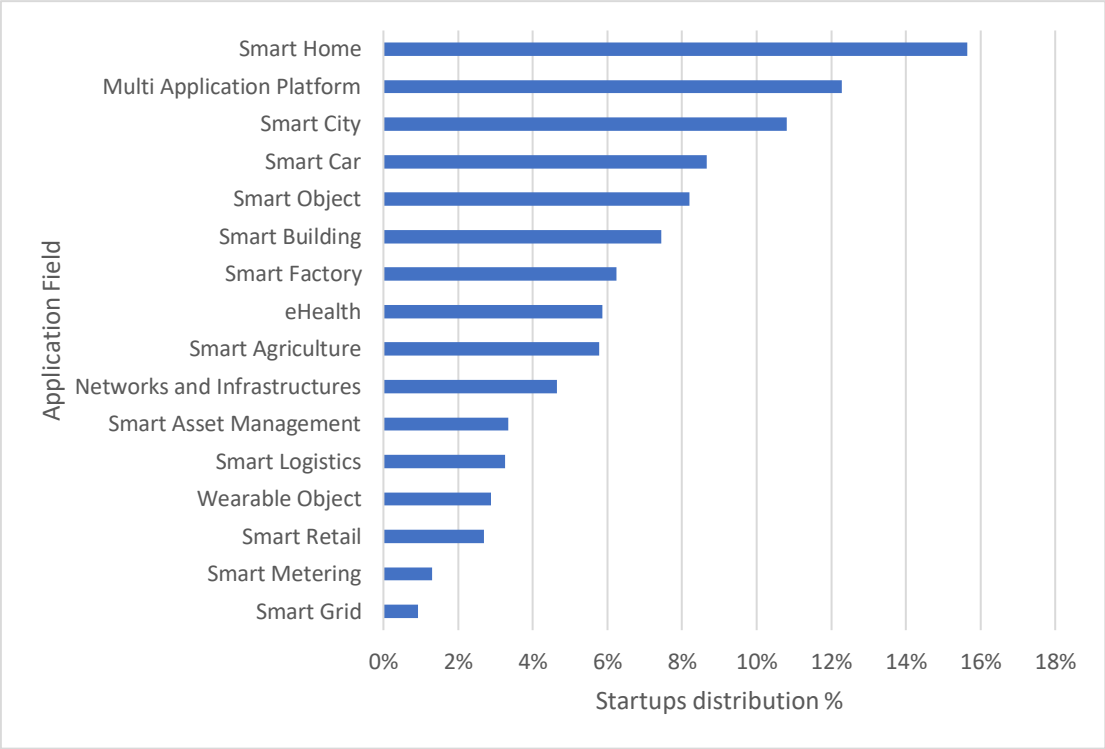

Figure 2: Distribution by application field of the 1079 startups

Smart Home is the application field where you can find the largest number of startups with 168 companies out of 1079, followed by Multi-Application Platform and Smart City. Going into detail, considering the functionalities applicable in the Smart Home and Smart City fields, it is possible to notice that notice that: for the former, Scenario Management and Security are the areas most exploited by startups (over 50% of the total number of smart home startups), while for the latter, Private Transportation is the preferred area for startups, with 35 Smart City startups out of 116. Analyzing instead the evolution of the application fields over the last decade, it can be seen that the first half of the time shows a preference towards Multi-Application Platform field, while the second half shows the growth of preferences in the Smart Home area. The phenomenon that sees the evolution of the Smart Home field is certainly facilitated by the fact that, in a world that is moving towards digitization, an everyday environment such as that of the home can certainly offer startups a higher user base, and therefore more clients.

By combining the analysis carried out for application areas with that of geographical distribution, it was possible to have an overview of how the various startups belonging to the different application fields of the IoT are geographically distributed. Table 1 illustrates the situation in the 3 main areas of analysis: North America, Asia and Europe. In the first two countries the IoT area most exploited by startups is that of the Smart Home, while in the European continent the field of application preferred by the new companies is that of the smart city. Smart Grid and Smart Metering instead , as also seen in Figure 2, are the least exploited IoT areas.

	North America	Asia	Europe
eHealth	6%	8%	5%
Networks and Infrastructures	4%	3%	6%
Multi-Application Platform	15%	11%	9%
Smart Agriculture	4%	6%	7%
Smart Asset Management	3%	5%	3%
Smart Building	8%	7%	7%
Smart Car	10%	10%	5%
Smart City	7%	11%	16%
Smart Factory	9%	5%	3%
Smart Grid	0%	1%	2%
Smart Home	19%	14%	13%
Smart Logistics	3%	4%	3%
Smart Metering	2%	0%	1%
Smart Object	7%	7%	12%
Smart Retail	3%	4%	2%
Wearable Object	1%	3%	5%

Table 1: Application fields percentage distribution of the 1048 startups distributed in the 3 main areas

Another aspect characterizing IoT startups is the type of offer proposed to the customer: it can be a Hardware, Software, Service or a combination of the three and the Networks and Infrastructures type. From figure 3 it is possible to see how the first three types of offer in the ranking are not pure Hardware, Software and Services but rather combinations of these. In this way, startups show that they want to offer the most complete solutions possible. In particular, the most chosen type of offer is a bundle of Hardware offer and Software offer with 361 startups up to 1079, followed by Software offer combined with a Service offer and then, in third position, a bundle of Hardware, Software and Service offer.

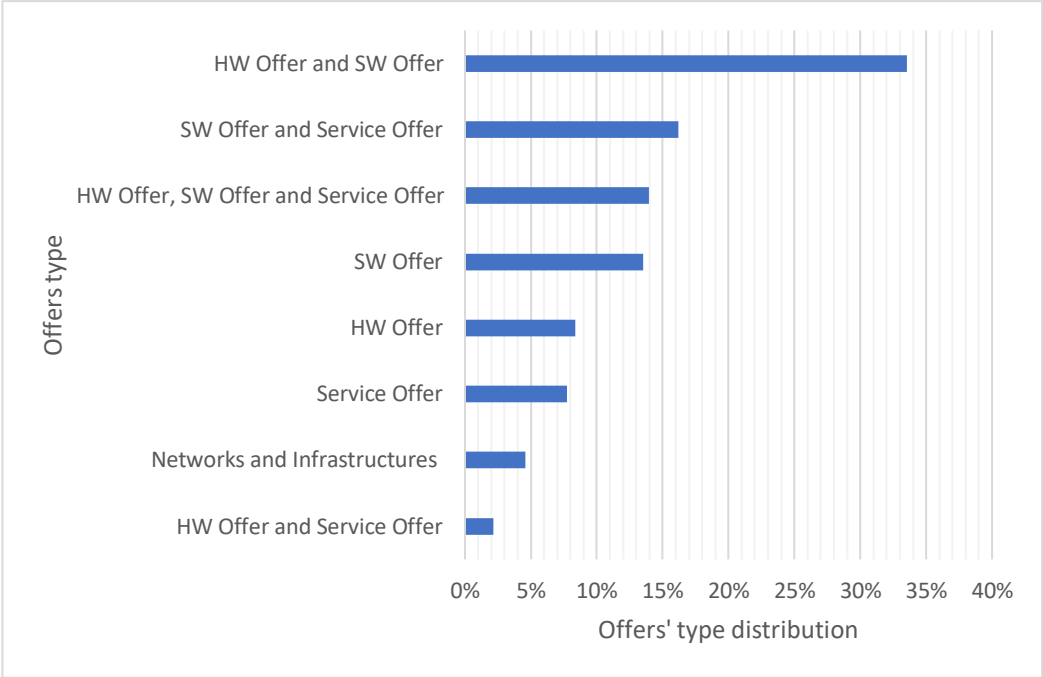

Figure 3: Offers' type distribution of the 1079 startups

A similar investigation is carried out regarding the type of client target of the mapped companies. There are mainly three targets servable, which are the final consumer (B2C), another business (B2B) or a developer (B2D). in reality, the offer can also be addressed to several types at the same time, therefore to a combination of the aforementioned targets. The two preferred targets are, in order, B2B, with 488 companies addressing their solutions to this kind of customer, and B2C with 337 startups out of 1079. As can also be seen from Figure 4, the least selected target types by firms are those that include developers, thus showing a secondary interest in this type of customers.

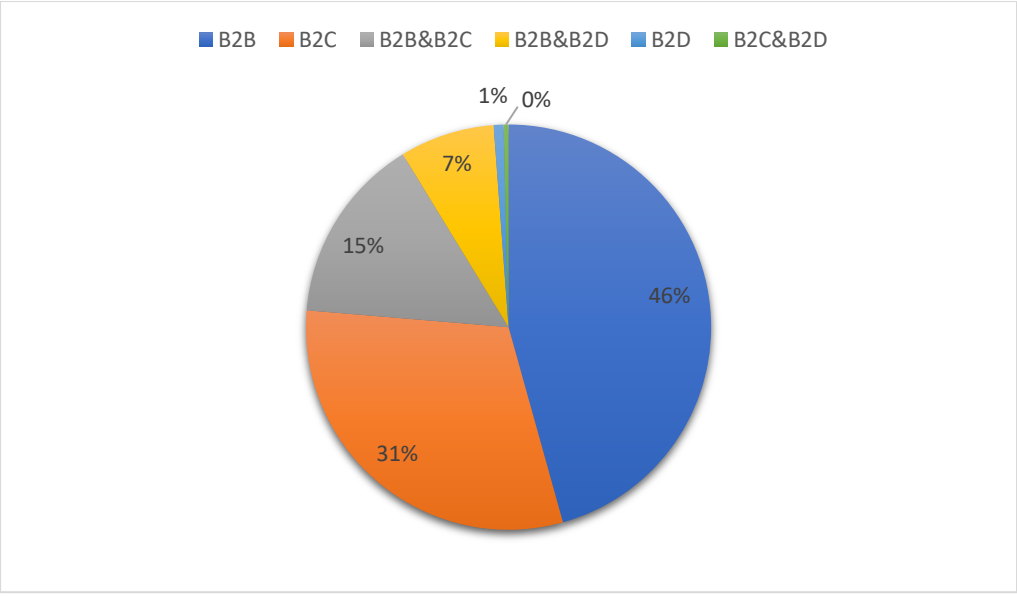

Figure 4: Distribution by customer target of the 1079 startups

Moving on to the analysis of the financial part, and therefore concerning the loans received by the startups, there is a premise to make: not all the companies present in the analyzed database offered financial data. Therefore, the basin of this analysis is reduced to 854 startups. The first type of analysis developed was the evolution of the funding received over the years, i.e. the average and total funding received by startups every year, from 2015 to 2021: it was possible to see how the trend is growing and therefore the amount of funding received by startups for each year is increasing. This demonstrates how the interest and confidence in this technology on the part of investors is constantly growing. This type of growth obviously does not include 2021, of which only the first two months have been analyzed and the data available are few.

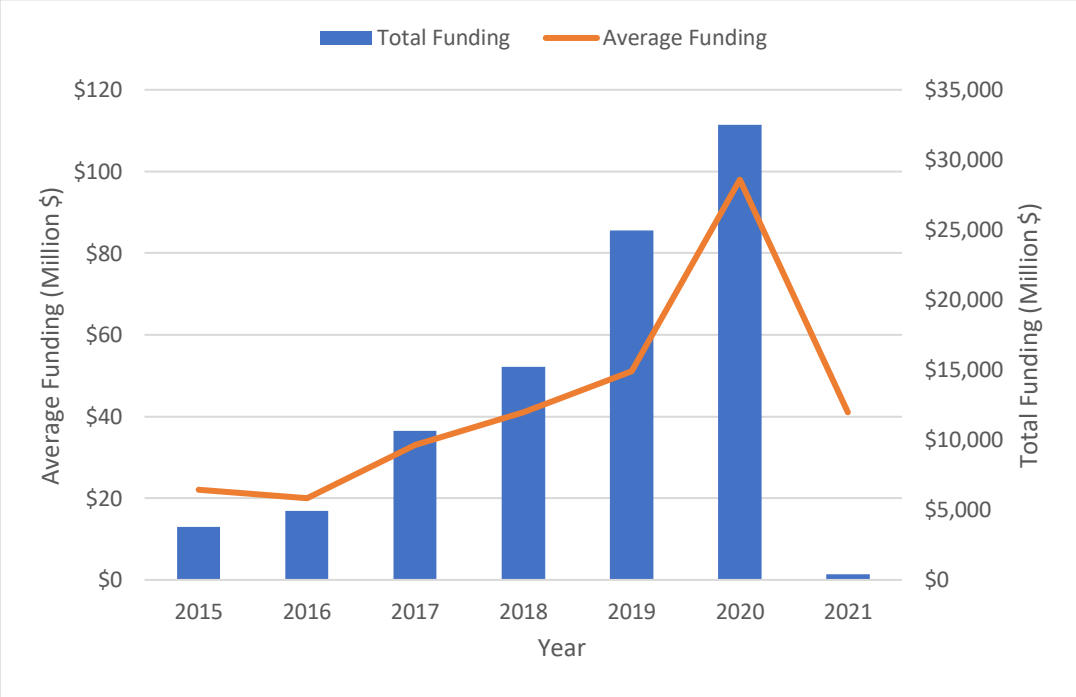

Figure 5: Total and Average Funding evolution of the 854 financed startups

The same analysis was done by removing the outliers, i.e. startups that have received at least one round of funding greater than or equal to one billion: as regards total funding, the trend is growing even if the peak is reached in 2019 with a slight decrease in 2020 compared to the previous year. As for the average funding per startup, the trend line continues to grow, reaching its peak in 2021.

In addition to the distribution of funding by year, also the one by continent was analyzed, as shown in Figure 6. The most surprising data in this case is the Asian one: as regards the total funding, despite being the third for number of startups, almost reaches the primacy North America, which has more than double the number of Asian startups. On the other hand, as regards the average startup loan, Asia dominates this ranking with about 248 million received per startup, doubling the American data, which is in the second position. Europe occupies the third position in this ranking, far from the first two in terms of numbers. these data show that investors are more attracted to Asian and North American startups. Instead, there is still a very low ability of European startups to attract

large investors.

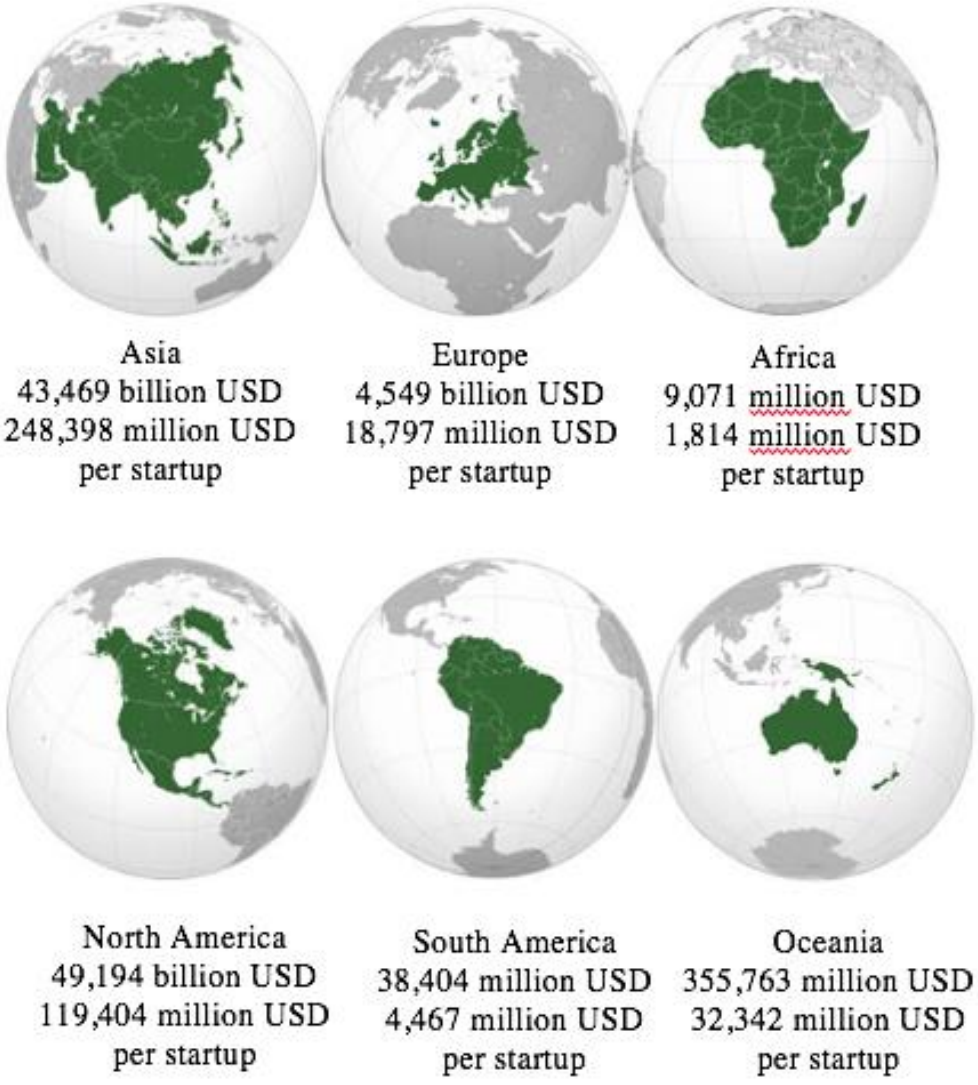

Figure 6: Total and Average Funding per continent of the 854 financed startups

Interesting and unexpected data emerge from the analysis of total and average funding received by field of application. Indeed, it is possible to note that Smart Home is only seventh in total funding received, less than 4.3 billion USD. Consequently, considering the low average funding value received for startups in this field, it appears to be an area of application that does not require huge capitals to develop their business. The most impressing data that emerges is the one related to the Networks and Infrastructures field: in fact, although it represents only 5% of the total by number of firms, it is by far the area that has collected the most funding and that has the higher average value per startup. On the other hand, this is for sure an application field that offers solutions that require significant capitals to be developed. Two other interesting data derive from the analysis of the trend line regarding the average funding per startup of the various application fields: it is possible to see how Smart Logistics and Smart Grid areas behave as outliers. These numbers are indicative of how companies operating in these areas need significant

funding to survive and develop their solutions.

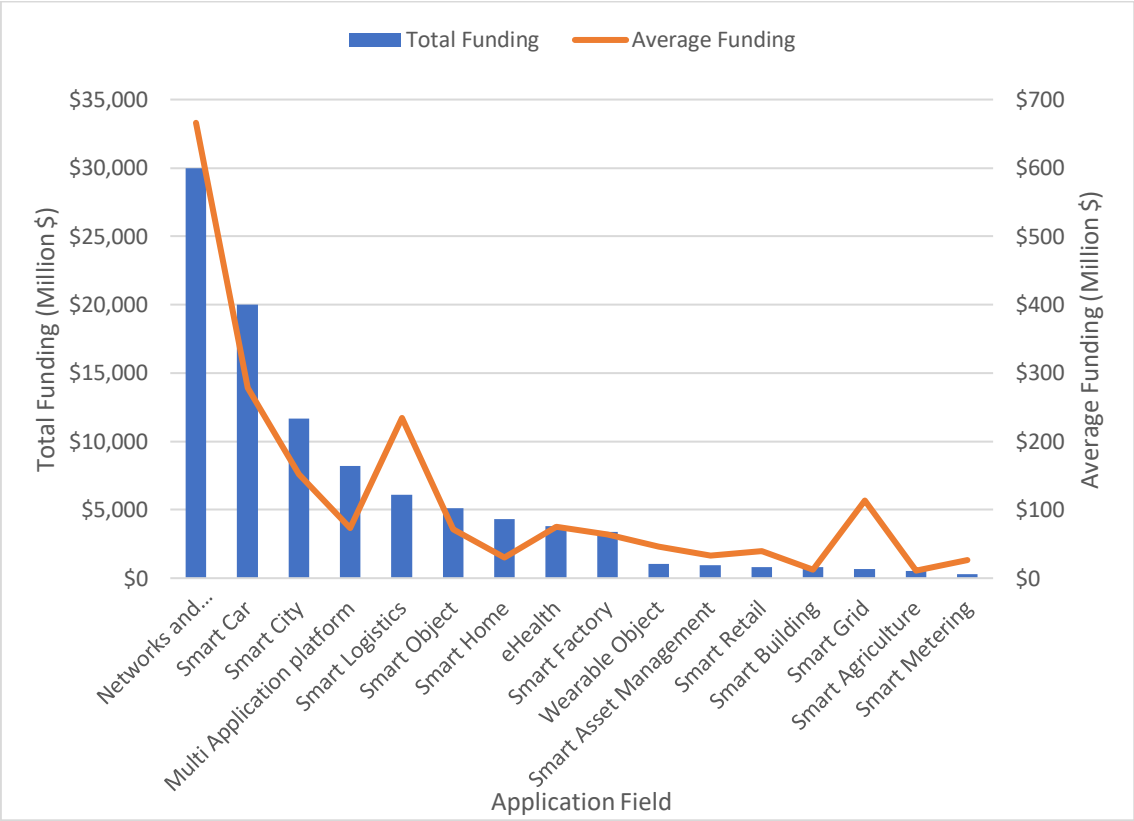

Figure 7: Total and Average funding per field of application of the 854 financed startups

Also in this analysis an exploratory focus on Smart City and Smart Home functionalities was developed. In particular, it was investigated which functionalities of these fields have received the most funding. As regards the Smart City area, Private Transportation is by far the most funded sector: in fact, 92% of the total smart city funding belong to this field. Slightly different is the situation for the Smart Home area, in which there is no a largely dominant functionality as is the case of Smart City, but Security, Scenario Management and Personal Assistance respectively share 86% of the total financing.

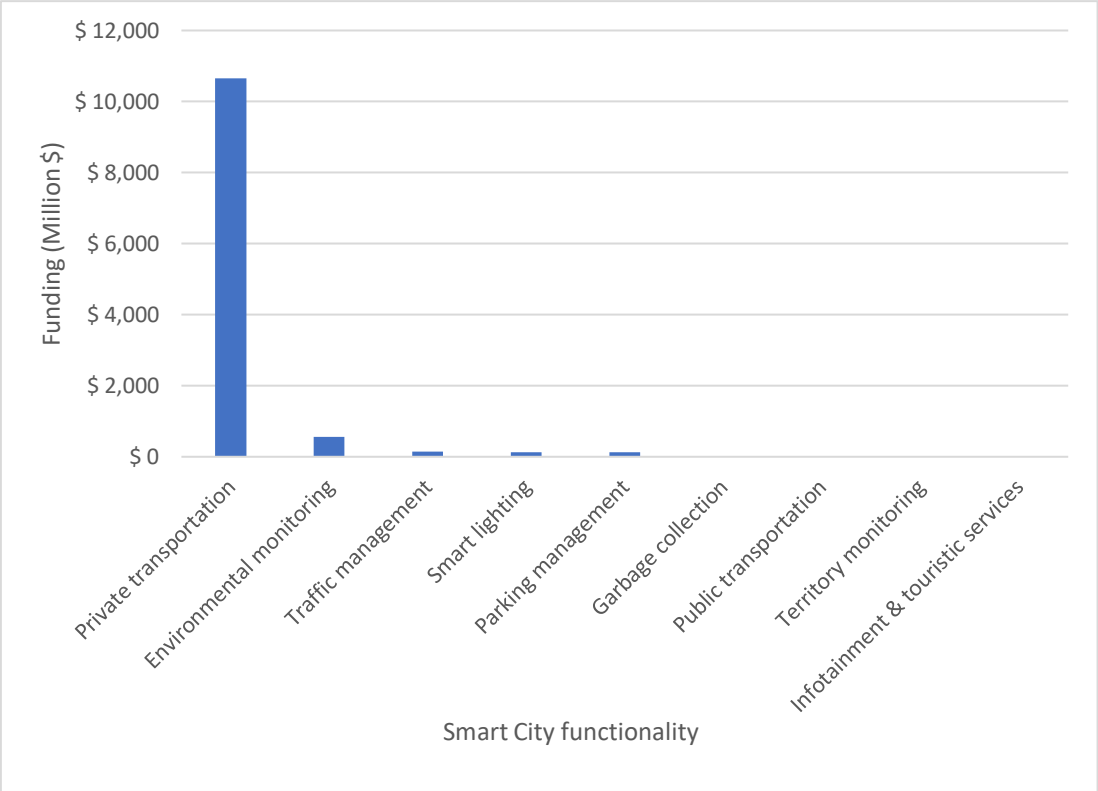

Figure 8: Funding distribution per functionality based on the 143 financed Smart City startups

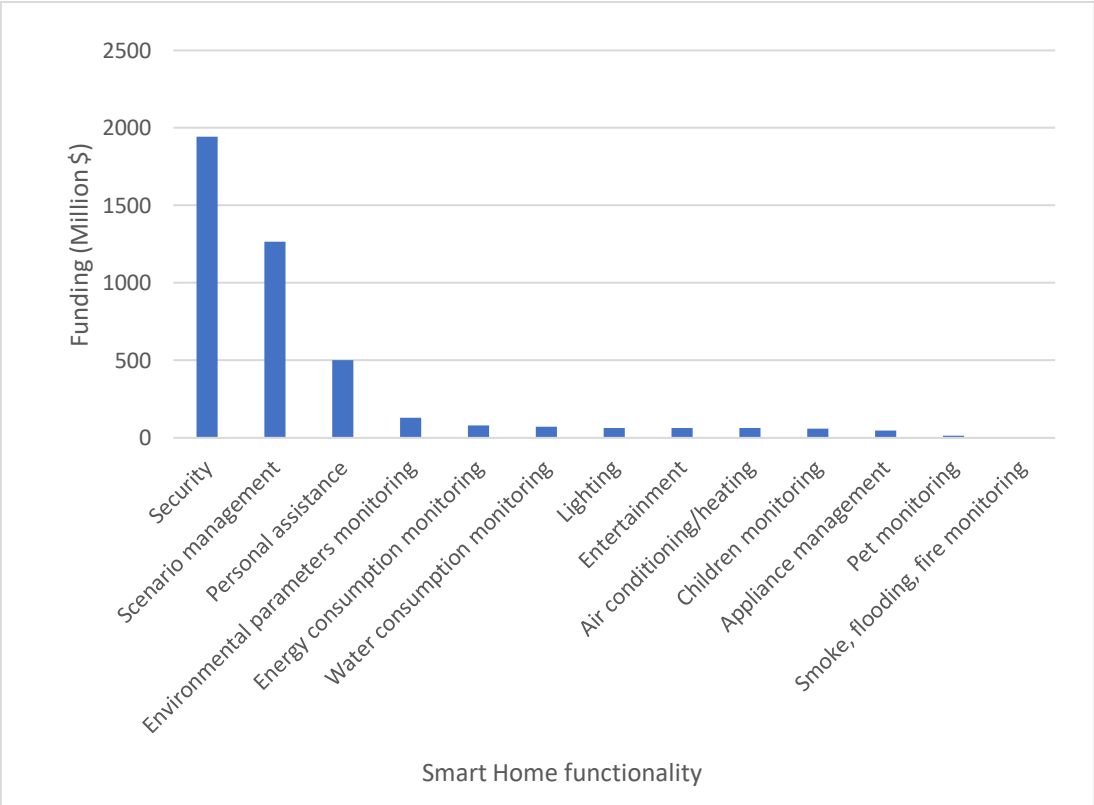

Figure 9: Funding distribution per functionality based on the 115 financed Smart Home startups

ANALYSIS OF THE SUCCESS OF IOT STARTUPS

The basic notion on which this type of analysis is based is that it is possible to distinguish 5 phases in the life cycle of a startup:

1. Pre-Seed Stage: it is the very initial phase, in which the startup has the idea and its priority is to raise money in order to start the business. In this stage, when it comes to capitals, it is necessary to talk about the triple F: friends, family and fools.
2. Seed Stage: here, awareness of the idea grows and the first steps are taken towards the creation of an MVP, a product prototype. There are figures such as incubators, which help to create the business model, and accelerators, which accelerate the idea.
3. Early Stage: in this phase, there is the transformation of the MVP into a tangible product, the production starts and the startups wants to increase its business. Here, usually, it is possible to rely on venture capital funds, a branch of private equities.
4. Growth Stage: this is the phase in which the startup grows, increases its turnover and the number of customers. together with these, the capitals necessary to increase the business also grows.
5. Exit Stage: the company has grown and it is ready to be sold, obtaining an extra yield. It is an optional step: in fact, startups can decide to remain so for life. There are mainly two ways to "exit": being bought by another company or through an Initial Public Offering (IPO).

Once this introduction has been made, the goal is to classify the startups analyzed in the various stages, according to their state of progress. To do this, a classification framework has been built which, considering the last funding round received by startups, allows to estimate the stage of the life cycle to which they belong. In fact, many funding rounds are characteristic of a particular stage of the life cycle, while others are generic and do not allow for the classification of startups.

Life Cycle stage	Funding Round type
Pre-Seed stage	Angel Pre-Seed
Seed stage	Equity Crowdfunding Product Crowdfunding Seed
Early stage	Series A Series B
Growth stage	Series C Series D Series E Series F Series G Series H Series I
Exit stage	Initial Coin Offering Post-IPO debt Post-IPO equity

Table 2: Classification framework

Considering that, the startups suitable for the analysis must first have financial information and, moreover, they must have received one of those mentioned in Table 2 as the type of last funding received. For this reason, only 667 of the initial 1079 startups participated in this analysis. Before proceeding with the stage-by-stage analysis it is necessary to underline one aspect: as the startup grows during its life cycle, the capitals needed by the startup also increase and with it the amount of the funding increases.

PRE-SEED STAGE ANALYSIS

In the very initial phase it is possible to find a very small percentage of the total number of startups analyzed (2% of the total), showing a certain ease in passing this stage. The fields with the highest percentage of startups in this phase are Smart Logistics, Smart Factory and eHealth, with values around the 10%. However, this seems to be mainly caused by the presence of newly born startups in these fields, rather than the inability to reach the next stages. In addition, the percentages of Networks and Infrastrucures (0%) and Multi-Application Platforms (2%) should be emphasized, demonstrating a certain speed even for the newest startups, to overcome the embryonic stage.

SEED STAGE ANALYSIS

In this phase, it is possible to find a larger sample of startups, more precisely about 42% of the total. Contrary to what happens in the previous step, in the Seed Stage the percentage distribution values of the startups belonging to the different application fields vary from 25% to 75%. Therefore, there are different situations and different behaviors of startups, area by area. In particular, analyzing some numbers, the lowest percentage value belongs to the Multi-Application Platform field, with 25% of the total startups in this phase, proving to be the most successful application field so far. High percentage values are instead those of the Smart Car, Smart city and Smart Home fields, all around 50%. In this case, the data can be partially explained considering that many of the startups belonging to these areas in this step are still young

EARLY STAGE ANALYSIS

In this phase, the transformation of the MVP into a tangible product takes place. This phase of the life cycle is also very populated (there are 243 startups, 37% of the total). The startups distributions of the various application fields in this phase amounted to between 30% and 40% of the total.
It is therefore possible to say that the startups of the different IoT areas of application are able to develop the MVP quite easily and transform it into a finished product. With 46% of the total number of startups, Multi-Application Platform is once again the field that stands out, also thanks to the low percentage values in the previous phases.

GROWTH STAGE ANALYSIS

This is the most interesting phase of the life cycle to analyze. It is a stage not so easy to achieve, in which the numbers in terms of customers, turnover and business start growing. In fact, only 15.6% of the startups analyzed were able to achieve this internship. The most successful areas of the Internet of Things are eHealth (26%), Multi-Application Platform (25%) and Smart Factory (23%), fields in which startups are able to reach this stage of growth quite easily. While the eHealth sector may have been facilitated by the pandemic that has hit the planet in the last year, the other two fields, being two large areas, need significant funding or are likely to fail.
The lowest percentages instead belong to the fields of Smart Agriculture, Smart Asset Management and Smart Home, none of which reaches 10%. The most surprising figure in this case is that of the Smart Home, a strong and continuously growing sector. This can be explained by considering the fact that startups in this area generally do not need large funding to develop their business.

EXIT STAGE

This is a phase of relative importance: firms do not necessarily have to reach this step, but may decide to remain startups for their entire life cycle (and therefore not to reach the exit phase). In fact, only 1.8% of the startups analyzed are in this phase. The most successful areas of IoT application of the growth stage also assert themselves in this phase, bringing a minimum number of startups to the end of their life cycle. Smart home is the application field that appears to have more startups in this phase (3), showing to be a well-established sector, even if it generally requires not huge funding.

CONCLUSION

From the analyzes previously developed, interesting elements emerge, which can be summarized below.

As regards the first research question, from the analysis of the global situation of IoT startups it emerges that there is an intense concentration of startups in 3 areas like North America (490 startups), Europe (332 startups) and Asia (226 startups). It must be considered that the numbers concerning Asia may be limited by the political restrictions that some countries may have on the spread of information.
With regard to the distribution relating to the areas of application of the IoT, it is possible to note a strong orientation towards the Smart Home, which appears to be the most popular field for companies, with 168 startups out of 1079 analyzed. Furthermore, by analyzing the trend of the application fields over the last ten years, it can be noted that in reality the IoT area preferred by startups was initially Multi-Application Platform, and only later the orientation shifted towards Smart Home.
By shifting the focus to the financial side instead, it can be seen that there is a growing trend over the years regarding the funding received by startups, showing the constant growth of interest in the IoT world. On the other hand, by analyzing the distribution of funding by geographical area, it can be seen that the figures reached by North America and Asia are significantly different from those of the other countries. Finally, looking at the fields of application of the Internet of Things, Networks and Infrastructures is the area that collects the most funding, surpassing the Smart Car area by 10 billion, the second most funded IoT area.

About the second research question it is possible to make some general considerations.

	Number of startups	Distribution of startups
Pre-Seed Stage	28	4%
Sed Stage	280	42%
Early Stage	243	36%
Growth Stage	104	16%
Exit Stage	12	2%

Table 3: Distribution of the 667 startups by life cycle stage

Most of the analysis sample (the 94%) is located in the central area of the life cycle and this is not surprising, considering that the very first phase is easily overcome by the startup while the last is not a necessary step for firms. The Seed Stage is the most populous phase and therefore appears to be the longest and most intensive to overcome. The most interesting step that is essentially the goal that startups aim to achieve is the Growth Stage,

the phase that represents success for the company. The percentage distribution in this phase (16% of the analyzed sample) shows that this is a phase that is not so easy and obvious to achieve. Table 4 summarizes the level of success of the application fields, classified in order of outcome considering the sum of the distributions of the startups in the Growth and Exit stages. The Smart Grid and Smart Building areas do not participate in this ranking because the sample of startups available for this IoT application area is too low, and therefore, the statistical significance of the numbers available for these two application fields is not sufficient to be able to insert them in the table and determine their success.

Growth Stage + Exit Stage distribution	**Application Field**
>=20%	Multi-Application Platform eHealth Smart Factory
>=15% & <20%	Smart Logistics Smart Car Smart Retail Networks and Infrastructures Smart Object
>=10% & <15%	Smart City Smart Building Smart Home Smart Asset Management Wearable Objects
<10%	Smart Agriculture

Table 4: Classification of application fields according to the cumulative distribution in the Growth and Exit stages

CHAPTER 1: INTERNET OF THINGS AND STARTUPS OVERVIEW

With the beginning of the new millennium, Internet of Things has taken hold in the world. In more and more daily areas it is possible to find the use of this technology, becoming a faithful companion of the human being. This happens because the idea behind this technology is that all the objects can be connected, can communicate with each other by exchanging information and acting on these. Objects become intelligent, capable of interacting autonomously with other devices connected to the network, and of performing certain actions following the receipt of specific inputs or the reading of data. The Internet of Things can be seen as a system in which all the objects within the connection network have their own specific role, and their presence becomes necessary in order to reach the final goal. Thanks to the implementation of systems of this type, it is expected to change people's daily way of life. Activities that each person performs every day, or actions that he should perform but he forgets about, can be performed by objects connected to the network. The autonomous communication between objects, which will therefore take place without human intermediation, will have the utility of being able to facilitate everyday life, simplifying the problems that may arise in different context. The different characteristics, typologies, field of applications and other details of this technology will be presented later in the course of the thesis.

Internet of Things is a technology which can grow exponentially over the years thanks to the global digitalization. Emerging startups are focusing more and more on the use and the development of this technology in order to exploit these characteristics. Focusing on a continuously developing and increasingly widespread technology can create value added for startups and their customers. Some of them use well established functionalities, others try to experiment with new uses of this technology, expanding the boundaries of use. The main goal of this thesis work is to analyze how Internet of Things is used by startups to create value.

1.1 INTERNET OF THINGS

In the last two decades, the field of information and related Information Technology has changed a lot. From the concept of the Internet to the Internet of Things, this progress can be realized and applied. A British entrepreneur, Kevin Ashton, coined the title Internet of Things in 1999. According to him, IoT refers to a global network of radio-frequency identification, or RFId, linked objects. Internet of Things is in an advancing phase.
The global network of computing devices around the globe is termed as the Internet. The internet provides an open-ended perspective for generating connectivity among various devices while the Internet of things provides another open-ended prospective for generating connectivity as well as embedded computing capabilities among them.
Nowadays, via the internet, each home, company, school, institute, private organization and government organization is linked to each other. More precisely, every single person is connected through an internet connection.
Internet-of-Things can be defined as "*a paradigm with a notion of enabling the things (physical entities e.g.: human, car, animal, mirror, bulb, plant etc.) to communicate with each other, to transfer and receive the information (read-only data), through the use of underlying network (wired or wireless), supporting technologies (e.g. ZigBee, Bluetooth, Wi-Fi etc.), required sensors, actuators and computing devices, and finally respond back in a way that requires least or negligible human intervention*"[1].
The general idea behind the IoT is that some devices are able to send the information collected from the external environment to someone else. This is what humans want to do: obtaining information from operating devices and supporting a flow of information from a device to somewhere.
Moreover, devices can be controlled thanks to a flow of information that is flowing in the opposite direction compared to the previous case. In fact, according to what devices communicate, it is possible to implement corrective actions in order to avoid anomalous behavior.
Of course, for getting information from a device, or else for controlling a device, it is needed a proper application which is able to understand the information coming from the device itself. Usually, applications are ran on the cloud. This is because the information comes from a large number of devices, thousands of devices and from thousands of users, and so the characteristics of the cloud are crucial for being able to run efficient and effective applications.
In other words, the Internet of Things allows to realize applications that will enable to make the user of an environment aware of what is going on and what is happening inside the environment itself, with the aim to react with an adaptive behavior and making the environment smart.

[1] International Conference of Computing, "All You Want To Know About Internet of Things (IoT)", 2017

1.1.1 INTERNET OF THINGS COMPONENTS

As the name implies, Internet of Things is a paradigm that is an aggregate of things, physical objects, and smart things more precisely. But its structure is not so easy. It is not made up only of smart things, but there are also other crucial components. Its main components are: Things, Sensors, Actuators, Fog Data Service and Storage Component[2].

Things

Things that make up the IoT are common but not ordinary things, they are Smart Things. These are the objects, entities, and devices which are well equipped with electronics, computing capabilities, and a communication interface, and therefore designated as Smart Things. These things can be discovered, managed, interacted, and controlled remotely via communication interfaces and computing capabilities, over the internet. Things may be an object, any animal, a human being, a personal computer, a Smartphone, a fan, a vehicle even a plant. Things as an entity have their attributes.

Sensors

A sensor forms an essential interface for the IoT implementation and therefore referred as the front end of the Internet of Things environment. In order to perform any of the tasks provided by any IoT implementation, sensor data collection acts as a stimulating event. In an IoT environment, every sensor has to write or generate, and implement a quite complex and heavy program code for appropriate and accurate data collection.
Sensors can vary according to the application field. Many sensors and their interfaces are dedicated to some particular applications, while others are adaptable for different domains. Sensors, especially multi-sensory acquisition devices, are attracting the attention of academics, researchers and manufacturers with the growing moment towards IoT.
However, they are classified on the basis of data size, sampling rate, the number of connected devices, types of signals associated with the sensor.

Actuators

Micro-electro-mechanical systems (MEMS) are computer chips that are the unavoidable integral part of an IoT implementation. These include both sensors and actuators. A sensor is a device that transforms the functional energy into electrical signals while, an

[2] International Conference of Computing, "All You Want To Know About Internet of Things (IoT)", 2017

actuator is a device that transforms electrical signals into functional and useful energy. It basically initiates motion or a mechanical action on energy supply. As we know sensors collect the data. The next issue is to process, analyze the collected data and generate appropriate action accordingly. This issue is sorted by the usage of actuators. Therefore, the sensor-actuator pair forms the backbone of an IoT implementation. The basic urge to develop and design more actuators is due to the fact that IoT actuators are the devices that actually transform the intelligent and processed data into energy. Another appealing factor towards the research of actuators is the big difference between the existing sensors and actuators. Sensors are present in a quite big number while actuators are not. Actuators are classified on the basis of their energy source that they need and use to cause the movement. The actuators related to IoT are also identified as pneumatic actuators, hydraulic actuators, electric actuators and thermal actuators.

Fog Data Service

Fog data services is an infrastructure placed between the edge and the cloud that is used to provide collection services and analysis services. So, it can be considered as a set of services that are working for collecting and analyzing data, providing then some results that are important parameters for running certain applications on the cloud. In this stage, on the basis of a set of rules and analysis algorithm, it is possible to filter and transform data and to transfer on the cloud only relevant information that can be used for running a smart application.

Storage Component

As IoT is a collection of a big number of devices, applications and services which are communicating with each other. All of which produces a huge amount of data. The produced, generated, processed data must be stored in appropriate storage devices, for processing, analyzing and triggering the appropriate actions. IoT applications like smart home, smart health monitoring, real-time financial analysis, smart banking, and similar applications generate massive amount of data. Traditional modes of storage that are basically designed to store average amount of homogenous data, are not sufficient to serve the purpose of IoT. Here the data is big and heterogeneous. Therefore, cloud based storage along with big data analytics is the solution for data storage in IoT.

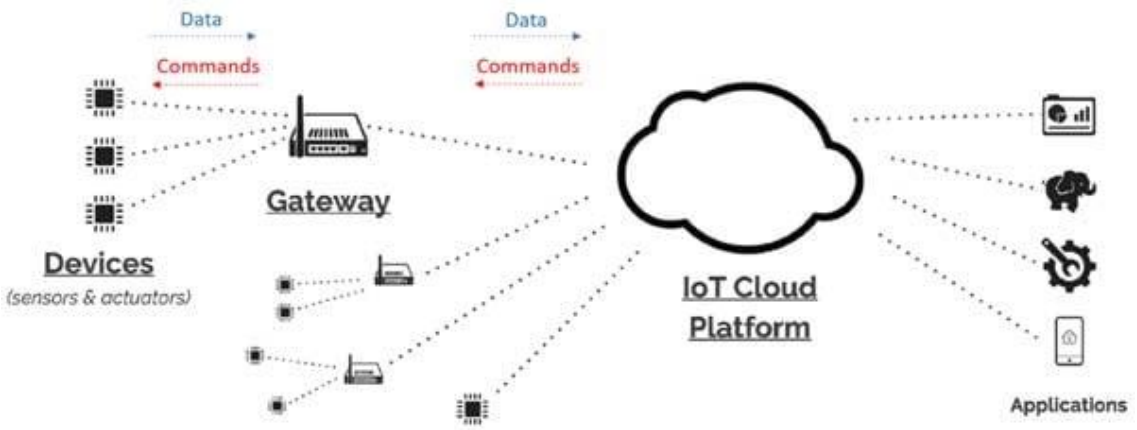

Figure 10: Internet of Things development services

1.1.2 INTERNET OF THINGS APPLICATIONS

IoT has a lot of potential for social, environmental, and economic impact towards its adaptation. This technology has many fields of application. Usage of these applications have an important role and now there is a huge dependency on their existence. During recent years, their existence and usability have attained a visionary scale and have become of paramount importance. According with the indications provided by Observatory of Politecnico di Milano, below are presented and analyzed the main features of the most relevant IoT applications.

Smart Home/Building

A Smart Home or a Building is a similar environment unlike any other living environment that is equipped with heating, lighting and other electronic devices. A significant difference is that they can be controlled remotely either by a smart phone or through a computer. During recent years, the concept of Smart Homes/Buildings have come up by incorporating various devices to the Internet. The main objectives of this application are to reduce the energy consumption and improve the comfort and safety of the environment.

Smart Grid

Smart Grid is an electricity supply network that uses digital communications technology to detect and react to local changes in usage. It can also be referred to as a digital technology that allows two-way communication enabling the customers to put up the requirement of electricity after performing observations with the help of sensors. The grid

channelizes the energy as per the calculated requirement. The goal is to reduce the wastes that characterize older solutions.

Smart Metering

The Smart Metering refers to systems that involve remote reading and remote management of electricity, gas and water meters. It could be considered as a "remote managed" meter that allows each user to know and manage all their consumption. A simple device, therefore, that provides very precise information on consumption, also entering into the details of the various appliances, so as to allow the user to fully control their consumption and identify, if necessary, even any loss of energy or gas.

Smart City

A Smart City is an urban area in which, thanks to the use of IoT and other digital technologies, it is possible to optimize and improve the infrastructures and services to citizens, making them more efficient. The services offered by a smart city touch systems like public transport and mobility, public lighting, urban security, environmental management and monitoring, waste management.

Smart Car

The term Smart Car means the connection of cars to communicate information to the consumer in real time. A connection that can be between vehicles, between cars and infrastructures for the prevention and detection of accidents, for the geo-detection of traffic and also to have all the insurance information. For example, a Smart Car can contact a workshop if there is an engine problem, or even an electrician for a technical problem. It can give the driver all the information on the road network and lead him on the less busy roads, or even to reduce consumption.

Smart Agriculture

Smart Agriculture goal is to combine traditional agriculture with new digital and technical solutions: a combination that will facilitate the work and increase efficiency in the daily activities of the farms. The new-age farmer has now moved from the conceptual farming to modernized concepts. Researchers working under this domain have come up with theories and practices that incorporate smart devices to evaluate the parameters that contribute towards the growth of plants and according to the observations, the agricultural activities are performed.

Smart Factory

During recent years, the concept of IoT has also flourished in the field of industry. Modern day industrial equipment and requirements are so intense that the functional capabilities of IoT are either molded or designed in specific to cater to the needs of the industry.

eHealth

This kind of solutions exploit technological innovation for the benefit of human health to generate numerous important benefits in terms of new life-saving solutions, or customized aids to significantly improve quality of life of people (improving their health, fitness, mental well-being, safety, etc.). Thanks to the use of technologies that are at least capable of transmitting new patient health data to the correct type of specialist, this job may be performed remotely, although in some situations they can also give recommendations themselves.

Smart Logistics

The Smart Logistic manages the design, planning and control of Supply Chain processes in an efficient and convenient way. This type of solution provides new storage, handling and transport systems, in order to make the logistic structure more efficient and safer thanks to the continuous monitoring of objects and means of transport.

Smart Retail

Smart Retail is a term that means an increasingly intelligent distribution capable of short-circuiting the information that revolves around the purchasing processes, making them extremely fast and functional. It allows to strengthen the relationship between products and consumers. The use of advanced sensors and diversified coding and reading systems, in fact, not only makes the products talking, that is intelligent and communicating but allows the shops to transform themselves, becoming more efficient and predictive.

Wearable Object

Wearable is a smart device which every individual can wear. This kind of device, through an internet connection, gives the possibility to collect, transfer and process data about the user. Wearable Objects have many application fields, ranging from the healthcare to the fitness one.

Smart Object

Smart Objects are characterized by having one or more of the following features: identification, localization, status diagnosis, interaction with the surrounding environment, data processing and connection. They are all the physical objects augmented with computation and networking capabilities, and which are therefore capable of communicating through the internet with remote services or other objects.

Smart Asset Management

This IoT application gives the possibility to the companies to exploit in the most efficient way the asset management. Some of the services provided are: remote management of valuable assets to detect faults and tampering, localization, traceability, and inventory management.

Networks & Infrastructures

Broad and grounded IoT networks that allow the communication of the elements that define the Internet of Things and the transmitting or processing of data and information collected by smart and connected objects.

Multi-Application Platform

In this category are considered platforms which can connect different types of smart objects and sensors, giving them the possibility to collect and process data from different sources.

1.1.3 INTERNET OF THINGS IMPACT ON FIRM PERFORMANCES

Internet of Things is for sure an innovative technology, capable of facilitating the life of the human being in many of its areas, as a faithful companion. However, this kind of innovation can help not only people, but entire organizations in increase their performances. At this regard, could be interesting analyze how much is impacting the implementation of IoT technologies on firms' performances. Stefan Ferber, CO-CEO & CTO of Bosh, stated the following about IoT's effects on the manufacturing field: "*The Internet of Things allows for a new way of organizing production: by connecting machines, warehousing systems and goods, we can create smart production that basically control each other without requiring any manual intervention*"[3]. Some interesting data come from a survey report from the American Society for Quality (ASQ), which studied how manufacturers are benefitting from IoT. This report states that manufacturing companies implement related IoT technologies through connecting manufacturing devices and aggregating the data created by enabling manufacturers to reduce overhead, conserve resources, increase profits, and optimize efficiencies. The ASQ surveyed manufacturing companies, which have digitized their processes and found 3 astounding results: firms have increased efficiency by 82% after implementing IoT technologies, have experienced 49% fewer product defects, and finally have increased customer satisfaction by 45%[4]. If companies implement IoT in their industry, then they should have better performance than those who do not; we call the former a better (IoT) performer.

1.1.3.1 SUPPLY CHAIN MANAGEMENT

The Internet of Things technology finds a field of application also in the management of the supply chain. The supply chain management is the process of supervising materials, information and financial flows that move from supplier to manufacturer, from wholesaler to retailer and consumer. Supply chain management involves the efficient coordination and integration of these flows both within and between companies. However, in traditional supply chain management systems exist several problems such as overstocking, stock out and delays. To partially solve SCM criticalities, to facilitate the management and to increase the efficiency, the Information Technology plays a very important role. In particular, enhancing the collection and integration of data, the IT has ability to integrate different processes, suppliers and customers internally and externally and then improve supply chain performance. Among the developments of IT, the Internet of Things has a great importance in this sector. In fact, the application of IoT to the management of the supply chain has brought great improvements. It can be defined as *a set of physical objects which are connected digitally for sensing, monitoring and interaction within a firm and among the firm and its SC cementing agility, visibility,*

[3] S. Ferber, "No one can do IoT alone", 2017

[4] Y. Vardi, "How Manufacturers use IoT for Operational Efficiencies", 2015

sharing of information and tracking to facilitate plan, control and coordination of processes for supply chains[5].

The main impacts that Internet of Things has on the supply chain can be summarized as follows:

- ✓ Enhance management of inventory: this is thanks to the real-time visibility of the inventory enabled by the IoT. It is now possible to have a 100% accuracy rate in the management of inventory by adding sensors devices and through RFId systems;
- ✓ Real time supply management: thanks to RFId tags it is possible to record all types of information, going from the production date to the expire date and warrant period, enabling an effective management of the supply chain;
- ✓ Maximize transparency of logistics: by using smart objects it is possible to make all transport information available to the entire supply chain. This will enable a better monitoring of goods.

In this regard, could be interesting to show an example of startup - taken from the database which will be presented later and used for the analysis conducted in the following chapters - offering this kind of advantage for the supply chain of a company.

[5] Mohamed Abdel-Basset, Gunasekaran Manogaran, Mai Mohamed, "Internet of Things (IoT) and its impact on supply chain: A framework for building smart, secure and efficient systems, 2018

Company Name	**Nexxiot**
Foundation Year	2015
Headquarter	Switzerland
Founder	Christoph Wartmann, Daniel MacGregor
Business description	Nexxiot is Europe's provider of integrated digital supply chain solutions. The company is built on over 10 years of research in complex systems, big data algorithms, and ultra-low-power embedded technology, and today equips entire fleets of logistics assets, such as railway wagons and cargo containers, with proprietary low-power sensors that provide raw data on location, movement, physical shock, and other parameters in near-real time to the Company's proprietary analytics platform, where it generates business-relevant complex events and communicates these directly "machine-to-machine" to the clients' systems.
Application Field	Smart Asset Management
Web Site	www.nexxiot.com

Table 5: Example of IoT utilization in Supply Chain

1.1.3.2 RFId APPLICATION

There are different types of IoT applications in supply chain management. One of the most important and spread technology is the use of Radio Frequency identification (RFId): it consists in the use of radio frequency tags to identify real smart objects. It provides an ID to smart objects. Normally, in this kind of communication, there is somebody which is transmitting the information (the ID), the transponder, somebody which is reading it, the transceiver, and then there is an antenna enabling the transmission. Usually, these RFId systems are used in supply chains to help with real-time location of assets, providing tracking and tracing. Anyway, this kind of technology is the basis of most IoT applications in the supply chain management, especially in the delivery processes: in example, IoT gives the possibility to easily manage the warehouses by saving time in joint ordering via using smart RFId tags. Or again, in inventory management, IoT enables sharing of information and inventory accuracy through RFId tags.
An important application of Internet of Things technology which not exploits RFId is visible in the manufacturing processes: thanks to IoT and sensor technology it is possible

to capture the real-time manufacturing status of different manufacturing resources, giving firms real-time visibility and traceability of manufacturing shopfloors. An overall framework[6] of this application is given by T. Wang in *Real-Time Visibility and Traceability Framework for Discrete Manufacturing Shopfloor* and it is reported below

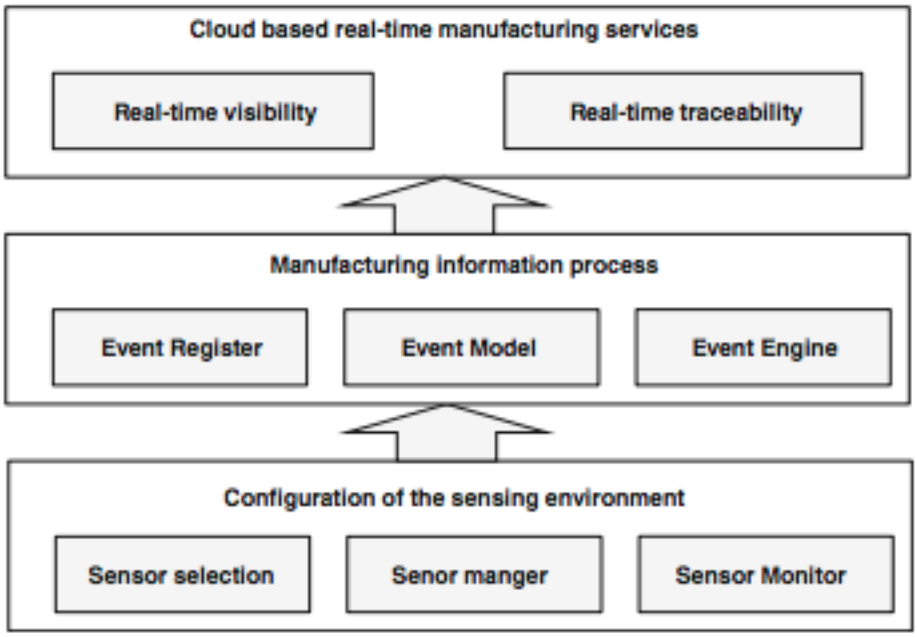

Figure 11: Real-Time Visibility and Traceability Framework

Three modules explain the framework:

- Configuration of the sensing environment: sensor devices collect real-time data from manufacturing sources;
- Manufacturing information process: this module is used to transform the data captured by sensors in meaningful manufacturing information;
- Cloud based Real-Time Manufacturing Services: on the Cloud data analysis are run and important real-time information have been provided.

[6] T. Wang, Y.F. Zhang, D.X. Zang, "Real-Time Visibility and Traceability Framework for Discrete Manufacturing Shopfloor", 2016

1.1.4 MARKET OVERVIEW

It is visible to the naked eye how IoT and ITs in general are developing and how they are more and more present in the everyday life of each individual. It is now time to show some data related to this growth and worldwide expansion.
The first interesting data to point out is about the current and forecasted end-user spending on IoT solutions worldwide from 2017 to 2025, visible in Figure 13. Statista forecast states that by 2025 the technology could reach 1.6 trillion dollars in market revenues[7].

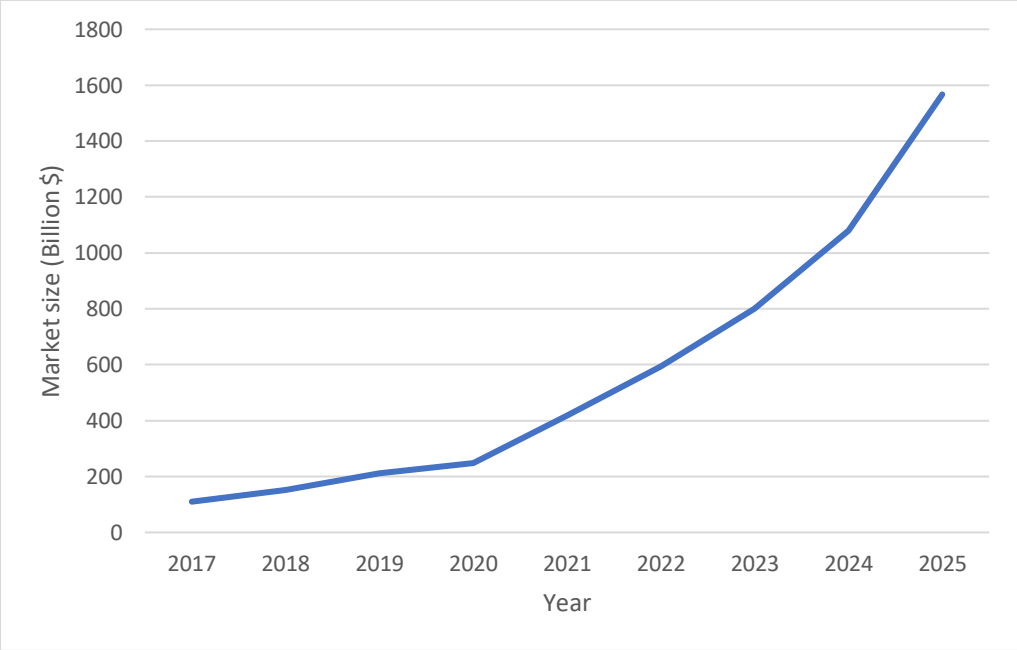

Figure 12: Global end-user spending on IoT solutions forecasted in the period 2017-2025

This is indicative of how the interest in this technology is constantly growing.
Another interesting aspect highlighting the constant growth of this kind of technology in the modern world is the active device connections installed base worldwide. From the data collected by Statista in this regard, it is clear how the IoT is evolving and spreading over the world: in the decade 2015-2025 is forecasted a jump from 3.8 billions to 21.5 billions of active device connections installed bases[8].

[7] Lionel Sujay Vailshery, "Forecast end-user spending on IoT solutions worldwide from 2017 to 2025", Statista, 2021
[8] "IoT active device connections installed base worldwide from 2015 to 2025", Statista, 2018

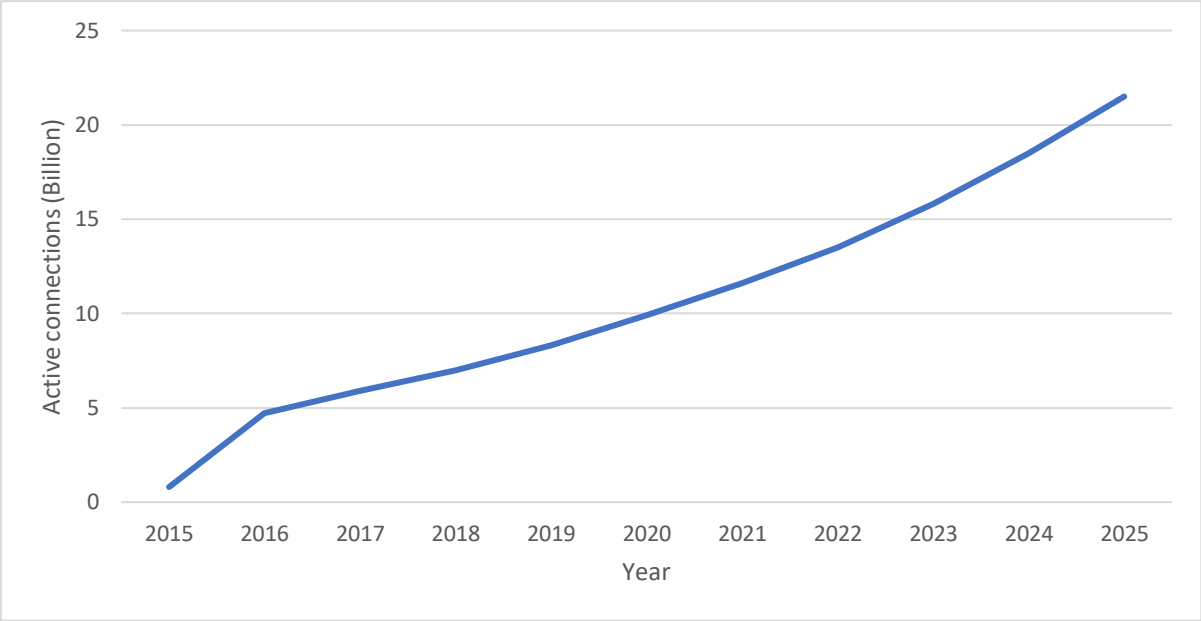

Figure 13: IoT active device connections installed base worldwide from 2015 to 2025, August 2018

Furthermore, considering the analysis carried out by the Observatory of Politecnico di Milano, during 2020 the global market of data generated by IoT is worth about 30 billion euros. This data show how this information is concrete in the IoT world. shifting the focus on the Italian reality, the Observatory reported some interesting data concerning 2019: the Internet of Things (IoT) market in Italy reached 6.2 billion euros, with a growth of + 24% compared to 2018, in line - in absolute terms - with that recorded in the previous twelve months (+ 1.2 billion euros). The growth rate is in line with that of other Western countries, which - according to most analysts - is between 20% and 25%. The sectors that show the greatest growth are those of the smart factory and smart home (+ 40%), although the highest turnover is recorded in the smart metering sector (1705 million euros)[9].
In short, the world seems ready to embrace the IoT in all its sectors.

1.1.4.1 COVID-19 IMPACT ON IOT WORLD

Covid-19 is impacting society culture and economy in an unprecedented manner. There are also clear signals that in the coming years, many technology will see rapid adoption when people become more technologically minded when operating from home as they accept technology. Worldwide IoT spending has been significantly impacted by the economic effects of the pandemic in 2020, although a back to double-digit growth rebound is expected both in the mid and long-term, according to IDC. IoT spending is growing 8.2% year over year to $742 billion in 2020 down from 14.9% growth forecast in the November 2019[10]. Nevertheless, IDC forecasts that global IoT spending is expected to return to double-digit growth rates in 2021 and achieve a compound annual growth rate

[9] "Internet of Things: l'innovazione parte da qui", Osservatorio Internet of Things, 2020
[10] "Worldwide Internet of Things forecast, 2020-2024", IDC, 2020

(CAGR) of 11.3% over the 2020-2024 forecast period. Moreover, IDC pointed out some numbers regarding the impact of the pandemic on the different industries and world regions, with interesting forecasts for the period 2020-2024[11].

Spending by Industry

The industries that will see the slowest year-over-year growth in IoT spending are the ones experiencing the greatest impact from the economic downturn caused by the pandemic. Personal and consumer services, which includes hotels, theme parks, casinos, and movie theaters, will be the only industry with a decline in IoT spending this year, down 0.1% from last year. The next three industries with the slowest growth in 2020 are discrete manufacturing (4.3% growth), resource industries including oil and gas (5.0% growth), and transportation (5.7% growth). However, these three industries will still manage to achieve a double-digit CAGR at the end of the forecast period (2024). Healthcare, insurance, and education will deliver the strongest industry gains in IoT spending this year with growth rates of 14.5%, 12.3%, and 11.9% respectively[12].

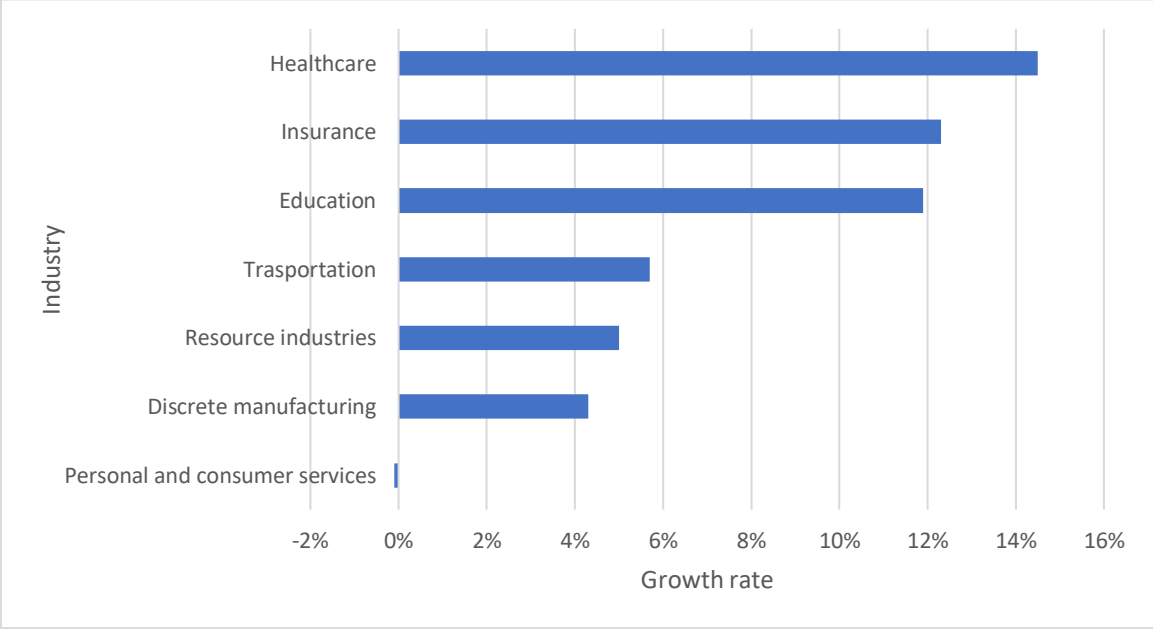

Figure 14: Growth in Iot spending by industry in 2020

[11] "Worldwide Internet of Things forecast, 2020-2024", IDC, 2020
[12] "Worldwide Internet of Things forecast, 2020-2024", IDC, 2020

Spending by Region

China, the United States, and Western Europe will account for roughly three quarters of all IoT spending throughout the forecast. Although the three regions will have similar spending totals initially, China's spending will grow at a faster rate than the other two regions – 13.4% CAGR compared to 9.0% and 11.4% – enabling it to become the dominant region for IoT spending. The fastest IoT spending growth will be in the Middle East & Africa (19.0% CAGR), Central & Eastern Europe (17.6% CAGR), and Latin America (15.8% CAGR) regions[13].

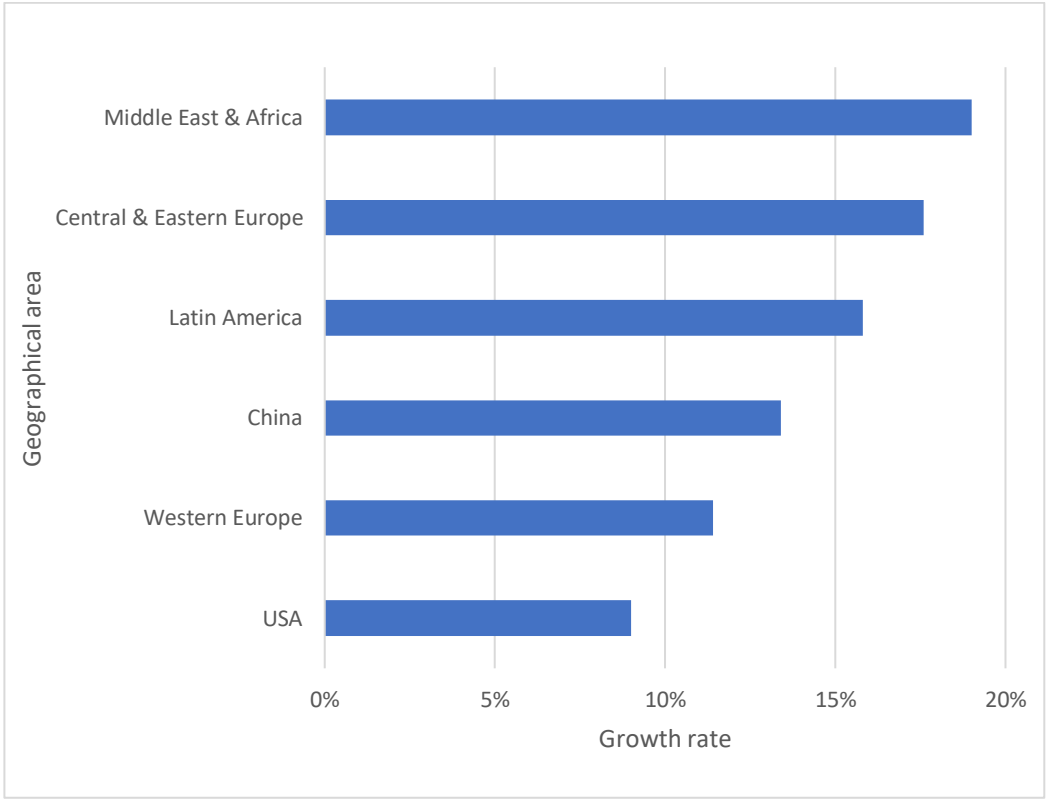

Figure 15: Growth in IoT spending by region

[13] "Worldwide Internet of Things forecast, 2020-2024", IDC, 2020

1.1.4.2 POSSIBLE INTERNET OF THINGS TRENDS AFTER THE PANDEMIC

Forbes, the American business magazine, has listed 5 possible trends impacting the IoT world in 2021, following the pandemic[14]. So, possible developments in some IoT sectors caused by COVID-19 according to Forbes, will be presented below.

Healthcare

Strong growth is also expected for devices that will allow seniors to stay at home independently for longer. In case of self-quarantine, IoT tools and remote control will allow to monitor the patient's health conditions in a short time. As a great demonstration of how the ongoing pandemic has accelerated the adoption of tech-driven healthcare transformation, original estimates for the number of "virtual visits" or online appointments with healthcare providers in the US was 36 million.

Retail

In 2021 could be possible to see the proliferation of innovative new store models such as Amazon's fully automated supermarkets, which eliminate human interaction in the store. More and more widespread contactless payment tools will be increasingly on the agenda. The technologies will also make it possible to better guarantee social distancing within the stores.

Smart City

In 2021 it is expected an increase in resources devoted to digital capacity building within municipal authorities. With the safety concerns related to public transport, city center offices and recreational facilities such as recreation centers and parks, IoT technology will enable authorities and businesses to better understand usage patterns, as well as plan measures more efficiently. security and emergency response strategies.

[14] Forbes, Bernand Marr, “The 5 biggest Internet of Things Trends in 2021 Everyone Must Get Ready For Now”, 2020

Edge Computing

Edge computing is another tech trend that will not go away due to Covid-19. With edge computing, the analysis and extraction of insights from IoT devices will be carried out directly on the devices themselves. A clear advantage is the huge savings in bandwidth usage and the reduced cost. However, just as vital in a post-Covid-19 world will be the benefits to privacy and data management.

Smart Working

Work from home is the "new normal". New tools for scheduling events and appointments, better quality, more interactive conferences, more technologies for virtual meetings. Tools for increasingly immersive presentations. The IoT for remote monitoring of production plants will be increasingly widespread and strategic.

1.1.5 IOT ECOSYSTEM

Internet of Things is at a peak of hype and builds its own Ecosystem based on sensors and actuators that communicate on custom-designed platforms through plenty of wireless, cellular and fixed communication networks. It can be useful to open this paragraph with a 2015 McKinsey analysis: it foresees that, by 2025, IoT applications will have an economic benefit of $3.9 to $11.1 trillion[15]. McKinsey analysis also points out a significant threat to the estimated economic benefit: missing interoperability. Specifically, the authors state that a 40% share of the estimated value directly depends on interoperability between IoT systems. It can only be achieved if two or more systems are able to work together. For example, an adaptive traffic control system of a city has more value, the more information systems it can interact with. Only if it can interoperate with different systems, for example, for digital traffic signage, traffic lights, parking systems, or public transport, a traffic control system can reach its full potential. It is in this regard and with this objective that it is developing the BIG IoT project: its vision is to establish interoperability on the Internet of Things[16]. In order to support the development of cross-

[15] J. Manyika, M. Chui, P. Bisson, J. Woetzel, R. Dobbs, J. Bughin and D. Aharon, "The Internet of Things: Mapping the Value Beyond the Hype", McKinsey Global Institute, 2015

[16] S. Schmid, A. Bröring, D. Kramer, S. Käbisch, A. Zappa, M. Lorenz, Y. Wang, A. Rausch, L. Gioppo, "An Architecture for Interoperable IoT Ecosystem", 2019

platform and even cross-domain applications and the emergence of entire IoT ecosystems, BIG IoT delivers key technological enablers. First, a common API among IoT platforms is developed so that application development is facilitated. Second, a marketplace as a center piece of an IoT ecosystem is introduced and implemented. The marketplace is key for enabling all stakeholders of the ecosystem to participate in revenue streams. This kind of Ecosystem produces a large volume of data that is collected, filtered, processed and executed by data analytics, a fundamental process for making IoT applications smart systems. IoT is a concept and a paradigm with different visions, and multidisciplinary activities. In the last few years IoT has evolved from being simply a concept built around communication protocols and devices to a multidisciplinary domain where devices, Internet technology, and people converge to create a complete ecosystem for business innovation, reusability, interoperability. In IoT applications, physical objects have features of digital cyber and virtual technology and they can sense/actuate, be programmable, addressed and communicate with other objects or/and humans. Combining digital, cyber and virtual technology with physical objects requires collaborations and cooperation between partners from different industrial sectors and domains.

The conceptual model[17] proposed by Simon Fabri in January, 2015 divides the connected ecosystem of things into industrial verticals and horizontal enablers. In this way, he wants to split the players of an ecosystem in two categories: on the one hand the companies who provide the technology, services, infrastructure and other capability to allow a company create a 'smart' experience. On the other hand, it is possible to find new or established companies who are using these enablers to create new products or enhance in some way existing products or operations. Below it is shown a more detailed presentation of these two categories.

[17] B. Jekov, E. Shoikova, P. Petkova, D. Donchev, "Study on the IoT Ecosystem Business Models and the Segment of Startups", 2017

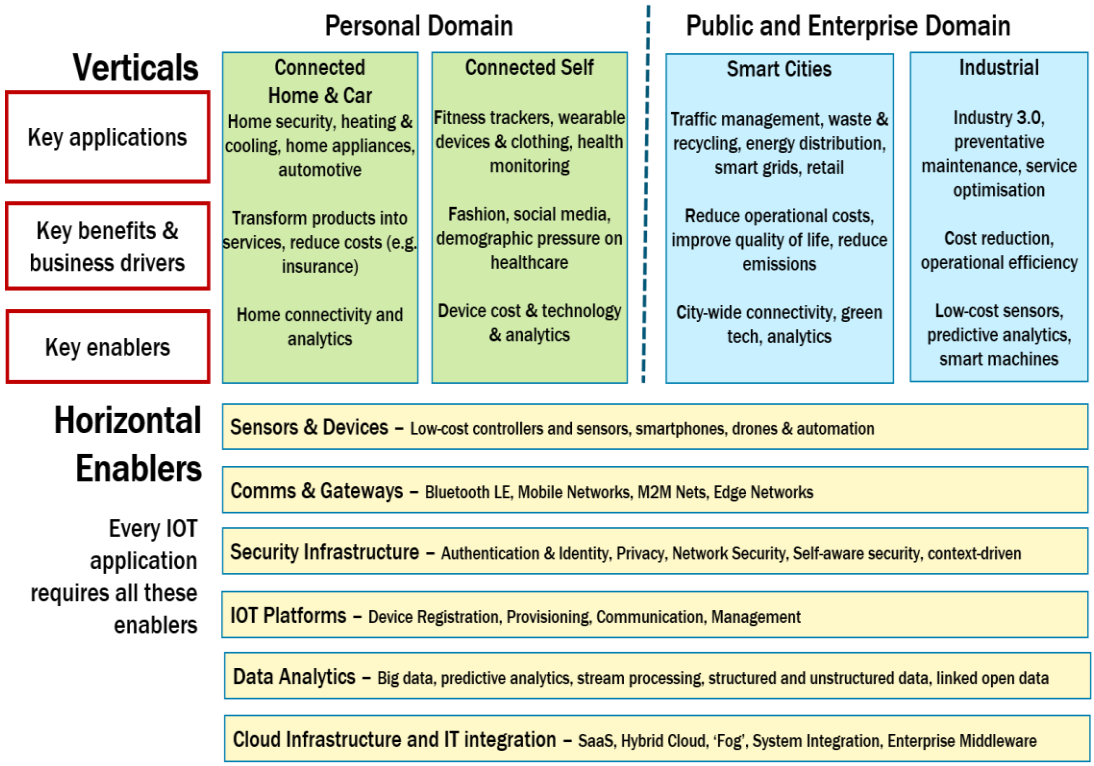

Figure 16: Internet of Things Industry Model by Simon Fabri, 2015

The *Verticals* comprehend all the products and services offered to end-users, and all the industries that can benefit from IoT technologies. The Verticals are separated into two sections, the Personal Domain and the Public Domain.
The Horizontal Enablers comprehend all those technologies and services elements required to create a smart connected system. They consist of main building blocks where physical devices are connected to centralized computing centers by smart systems. Sensors and devices communicate with the real world. The IoT space sees a lot of early activities directly at the vertical application level, as the Big Data space move from core infrastructure to vertical applications. Internet of Thing is the place where it is possible to observe three important technological trends: increasing distribution of mobile and social media networks, ubiquitous increase in the amount of data generated by new device, and nosiness efficiency to promote growth by shifting from Edge computing to Cloud computing through Fog. In this scenario, companies will change their operation management using smarter decision making based on real-time data analytics.

In Figure 18 are shown the generic concepts populating an IoT ecosystem and the interactions between them[18]. The core concepts are: offerings, providers and consumers,

[18] S. Schmid, A. Bröring, D. Kramer, S. Käbisch, A. Zappa, M. Lorenz, Y. Wang, A. Rausch, L. Gioppo, "An Architecture for Interoperable IoT Ecosystem", 2019

and the interactions of registering and discovering offerings via a marketplace, and accessing the resources offered by a provider.
With offering is meant a set of IoT resources, that could be a set of information or functions, that are offered on a marketplace.
Providers are responsible for registering these offerings on a marketplace and providing access to the offered resources via a common API. A provider can be either a platform or a service instance that offers available resources on the marketplace (for example an IoT platform of a parking loT provider). If a consumer wants to access the resources, he will subscribe to offerings of interest via a marketplace. Usually, a consumer can be either an application or service instance that requires access to IoT resources in order to implement an intended service or function.
In technical terms, a provider records its offerings on the marketplace by giving a summary of the offering. Usually, the description of the offering is provided in a machine-interpretable way in order to improve interoperability between different Internet of Things platforms. The offering description should include a local identifier (unique to a provider), the offering name, and the input and/or output data provided to a consumer when the offering is accessed. The description may also include information about the region (e.g. the city or spatial extent) Some additional information are usually provided, as for example the price for accessing the resources.

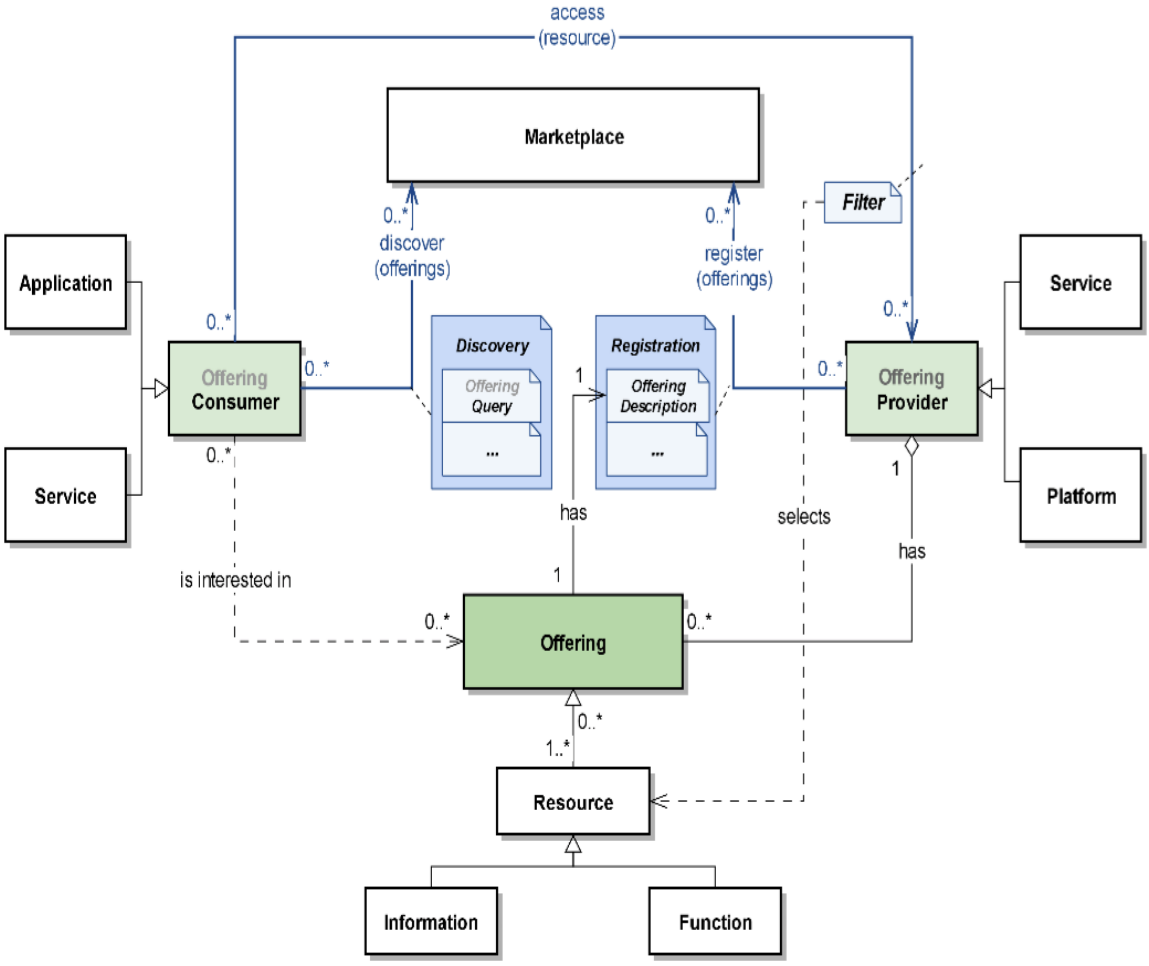

Figure 17: Conceptual model for an IoT architecture

Looking at the consumer side, they find the offerings of interest on the marketplace through a query. The query requires that the consumers insert in the researches a specification about what they are searching for, the kind of offerings in which they are interested. For example, consumers, when they look for an offering, can add details like resources desired, maximum price and other information like these. The marketplace identifies all the offerings that reflect customer research, and show them to him. Then, consumers can choose the offering that prefer and subscribe to those on the marketplace.

1.2 STARTUP

Startup is a temporary organization looking for a scalable and replicable business model. It can be considered as the starting point of the lifecycle of every company, as the birth of any business reality. It is a temporary situation because this kind of entity re-arranges itself continuously, as opportunities move in order to find the right business model. The startup does not really know if the business model will work or not, it is looking to the business model validations, it has to be flexible. Therefore, the main difference between a Startup and a traditional business is the scalability of the business model and its replicability: the growth of the business in term of clients and volume is not proportional to the resources invested and the business model can be repeated in different period and places without significant changes. What characterizes a startup is its entrepreneurial mindset: opportunity seeking behavior is fundamental to survive in the long term, and startups are very good in spotting opportunities. Exploiting a business opportunity means understand if the idea could generate profit on the market and if it provides a solution, which is perceived as interesting from the potential customers. In order to evaluate this, some factors have to be taken into account:

- Marketing factors: analyze which are the problems that the Startup is trying to solve, if these problems are real and which are the market needs satisfied. Then, focusing on the Startup solution: analyze how this solution solve the problem, how it works and if it is better than the existing ones;

- Competition: understand the current competitive system in terms of direct competitors and substitute products, and how it will evolve in future. Find the competitive advantage5 of the solution and if it is sustainable in time;

- Economics: define the target market for the solution and its size. Determine the investments necessary to reach the market and the expected return on the investment;

➢ Management: focus the attention on the team its composition, backgrounds and role necessary in order to develop the offer.

1.2.1 STARTUP STRATEGY

Entrepreneurship come first, then strategy arrives. Startups are good at innovation. They start out being entrepreneurial. Strategic entrepreneurship is about developing a business model that is embedded in the strategy formulation process, stimulating the ability of entrepreneurs and managers to be both strategic and innovative at the same time. The strategy formulation has of course come steps that have to be followed.

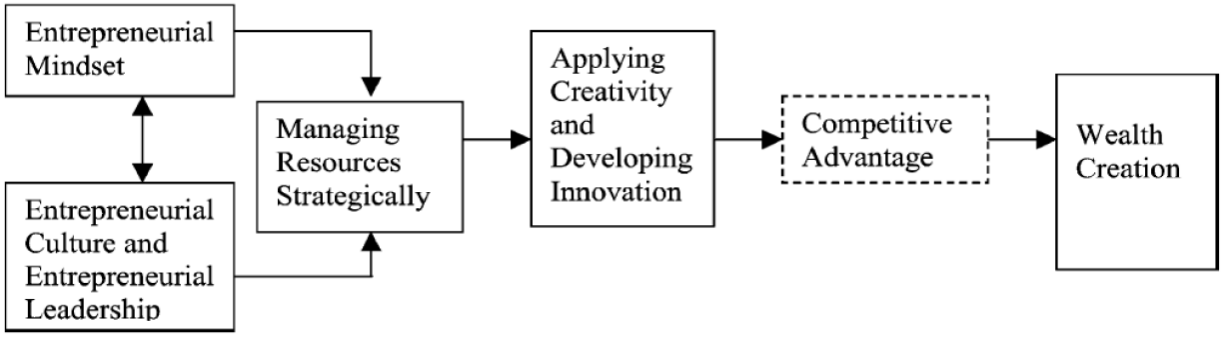

Figure 18: Strategy formulation

Entrepreneurial mindset, culture and leadership are essential characteristics for a startup. Risk acceptance, exploration, openness to future opportunities, ability to recognize them are what make a startup good and ready to grow. In the first phases of life human capital, financial capital and social capital have to be managed smartly because these kinds of resources can determine the survival of the startup. Indeed, most of the startups fail in their initial phase, during the very first year. Once this critical stage has passed it is important to come up with and to create something new, useful and most of all needed. Innovation is taking what is created and find an application for it. The final goal is to have a valuable product or service which gives the company the opportunity to create a competitive advantage over incumbents.

1.2.2 STARTUPS ECOSYSTEM

Startup companies are defined to be a fast growing, entrepreneurial venture which aims to meet the needs of a marketplace with an innovative product, process service. According to some researches, startups are better in creating innovations and are, in general, more innovative than traditional incumbent firms[19]. Their peculiarity is that of being able to adapt to the market, quickly changing strategy and business plan. However, one of the main problems that startups initially encounter is the fact that they have no resources to develop their innovative ideas. In most cases, startups lack financial capital, contributing to the absence of personnel, infrastructure and market search for the launching of product and service. Since startups have this type of need, investors play a key role in supporting them, creating an investor-investee relationship that can easily be portrayed as a network. This investor-investee network can be reflected as a startup ecosystem, in which each player is linked among each other through various connections[20]. Startups and investors can be seen as the nodes of the network, and they are connected through various link (for example, a kind of link can be a financial support or a technological support to the startup from the investor), and startups give shares and profit in return. In the last years, new typologies of investments have appeared. In fact, with the evolution of methods and forms of investments it has become easier to participate in the support of startups. Ways like online investment platforms and crowd funding have simplified the operations. Investments in innovative startups have become an important social and economic phenomenon, also thanks to the evolution of investment methods. Through this increasing participation of different players, the ecosystem grows and benefit the startups through different supports deriving from the network connections. Past researches point out that entrepreneurial networks help entrepreneurs by sharing ideas and knowledge, allowing them to increase their potential abilities[21].

1.2.3 INVESTORS ROLE IN THE NETWORK

What is critical for the success of a company is not only the transfer of capital but mostly the transfer of knowledge and technology. Knowledge can be defined as shaped into the form of technology by patents and products. According to some studies by Kim in 2015, technologies belonging to different industries come together, generating new

[19] Song, L.Z., Song, M., Parry, M.E. "Perspective: economic conditions entrepreneurship, first-product development, and new venture success", 2010
[20] Motoyama Y., Knowlton K., "Examining the connection within the startup ecosystem: a case study of St. Louis", 2017
[21] Birley S., "The role of networks in the entrepreneurial process", 1985

technologies through a sort of convergence[22]. In a different form of information exchange in the technology flow, businesses may adapt this new knowledge to their strategy or products and find insights into services and functionality that could be found in markets. In small businesses, the value of information acquisition is increased, as it is found that startups typically rely heavily on the use of established knowledge as well. Investors work also as channels of knowledge transferring by offering know-how and information to startups in order to foster better alliances. Startups, in their seed and early stages, use the information received by investors as a solution to reduce the uncertainty of technology development and as a way to achieve a further development. In particular, venture capitalists are seen to be the main source to transmit information, offering to startups the better resources and the appropriate access to information[23]. Startups are for sure the most users of knowledge from different sectors, the ones who mostly exploit it. They gain the most from new markets opportunities. In this context, as information and technology are transferred to startups through venture capitalists, investment links can operate as channels for knowledge spillover, eventually leading to the convergence of technology among startups.

1.3 IOT STARTUP

With the ever-increasing development and spread of Internet of Things all over the world, startups that decide to use and implement this technology are more and more. According to a report by Forbes studying the North America based startups in the IoT industry, in 2017 $125 billion was invested to 2888 startups. The value of these startups grew to $613 billion, and produced 95 startups that are now worth a billion dollars so called unicorns[24]. Hand in hand with the growth of the IoT there is the development of new technologies and new applications by IoT startups, always based on the use of the internet of things. In this regard, as it is possible to see from past research, through the convergence of existing technologies there has been the creation of new ones[25]. The basic idea adopted by innovative startups is to make the greatest number of objects "smart". Many startups have created products and services that have great influence in human lives by merging traditional knowledge with the internet to create new ones. In this way, a double added value is created. For startups, which can take advantage of the IoT to build their business

[22] Kim N., Lee H., Kim W., Suh J.H., "Dynamic patterns of industry convergence: evidence from a large amount of unstructured data", 2015

[23] Gans J.S., Hsu D.D., Stern S., "When does startup innovation spur the gale of creative destruction?", 2002

[24] www.forbes.com

[25] Atzori L., Iera A., Morabito G., "The internet of things: a survey", 2010

around it. For the Internet of Things, as it can benefit from the new applications and technologies developed by startups.

1.3.1 HARDWARE AND SOFTWARE STARTUPS

The first distinction that must be done when it comes to IoT startups is between hardware startups and software startups. This is a crucial difference because the two types of startup will have two different kinds of product development. More precisely, hardware startups have a more tortuous path than software ones. First of all, it is necessary to considerate that hardware startups are those startups that develop products with mixed hardware and software parts, including embedded systems, sensor devices, and advanced robotics. So, hardware startups have to develop both the hardware side (hardware design, development and manufacturing) and the software side. They also have to deal with production and logistics issues like packaging, shipping, and customs.

Another difficulty comes from the fact that IoT products are normally regulated by domain-specific standards, regulations and fixed-requirements. Quality attributes such as performance, robustness, safety and security are critical to the success of an Internet of Things product (Minimum Viable Product). This problem has, obviously, a lower weight for software startups.

Furthermore, hardware products have to be tested heavily in various operational environment in order to understand the validity and good functioning of the products themselves.

The last main issue concerns the changing costs: modify a software is much more easy and cheaper than changing a hardware product. Related to this there is the fact that for software refactoring and extension are common after a release while physical component cannot be refactored.

CHAPTER 2: RESEARCH QUESTIONS AND METHODOLOGIES

In the literature review conducted previously it was possible to analyze the world of the Internet of Things in all its characteristics, also showing how it is evolving and affirming in today's society. In this scenario startups play a fundamental role, entities which by definition are usually carriers of innovation. In fact, as it will be possible to see in the course of the analysis, it is possible to find startups in every field of the Internet of Things technology. Another key role in this ecosystem is played by investors, responsible for providing startups with the funds and knowledge necessary to develop their business. All these aspects will be touched upon in the course of the analysis.

2.1 RESEARCH QUESTIONS

First of all, it is necessary to clarify what are the ideas and reflections that guided the reasoning during the analysis carried out. According to this, the research questions used are presented below:

1. What is the state of the art of IoT startups at international level?
2. What is the level of success of the IoT startups belonging to the different application fields?

The first question is about the main purpose of the thesis, and it concerns the analysis carried out on the database compiled over time, not only during this project but also thanks to the work of colleagues and teachers in past years. Specifically, it refers to the analysis of those IoT startups that comply with the definition adopted by the Observatory of Internet of Things. This type of analysis tries to touch all the areas characterizing IoT startups: from geographical distribution to financial analysis, passing through an interlude of other analyzes that take into consideration all the characteristics of these startups.

The second research question, on the other hand, intends to understand what is the state of progress of the analyzed startup and at what stage of their life cycle they are. To do this, the different types of last financing rounds received are considered, which offer hints to be able to classify startups in certain phase of their life cycle. In this way, it is possible to see which startups are able to reach the most advanced stages and which, on the other hand, are still in their infancy. The final goal of this analysis is to understand which field of application of the Internet of Things allows its startups to reach the final stages of their life cycle, in order to establish themselves and perhaps move on the next step.

2.2 METHODOLOGIES

In this section the aim is to explain the methodologies used in the analysis conducted during the thesis project, starting from the questions above. In this sense, the two main performed activities are literature review and investigation of secondary sources.

2.2.1 LITERATURE REVIEW

Review of the academic literature is a fundamental procedure in order to investigate and understand the main findings on a specific topic. Moreover, this procedure gives the possibility to gain the necessary knowledge to carry out a following analysis about the research topic.

The literature review of this thesis work is focused on two main topics:

1. Internet of Things: the first main topic is about the analysis of the IoT technology, its characteristics, its development and its use in the modern world.
2. IoT startups: the second topic is represented by the general description of startups and then a focus on startups which use Internet of Things.

Considering the current health crisis situation, a short chapter was dedicated to the impact that covid-19 has had on IoT world.

The goal of this literature review is to provide foundation of knowledge on these topics, understanding which are the aspects that need a further investigation. The analysis is based on scholars and researchers' academic papers related to the topics. The approach used for the papers' selection was to insert keywords related to the topic of interest in a search engine. This procedure allows to identify and select the papers according to their relevance. The main source from which papers were collected was Scopus, but some additional papers have been integrated from Google scholar. So, general keywords were used in search engine in order to find useful and interesting sources of knowledge about the Internet of Things world and its use by startups. The most used were "IoT characteristics", "IoT development", "IoT trends", "IoT applications", "IoT startups", "Startup characteristics", "Startup lifecycle stages". Due to the vastness of the research results for some topics, some restrictions have been adopted to streamline the papers. For example, the most recent papers have been selected, in order to have the most up-to-date information available. The result of the procedure explained above was the classification of about 20 scientific papers both from the academic library database and google scholar.

Other relevant sources used for this review were the notes and handouts of some

university courses. Or again, papers from “osservatori.net” were useful for retrieving information about Internet of Things and, more in general, digital innovation.

2.2.2 SECONDARY SOURCES

The starting point is a database provided by the Observatory and consisting of an Excel file containing a list of startups in the rows, one startup for each row, and a series of columns related to specific information on startups. These kind of structure gives the possibility to have a complete view for each startup, addressing the most relevant information, in order to create the possibility to classify startups in different ways. A better overview on the information about startups reported on the database will be given later in the thesis work, at chapter 3.1.
The database provided was compiled by the work of several people who, year after year, updated the census.
Regarding the sources, Crunchbase has been mainly used to get the information searched about startups. This platform is one of the best platform where a lot of information about companies can be found. This information includes founded date, headquarter region, investments, funding and mergers and acquisitions information. However, due to the lack of information about some startups, Google search engine has been used in order to find them and complete the database with the information searched. Moreover, for the majority of the startups classified, information about the offering provided has been searched directly on the website in order to understand the offering and classify the startups in the right way.
As for the methodology, the first step has been to define some specific criteria to understand which startups to include in the database. In particular, the startups, to be selected, had to respect these criteria:

- The startup has to be founded no more than 5 years ago (founded in 2016 or after);
- The last funding round has to be happened no more than 2 years ago (happened in 2019 or after);
- The startup has to be an IoT one.

Once the startup selection criterion has been defined, the first step was to check that the startups already present in the database complied with the criterion, excluding the ones which did not respect it. Then, new startups in line with the chosen criteria and not yet present in the database were added. As reported before, Crunchbase is the main platform used to perform these kind of operations. The first two criteria have been put in form of filters, searching on Crunchbase, in order to find only startups that respect the constraints defined. Moreover, as to accomplish to the third constraint, the tag “IoT” was added to the research.

CHAPTER 3: STATE OF THE ART OF IOT STARTUPS AT INTERNATIONAL LEVEL

In this section, the census made on startups with the analysis part and the results are explained. The goal of this chapter is to answer the first research question presented in the previous section: “What is the global landscape of the IoT startups?”. It is related to the analysis around which the thesis work was created.

3.1 DATABASE CONFIGURATION

As already explained, this kind of analysis is based on the database compiled with the methodologies presented in the previous chapter. In this sense, a good starting point could be a more detailed presentation of the database.

Framework and Classification

After the selection, startups have been classified according to different dimensions in the database. In particular, the characteristics describing the startups are:

- Name of the startup
- Website links
- Description
- Founded date
- Technological cluster
- Headquarter continent
- Nation
- Contacts
- IoT application fields
- Funding rounds
- Total funding amount
- Last 2-years founding amount
- Last round typology
- Main Investor
- Founders
- Acquisition
- Revenues
- B2B, B2C or B2D
- Offering

While some of these dimensions are simple and easily understandable, others need an

explanation in order to clarify their meaning. In particular:

- *Technological Cluster:* this kind of information represents the technological cluster on which the underlying company's Iot offer is based. The technological clusters considered are:
    - Bluetooth Low-Energy
    - Cellular Networks
    - Low Power Mesh Networks
    - LPWA Networks
    - Personal Communication
    - PLC
    - RFId
    - Wi-Fi

  Not all the proposals were categorized under one of the alternatives proposed above. This happened either because it was not possible to understand it from the information available on the analyzed websites, or because they did not propose offers related to one of these clusters.

- *IoT application fields:* this column of the database represents the main characterizing information: which is the application area each startup refers to. The list of possible application fields is already reported previously in the thesiswork ("IoT applications" chapter). Considering the fact that a startup bid may be not specific to only one of the fields, there is the possibility to indicate up to three IoT application scopes. Furthermore, since the fields "Smart Building", "Smart City" and "Smart Home" are very broad and include several areas of applications, it is possible to go deeper in detail for these three alternatives. In fact, a specific column was created in the database for these three solutions, in order to specify the application area (i.e. heating, lighting, safety management for Smart Home/Building and traffic, parking and garbage management for Smart City).

- *Funding*: about funding were reported some information about the total amount received, the detail of funding rounds for each year from 2015 onwards) and the last two-year amount raised by the startup. Unfortunately, for some startups it was not possible to find information about funding rounds received during the years, nor the total amount received. In addition to these values, there is also a column which reports the type of the last financing received: it is interesting because the last type of funding received helps to understand the state of development of the company under consideration. In this regard, a brief description of the different types of funding rounds is reported below[26]:

[26] https://support.crunchbase.com/hc/en-us/articles/115010458467-Glossary-of-Funding-Types

- Angel: an angel round is typically a small round designed to get a new company off the ground. Investors in an angel round include individual angel investors, angel investor groups, friends, and family;
- Series A and Series B: Series A and Series B rounds are funding rounds for earlier stage companies and range on average between $1M–$30M;
- Series C: Series C rounds and onwards are for later stage and more established companies. These rounds are usually $10M+ and are often much larger;
- Convertible Note: A convertible note is an 'in-between' round funding to help companies hold over until they want to raise their next round of funding. When they raise the next round, this note 'converts' with a discount at the price of the new round. This will be typically seen convertible notes after a company raises, for example, a Series A round but does not yet want to raise a Series B round;
- Corporate Round: A corporate round occurs when a company, rather than a venture capital firm, makes an investment in another company. These are often, though not necessarily, done for the purpose of forming a strategic partnership.
- Debt Financing: In a debt round, an investor lends money to a company, and the company promises to repay the debt with added interest;
- Equity Crowdfunding: Equity crowdfunding platforms allow individual users to invest in companies in exchange for equity. Typically, on these platforms the investors invest small amounts of money, though syndicates are formed to allow an individual to take a lead on evaluating an investment and pooling funding from a group of individual investor;
- Funding Round: “Funding round” is the general term used for a round when information regarding a more specific designation of the funding type is unavailable;
- Grant: A grant is when a company, investor, or government agency provides capital to a company without taking an equity stake in the company;
- Initial Coin Offering: An initial coin offering (ICO) is a means of raising money via crowdfunding using cryptocurrency as capital. A company raising money through an ICO holds a fundraising campaign, and during this campaign, backers will purchase a percentage of a new cryptocurrency (called a “token” or “coin”), often using another cryptocurrency like bitcoin to make the purchase, in the hopes that the new cryptocurrency grows in value;
- Non-Equity Assistance: A non-equity assistance round occurs when a company or investor provides office space or mentorship and does not get equity in return;
- Post-IPO Debt: A post-IPO debt round takes place when firms loan a company money after the company has already gone public. Similar to

debt financing, a company will promise to repay the principal as well as added interest on the debt;
    - Post-IPO Equity: A post-IPO equity round takes place when firms invest in a company after the company has already gone public;
    - Pre-Seed: A Pre-Seed round is a pre-institutional seed round that either has no institutional investors or is a very low amount, often below $150k;
    - Private Equity: A private equity round is led by a private equity firm or a hedge fund and is a late stage round. It is a less risky investment because the company is more firmly established, and the rounds are typically upwards of $50M;
    - Product Crowdfunding: In a product crowdfunding round, a company will provide its product, which is often still in development, in exchange for capital. This kind of round is also typically completed on a funding platform;
    - Secondary Market: A secondary market transaction is a fundraising event in which one investor purchases shares of stock in a company from other, existing shareholders rather than from the company directly. These transactions often occur when a private company becomes highly valuable and early stage investors or employees want to earn a profit on their investment, and these transactions are rarely announced or publicized;
    - Seed: Seed rounds are among the first rounds of funding a company will receive, generally while the company is young and working to gain traction. Round sizes range between $10k–$2M, though larger seed rounds have become more common in recent years. A seed round typically comes after an angel round (if applicable) and before a company's Series A round;
    - Venture- Series Unknown: Venture funding refers to an investment that comes from a venture capital firm and describes Series A, Series B, and later rounds. This funding type is used for any funding round that is clearly a venture round but where the series has not been specified.

- *Revenue:* with this column it is possible to understand which is the turnover of the startup. This kind of information was not easily available: in fact for some of the startups was not possible to find it. In the Cruchbase platform, for some of the startups, was reported a range of revenue, from which was decided to report the average value of this within the database.

- *Acquisition:* this column is referred to the possibility of acquisition of the startup by an external company. It represents the M&A's status, if the startup has been acquired or not. Also, other details were reported in case of acquisition: acquisition year, acquiring company and value of acquisition.

- *B2C, B2B or B2D*: this box of the database reports the type of target the company has in mind with its offer. In particular, there are three possible options of offering target:

- B2C (Business to Consumers) is a process where the company sells its offering directly to customers.
- B2B (Business to Business), on the opposite, is the process where the company sells its offering to other businesses.
- B2D (Business to Developer) represents the option in which the startup deals with the developers, which can take a component and turn it into another product, alone or together with other components

In reality, it can happen that the startup addressed its offering to more than one target, making a mix of the presented alternatives.

- *Offering*: the last characterization column of the database is represented by the type of offer presented by the startup. More in detail, it specifies if the startup is dealing with hardware products, software products or is providing only services related to the Internet of Things. Again, as for the previous solution, the company can offer a combination of these solutions. There is also another category of the offer that is related to Infrastructures and Networks: in this last case, the aim is to build the appropriate infrastructure for the development and implementation of IoT products and services.

3.2 GENERAL ANALYSIS

The initial database counted 1594 startups, 495 of which did not respect the constraints set by the definition of startup provided by the Internet of Things Observatory. The result obtained from the research has been the selection and classification of 1079 international IoT startups. In this update, it is possible to notice how the number of startups considered has decreased compared to the initial number (1102), despite the addition of 180 new startups to the database (1774 total startups in the database). This is because many startups previously considered no longer respected the parameters of the definition, and therefore no longer useful for the analysis.
As first point of analysis let's see a simple evolution over years of the 1079 IoT startups considered in the database, just to see what was the trend. Let's consider the foundation date of all these startups, in order to have a view of the situation year per year.

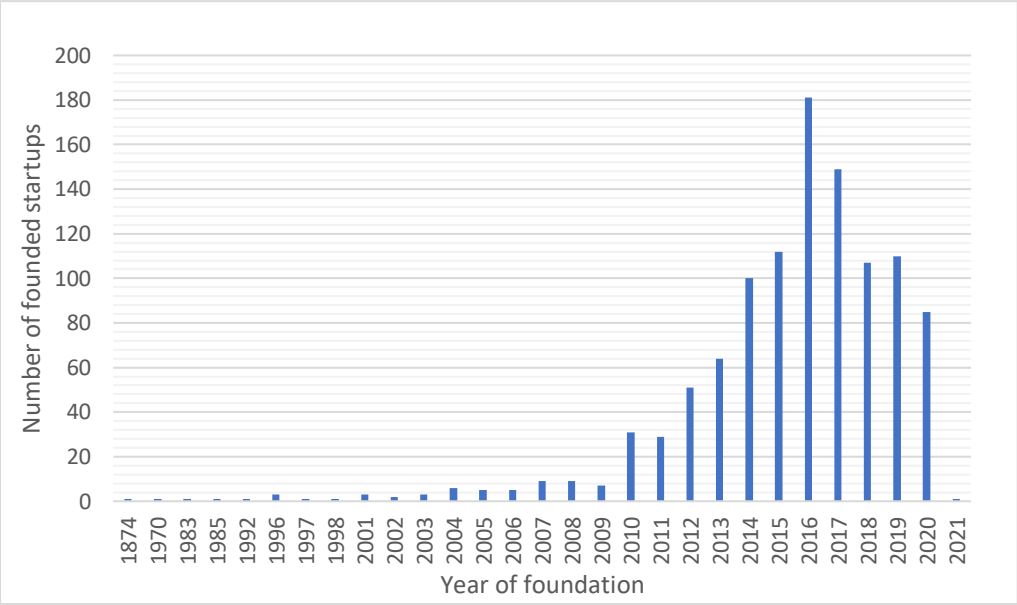

Figure 19: Foundation year of the 1079 startups

As explained before, the startups considered are not only the companies founded in the last five years, but also the ones which received a funding round in the last two years. In fact, as it is possible to see from the graph above, there is also a startup founded in 1874. Looking at the Figure 11, it is clear as the number of IoT startups starts to be consistent from 2010, reaching important numbers from 2014. In particular, the peak is reached in 2016 with 181 founded startups. The number corresponding to the year 2021 is not very relevant as it only considers the first two months of the year. From 2019 to 2020 there is a little decrease in the number of new founded startups, probably due to the crisis caused by COVID-19. In any case, the numbers are affected by how the database was compiled and to some specificities of IoT startups. Indeed, could happens that may companies founded in the last years have not yet reported financing on the Crunchbase website. This kind of issue is relevant because some companies were not chosen as they, also considering the kind of offer proposed, did not seem attractive and so were not included in the database.

3.2.1 GEOGRAPHICAL DISTRIBUTION

The first analysis carried out on these 1079 startups is related to the geographical distribution. In particular, as a reference point, the countries in which the headquarters of the different companies are located are considered.

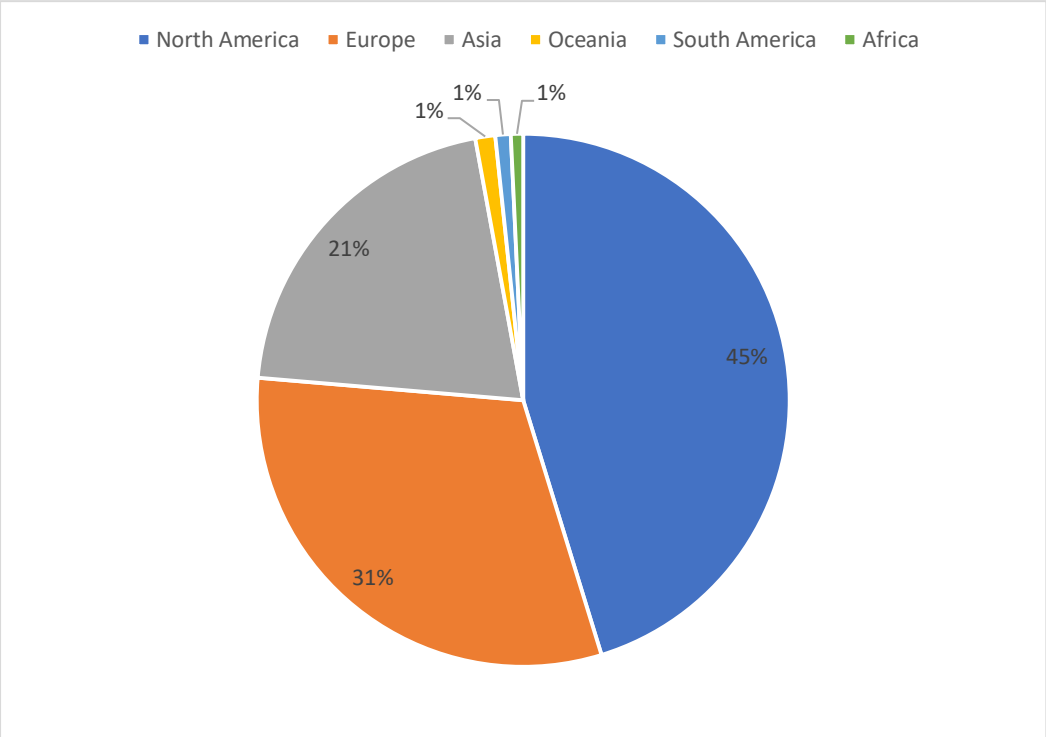

Figure 20: Geographical distribution of the 1074 startups

As can be seen from the graph above and how it could be predicted, almost the total number of startups, precisely 97%, is located among North America, Europe and Asia. As a consequence, the remaining three continents do not reach all together the 3%. Going into more detail, making a greater focus, it is possible to report some numbers:

- North America counts 490 startups, 439 of which are located in the United States of America, 46 in Canada and 5 in Mexico;
- South America has 10 startups, of which 7 located in Brazil, 2 in Chile and 1 in Colombia;
- In Africa are present 8 startups: 4 in Nigeria, 2 in Egypt, 1 in Senegal and 1 in Uganda;
- 13 startups have their headquarters in Oceania, in particular 12 in Australia and 1 in New Zeeland.

More interesting is the situation in Europe and Asia, where the geographic distribution of startups is more heterogeneous. In particular, Europe counts 332 startups while Asia 226. Their distributions can be synthesized with the following graphs.

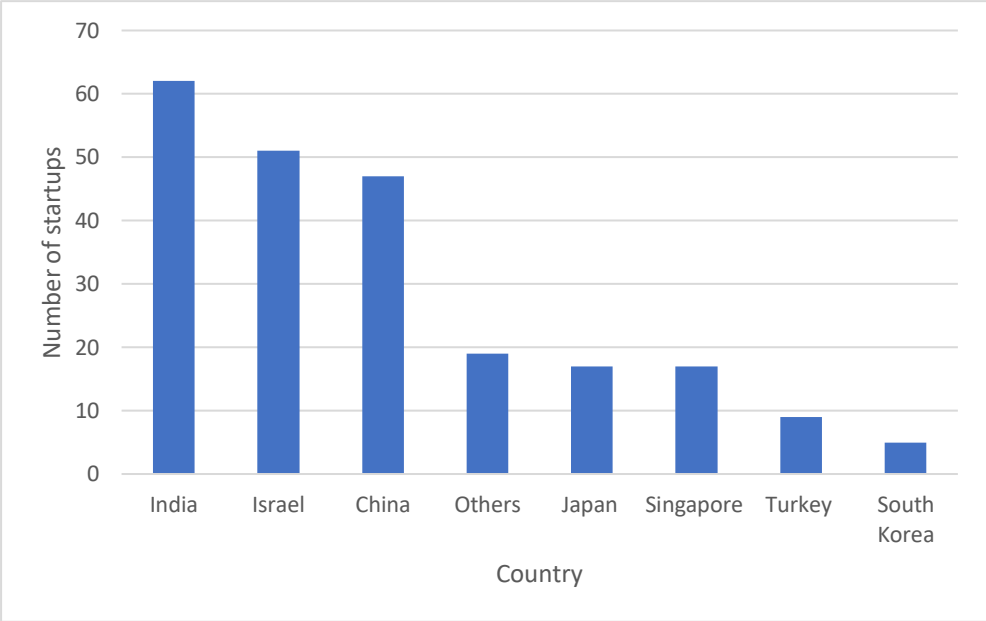

Figure 21: Distribution by country of the 226 Asian startups

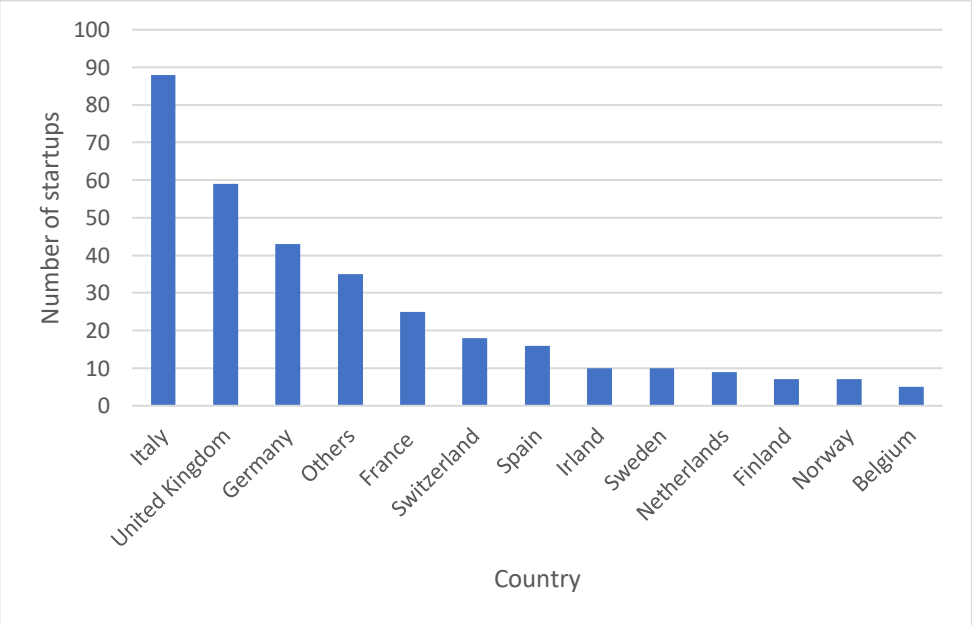

Figure 22: Distribution by country of the 332 European startups

It is a bit surprising that a continent so technologically advanced like Asia, thanks mostly to countries like China, India and Japan, is just third for number of startups in this special chart. This is mainly due to the fact that some Asian countries' policies impose severe limitations on information sharing, which make it more difficult to find information or even entire companies on the Web. It is also interesting to see how Italy, according to the definition and the information raised, together with United Kingdom, Germany and France counts the 57.4% of the European IoT startups. Again, to explain Italy high numbers, contrary to what has been said for Asia, there is the greater availability of information and numbers regarding Italian startups. In Asia, instead, India, Israel and

China are the "dominating" countries, counting together 159 out of 226 startups.

3.2.2 APPLICATION FIELDS

Another interesting analysis regards the Internet of Things application fields. It is valuable understand which are the main orientations of the startups and how the latter prefer to exploit the peculiarities of this technology. The graph below shows how the startups are distributed according to the different application fields.

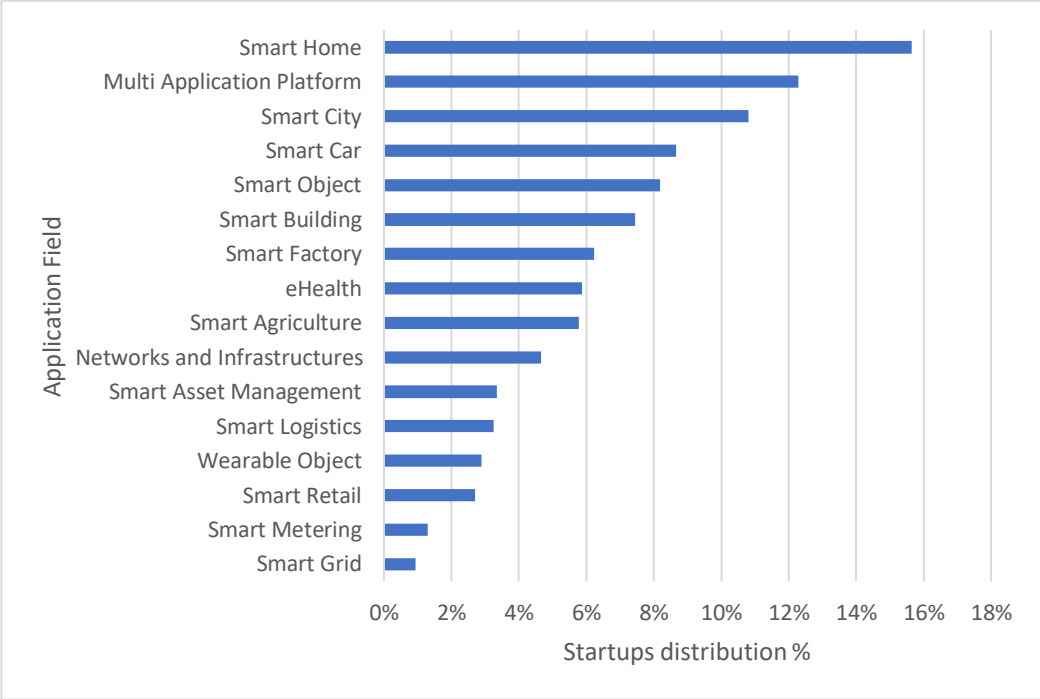

Figure 23: Distribution by application field of the 1079 startups

As it is visible, Smart Home seems to be the most "fertile" field with 168 startups, the 15.6% of the total. Certainly, in a world that is increasingly moving towards technology, the Smart Home sector is the one that can accommodate the largest number of customers. Potentially every citizen can be a customer of these solutions as they can purchase this kind of product/service for their home. This situation can explain the tendency of startups to apply themselves in this sector. Smart Home field is followed in term of number by Multi-Application Platform field which counts 132 startups (12.3% of the database) and Smart City applications which have 116 companies (10.8% of the database). On the contrary, the areas that are less exploited by startups are Smart Metering, representing 1.3% of the database, and Smart Grid, with only 10 companies out of 1074.
Considering the great spread of IoT technology application in the Smart Home and Smart City sectors, a further more detailed analysis was carried out. In particular, the aim is to understand which are the sub-areas of these fields most affected by the application of the

IoT technology.

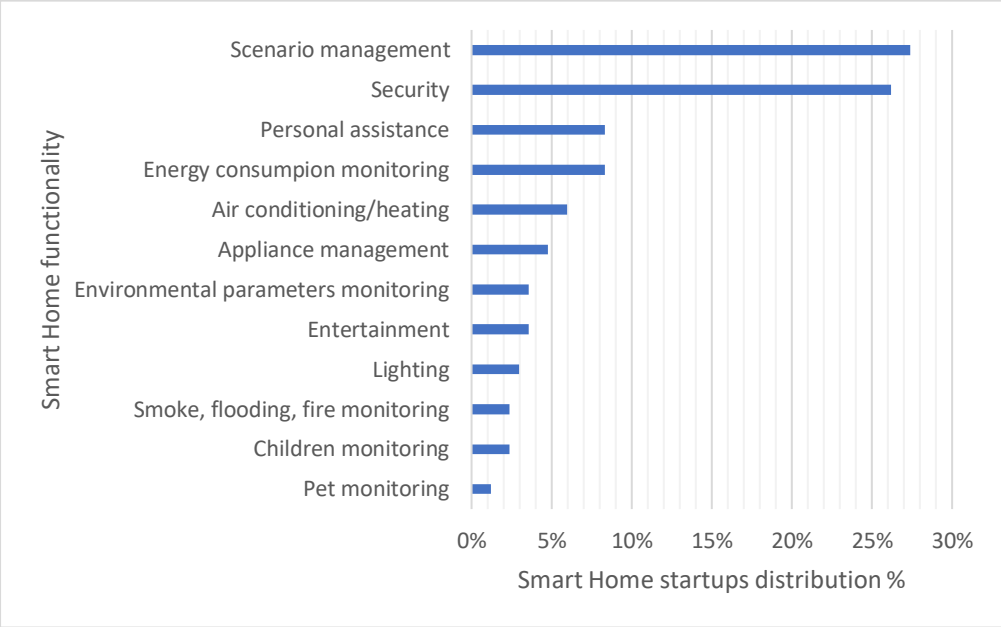

Figure 24: Distribution by application of the 168 Smart Home startups

Investigating in the various areas of the Smart Home applications, as visible in the graph above, founders of IoT startups seem to favor Scenario management and Security issues: together they represent almost the 60% of the total Smart Home applications. Scenario management solutions give the home owners the possibility to keep different aspects of homes under control. An explanatory example of this application is given by SHIPSHAPE, a startup of the compiled database and founded in 2020: it provides a software platform that unlocks and analyzes data by networking physical infrastructures and mechanical systems, providing practical advice linking them to service providers and virtual home assistant to improve their performance and save time and money for homeowners. Security solutions, instead, use the Internet of Things to protect and prevent homes from unwanted intrusions. For sure, home security is a priority for homeowners, who gladly take advantage of these new technologies to protect themselves and their family.

On the contrary, the least preferred solution by startups is the pet monitoring, with only the 2 out of 168 implementations.

Below, instead, it is possible to find the chart related to the Smart City applications. Private transportation, which use the Internet of Things technology to optimize private mobility, is for sure the most attractive field for the startups: in fact, the 30.2% of the startups which decided to invest in Smart City IoT applications chose this area. In this regard, could be interesting to show an example of a startup belonging to this sector, taken from the database: the selected startup is LIME, founded in 2017. Lime aims to revolutionize mobility in cities by providing an environmentally friendly, efficient and

affordable transportation option through the implementation of smart bike fleets (bicycles, electric bicycles and electric scooters) enabled with GPS, wireless technology anti-theft locks, in various cities around the world.
Traffic management, Environmental monitoring and Parking management are other areas highly selected by startup founders. Problems reports and Infotainment & touristic services, instead, seems to be the least popular applications, with only 1 and 3 out of 110 implementations respectively.

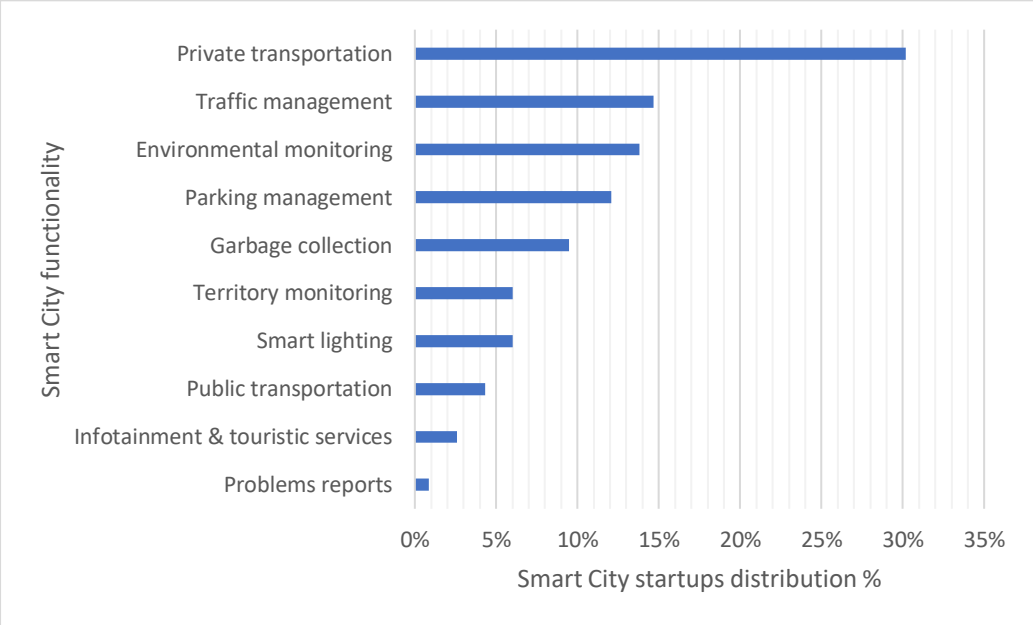

Figure 25: Distribution by application of the 116 Smart City startups

3.2.3 APPLICATION FIELDS EVOLUTION

Another interesting analysis is represented by the evolution of the different application fields during the years, in order to identify some existing trends. The decade from 2010 to 2020 is considered as a time window, a period that offers more insights on a numerical level. For each year, the percentage subdivision by application field of the total number of new startups born in that same year is considered. The table below shows the general view of this kind of evolution for each field. The field of application of the Internet of Things preferred by startups in the different years is highlighted in green.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
eHealth	7%	14%	2%	6%	3%	8%	5%	3%	5%	9%	6%
Networks and Infrastructures	0%	0%	10%	3%	8%	4%	6%	2%	7%	5%	2%
Multi-application platform	21%	14%	10%	17%	19%	18%	9%	7%	10%	12%	8%
Smart Agriculture	3%	7%	4%	6%	7%	5%	6%	6%	5%	3%	12%
Smart Asset Management	3%	0%	2%	0%	2%	5%	2%	7%	1%	7%	1%
Smart Building	7%	11%	16%	11%	7%	5%	9%	6%	4%	2%	12%
Smart Car	0%	4%	8%	3%	9%	9%	10%	11%	17%	9%	2%
Smart City	14%	11%	12%	6%	6%	5%	9%	17%	16%	15%	11%
Smart Factory	14%	18%	10%	8%	10%	7%	7%	3%	5%	0%	6%
Smart Home	21%	11%	12%	14%	15%	16%	16%	22%	12%	10%	17%
Smart Grid	3%	0%	0%	0%	0%	1%	0%	3%	1%	1%	1%
Smart Logistics	0%	4%	4%	5%	3%	3%	4%	2%	4%	3%	6%
Smart Metering	3%	0%	0%	0%	2%	1%	0%	1%	2%	5%	0%
Smart Object	0%	4%	8%	8%	10%	11%	13%	4%	9%	11%	2%
Smart Retail	3%	0%	2%	2%	0%	2%	4%	3%	2%	3%	7%
Wearable Object	0%	4%	2%	10%	1%	2%	1%	3%	2%	5%	5%
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 6: Percentage subdivision by application fields of the 1019 startups born during the 2010-2020 period

As it is visible by Table 6, some field of application shows interesting insights, especially the most diffused ones. For example, considering Smart Car, Smart City and Smart Home, they have a similar trend. Both started with percentages. Then, with the evolution of the technology and the spread of these technologies, startups have started more and more to develop solutions related to the use of these applications, reaching higher percentages in the last few years. However, this kind of application follow more or less the general growing trend of the Internet of Things, which shows an increasing number of new startups year after year as already seen previously in the thesis. Again, Smart Object field has a trend similar to the one just described. Different is the case for the Multi-Application Platform: it was the most preferred kind of application for the IoT by startups, at the beginning of the considered time period. In fact, it was the most diffused in 2010 and from 2013 to 2015. Then, companies born before this initial period, preferred to go in other directions, offering customers different solutions. However, the numbers related to this field of application after 2015 are not low. But considering the preferences up to that

moment and the growing diffusion of the Internet of Things, the expectations were different.

3.2.4 GEOGRAPHICAL DISTRIBUTION OF APPLICATION FIELDS

After having carried out an analysis concerning the geographical distribution of startups and after having analyzed in detail the various fields of application of the IoT startups, it is possible to combine these two dimension to create a wider view of the situation. With this kind of view it is visible how the startups in each continent have decided to develop their business, which kind of solution they propose to their customers.

	South America	Oceania	North America	Asia	Europe	Africa	
eHealth	1	0	28	17	17	0	63
Networks and Infrastructures	1	1	21	8	21	0	50
Multi-Application Platform	0	2	77	25	31	0	132
Smart Agriculture	3	3	20	14	22	0	62
Smart Asset Management	0	0	13	12	11	0	36
Smart Building	2	1	37	16	23	1	80
Smart Car	2	1	47	23	18	2	93
Smart City	0	1	33	25	54	2	116
Smart Factory	1	1	43	12	10	0	67
Smart Grid	0	0	2	2	5	1	10
Smart Home	0	0	94	32	43	0	168
Smart Logistics	0	2	12	9	9	2	35
Smart Metering	0	0	9	1	4	0	14
Smart Object	0	1	34	15	39	0	88
Smart Retail	0	0	13	8	8	0	29
Wearable Object	0	0	7	7	17	0	31
	10	13	490	226	332	8	1079

Table 7: Distribution by application field and geographical area of the 1079 startups

From Table 4 it is possible to highlight some relevant patterns. First of all, it is possible to notice that in countries like South America and Oceania, where IoT is not spread on a

large scale, the focus is not on the worldwide predominant application fields, but the most diffused IoT startups develop Smart Agriculture solutions. Fields like Smart City and Smart Home count zero startups in these countries. This kind of situation could be related to the primary needs of the population in these areas: in fact, agriculture has a fundamental importance there. On the contrary, Smart City is the most diffused application field in Europe while Smart home is the most preferred IoT application by startups. In Africa, instead, the situation does not seem to have particular patterns, also due to the very low number of startups.

Let's have a more detailed focus on the three bigger characters of the analysis: North America, Asia and Europe.

	North America	Asia	Europe
eHealth	6%	8%	5%
Networks and Infrastructures	4%	3%	6%
Multi-Application Platform	15%	11%	9%
Smart Agriculture	4%	6%	7%
Smart Asset Management	3%	5%	3%
Smart Building	8%	7%	7%
Smart Car	10%	10%	5%
Smart City	7%	11%	16%
Smart Factory	9%	5%	3%
Smart Grid	0%	1%	2%
Smart Home	19%	14%	13%
Smart Logistics	3%	4%	3%
Smart Metering	2%	0%	1%
Smart Object	7%	7%	12%
Smart Retail	3%	4%	2%
Wearable Object	1%	3%	5%

Table 8: Application fields percentage distribution of the 1048 startups distributed in the 3 main areas

In table 8 are represented the percentages of the total number of startups in each country for each application field. Looking at the percentages for each field, they are more or less the same in every country. This shows that the interest of the startups towards the different application fields is more or less the same in every country. A first point to underline is that, in North America, the two most preferred application fields (Smart Home and Multi-Application Platform) total the 34% of startups, while in Asia (Smart Home and Smart City) and in Europe (Smart City and Smart Home) reach respectively the 25% and 29% of the total. This shows a greater predominance of two fields above all in North America

respect to Europe and Asia, where there is a slightly less unbalanced distribution. However, without considering the already mentioned preferences of startups for each country in the previous paragraph, there are some little unbalances in some fields. For example, considering the Multi-Application Platform, there is the 15% of the total startups in North America that provide solutions inherent in this field while in Asia and Europe only around the 10%. This means that in North America there is more interest in this type of application. Or again, considering the Smart Car application field, in Europe startups show less interest (only 5%) than North America and Asia, where the percentage is respectively 10%. Other situations like those are visible in Smart Object and Wearable Object fields, where European startups have bet more than North American and Asian ones.

3.2.5 TYPE OF OFFER

Another factor characterizing startups is the type of offer proposed to customers. The three main kinds of offer are Hardware offer (HW), Software offer (SW) and Service offer. In addition to them there is the combination of the three and the Networks and Infrastructures type. Figure 18 is indicative in this regard, as it shows the different possibilities with related percentages derived from the 1074 startups mapped.

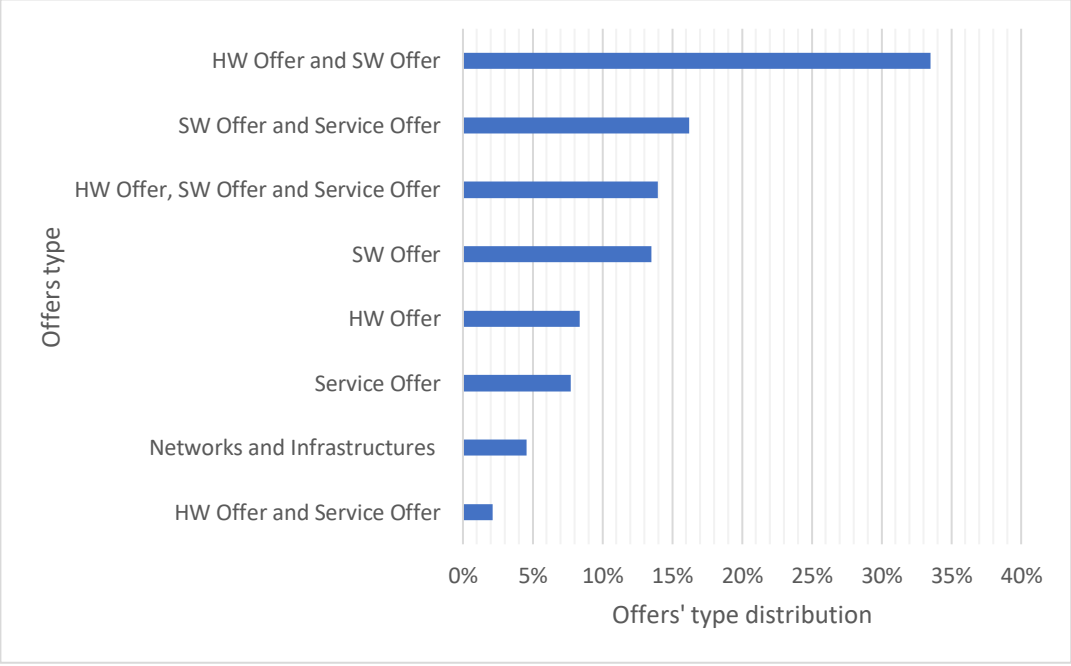

Figure 26: Offers' type distribution of the 1079 startups

As it is visible form the figure, the most preferred kind of offer adopted by startups is the one that sees the combination between Hardware and Software, with 360 startups up to 1074 offering this kind of solution. So, companies seem to favor this type of offer in order

to propose to the end customer a solution that is as complete as possible, creating value added by exploiting both hardware and software characteristics. A similar argument can be made considering the offer that includes together Hardware, Software and Service, which constitutes the 14% of the total with 150 startups, ranking in the third place. This demonstrates again how the completeness of the solution provided is relevant for the companies. It is interesting to see how the single pure HW offer occupies the fifth position in this special ranking, with only 90 companies. In particular, this data is even more relevant if it is compared to the pure SW offers, which count 145 startups, the 13.5% of the total. This data reflects the vision of many players in the sector, oriented more to developing more software than hardware. Hardware and Software startups with their respective characteristics have already been introduced in chapter 1.3.1, together with the advantages of the latter over the former which may explain the discrepancy between the data of the two types of offer. In this regard, it can be noted that if considering all the offers that do not include hardware from the analysis, the sum gives around 42% of the total, an important percentage. Probably, this can be explained considering the fact that these typologies of offers are usually supplementary to the Hardware that the customer already has, producing it or purchasing from third parties. Networks and Infrastructures offer, instead, reflects what already seen in the application fields analysis chapter, with the 4.6% of the startups choosing this typology. The less preferred type of offer, with only 23 startups up to 1079. In a scenario that sees the rapid spread of the servitization, phenomenon according to which a lot of infrastructures, software and products are becoming services, pure service offers are the 7.7% of the total, and this kind of data is destined to grow during the years. In this regard, below are provided examples of pure Internet of Things Hardware, Software and Service startups, in order to better understand the type of offers provided in the different cases.

Company Name	**Ecosteer**
Foundation Year	2017
Headquarter	Europe
Founder	Daniel Grazioli, Elena Pasquali
Business description	EcoSteer is an IoT and Blockchain software startup for data ownership and monetization. Based on end-to-end encryption and smart contracts, EcoSteer US-patented Data Ownership Platform (DOP) is a data sharing governance layer that decentralizes data access control, giving it back to data owners, who have full control over third party access to their data and are compensated for data sharing. DOP supports GDPR-compliant, decentralized corporate data streams marketplaces, allowing companies to invite selected partners to access IoT customer data in compliance with privacy laws, generating new revenues while involving customers into the data value chain.
Application Field	Smart City
Web Site	www.ecosteer.com

Table 9: Software IoT startup example

Company Name	**Leafi Home**
Foundation Year	2019
Headquarter	Canada
Founder	Christopher Pang, William Wang
Business description	Leafi Home is a hardware start-up focused on developing affordable, user-friendly, and sustainable building automation solutions to improve people's quality of life and wellness. The first product under development is a retrofit IoT device to automate any existing window blinds and enable them with smart home features like voice control, scheduling, and remote access.
Application field	Smart Home
Web Site	www.leafihome.com

Table 10: Hardware IoT startup example

Company Name	**Roambee**
Foundation Year	2014
Headquarter	San Francisco Bay Area, Silicon Valley, West Coast
Founder	Sanjay Sharma, Vidya Subramanian
Business description	Roambee provides a reliable and cost-effective end-to-end service to track shipments and their condition in real time. Within minutes customers, regardless of the industry, can access information about shipments and their in-transit condition to avoid loss, improve operational efficiency and save money.
Application Field	Smart Asset Management
Web Site	www.roambee.com

Table 11: Example of Service Offer by IoT startup

3.2.6 TARGETS

This chapter analyzes the different types of target to which the offers of startups are addressed. Not only the classic B2B and B2C are considered, but often the offers have not a specific target: sometimes, in fact, the startups in offering the product/service have more than one type of customer in their sights. All the types of target considered in the database are presented below:

- B2B
- B2C
- B2D
- B2B&B2C
- B2B&B2D
- B2C&B2D

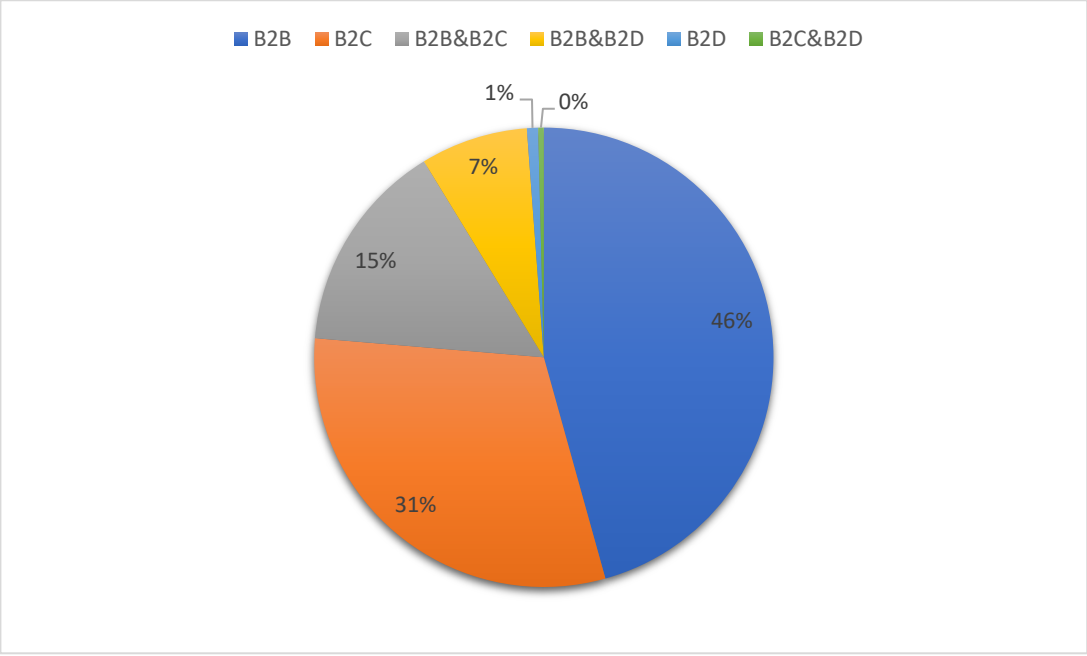

Figure 27: Distribution by customer target of the 1079 startups

As it is possible to see from the image above, the type of target preferred by startup is the Business one, with 488 companies addressing their products and services to this kind of customer. As expected after having discovered the most preferred kind of customer, the second position in order of startups preference is occupied by the B2C target, with 337 out of 1079 startups. A good percentage of startups (14.9%), instead, have developed a solution for a combination of the two main targets (B2B&B2C). As it is visible,

companies do not like to create solutions for only developers: only the 0.8% of startups decided to go in this direction. The same can be said for B2D associated with B2C targets. Differently, companies oriented to realize value for other companies, businesses and developers has a slight relevance on the total (7.6%).
Below are three example of startup, one for each single type of target (B2B, B2C and B2D) taken directly from the compiled database.

Company Name	**OpSense**
Foundation Year	2019
Headquarter	Washington DC Metro Area, Southern US
Founder	Carson McDonald, Stuart Gavurin
Business description	OpSense is an Internet of Things (IoT) platform built for food safety and quality monitoring for retail and foodservice industries. The OpSense platform monitors temperature, humidity, open doors, HVAC conditions and more, to help improve productivity across operations, facilities, equipment, and the workforce. The system also provides task management checklists, customizable alerts, and reports.
Application Field	Smart Retail
Web Site	www.opsense.com

Table 12: Example of startup with B2B target

Company Name	**Kryo**
Foundation Year	2016
Headquarter	East Cost, Southern US
Founder	Tara Youtgblood, Todd Youngblood
Business description	Kryo is a company developing IoT-based sleeping products designed to h with temperature technology. Its products include sleep systems comprise mattress pad, thermal regulating control unit, a remote and an application well as a hydro-powered, temperature-controlled weighted blanket, enabling users to monitor and optimize their sleep and even in extreme temperature conditions.
Application Field	eHealth
Web Site	kryoinc.com

Table 13: Example of startup with B2C target

Company Name	**PubNub**
Foundation Year	2010
Headquarter	San Francisco Bay Area, West Coast, Western US
Founder	Stephen Blum, Todd Greene
Business description	PubNub enables software developers to rapidly build and scale real-time applications, cloud infrastructures, links and key blocks for real-time interactivity. Developers can create real-time applications such as live dashboards and data dissemination, real-time collaboration, second screen synchronization and machine to machine reporting for any device.
Application Field	Multi-Application Platform
Web Site	www.pubnub.com

Table 14: Example of startup with B2D target

Doing a more in-depth analysis, considering for example the foundation dates of the startups, it can be seen that the newest startups are directed more towards a B2C kind of target, while the older ones seem to be more inclined to offer solutions for the Business customer. This can represent a shift of focus in the mindset of entrepreneurs, who have probably noticed a greater chance of success with this kind of target. Modelling the solutions on the needs of the customer can generate a competitive advantage for companies.

3.3 FINANCIAL ANALYSIS

In this chapter the goal is to investigate and to analyze the funding rounds received by the mapped IoT startups. It is necessary to make a fundamental preamble for this type of analysis: not all the startups present in the database report financing data as there was no such type of information on Crunchbase platform. The reasons may be related to the fact that companies themselves has decided not to make this information public. Or again, can be related to the fact that some funding has not been registered on Crunchbase or has not yet been received. Once these considerations have been made, it is possible to proceed with the analysis. The startups with a non-zero financing box within the database are 854, and will therefore constitute the object of analysis in this chapter.
In any case, this kind of analysis is relevant because give the possibility to have a more complete view about which are the typologies of startups more attractive for investors.
Below it is deployed the distribution of the 854 financed IoT startups.

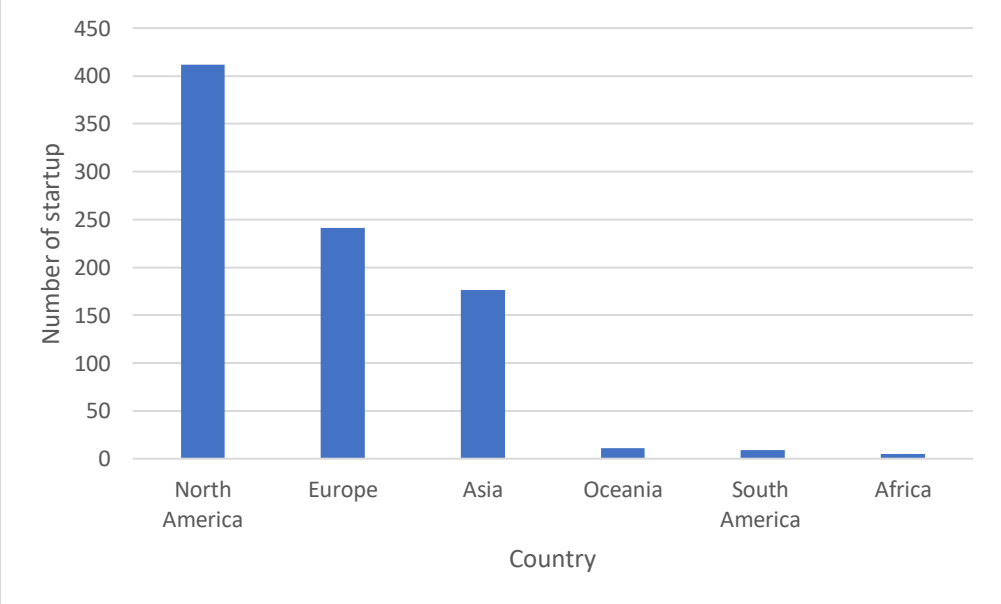

Figure 28: Distribution by country of the 854 financed IoT startups

3.3.1 FUNDING EVOLUTION

First of all, it can be interesting to analyze the trend of the funding received by IoT mapped startups during the years. As it is visible from Figure 30, looking at the total funding amount there is a growing trend, reflecting a growing interest for IoT startups and, more in general, towards the Internet of Things. Obviously, data about 2021 is not relevant since it considers the first two months of the year. Together with the total funding amount grows also the average funding amount, which corresponds to the sum funding of the funding received in the year divided by the number of startups financed in that specific year. So, these data show how in addition to interest, trust grows in a sector that affirms itself year after year, offering companies the necessary resources to develop their business.

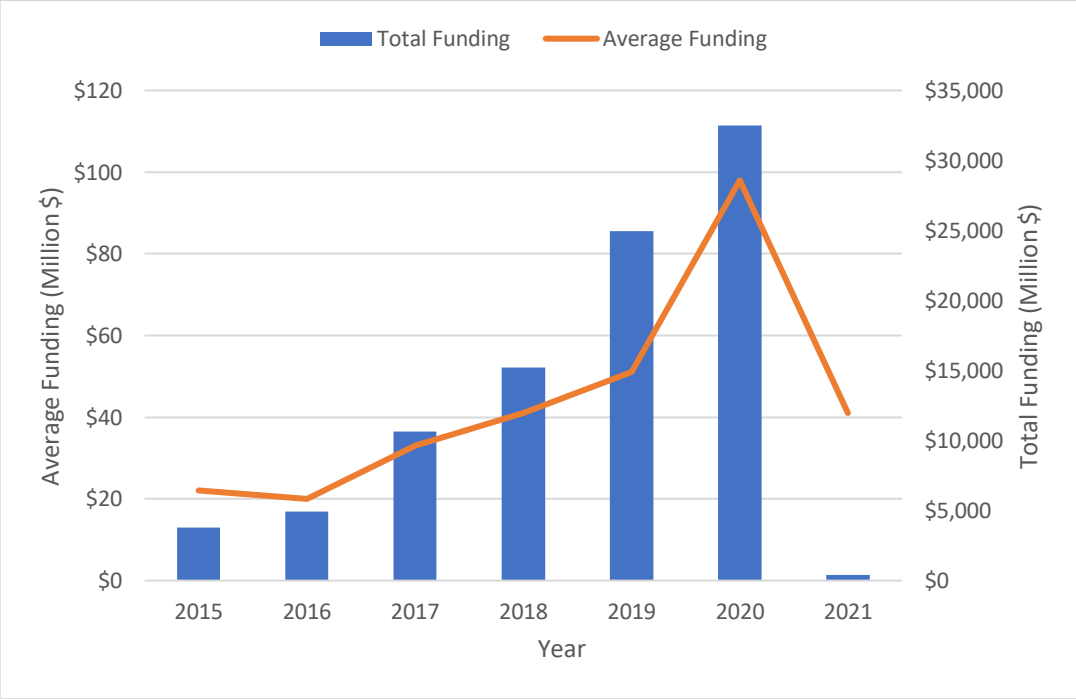

Figure 29: Total and Average Funding evolution of the 854 financed startups

Doing a more in-depth analysis it is good to underline the presence of outliers in the data that can, in a certain way, influence the results. It is therefore good to make a second analysis as the first one, removing any values that can distort the results. By convention, a threshold higher or equal to 1 billion dollars is considered, i.e. startups that have received at least one round in one or more years higher than or equal to 1 billion dollars are excluded from the analysis. Following this direction, 8 startups are removed because of the presence of outliers.

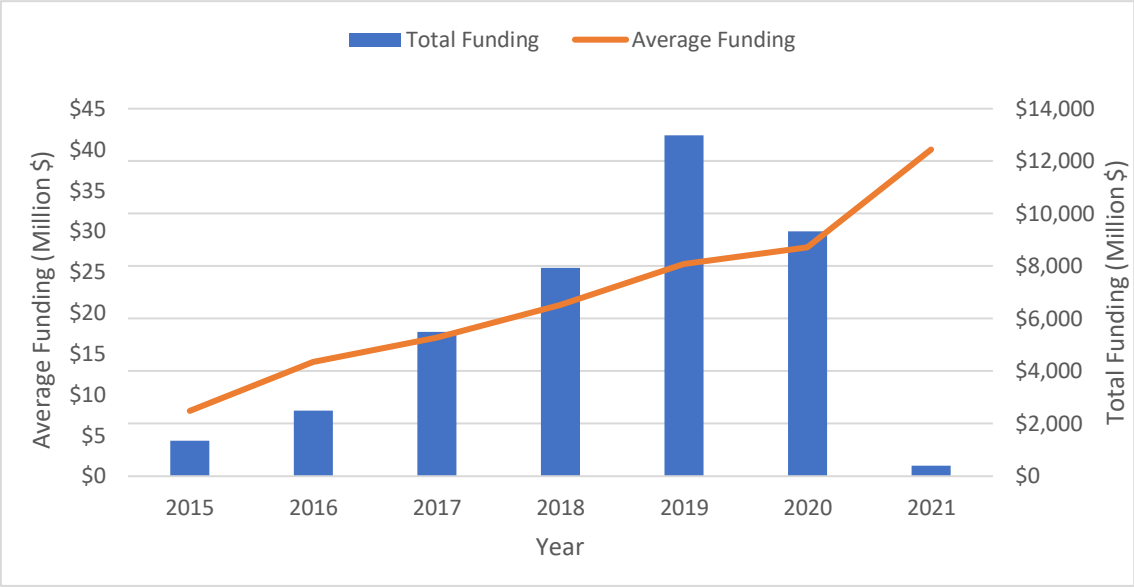

Figure 30: Total and Average Funding evolution of the 846 startups without outliers

The values are slightly different, as Figure 21 shows. The growth is still present even if there is a slight flection from 2019 to 2020, considering the total amount. This shows how in 2020 the presence of more substantial funding rounds is higher than in other years. As it is visible looking at the differences between Figure 30 and Figure 31, every year has at least an outlier since in every year there is a reduction in the total funding amount. The only exception is 2021, which confirms the same data in both the figures. Considering this, by analyzing the average amount instead, it is possible to see how the growth is straight and how in 2021 the average funding value per startup is promising. In short, it seems a possible sign of ever increasing trust of lenders in this kind of solutions, always considering the limits of an analysis like this.

3.3.2 GEOGRAPHICAL DISTRIBUTION OF FUNDING

This kind of analysis is aimed at understanding where most of the funding is concentrated. It is done by summing the capitals received by the different companies of a continent. As for the previous analyzes, the average funding received by a startup for each continent was calculated, given by the sum of the financing received in the continent and divided by the number of companies financed in that specific area.
The situation is illustrated in Figure 32. It is possible to notice some interesting issues: the first fact that catches the eye is how Asia, as regards the total funding, despite being third for number of startups, almost reaches the primacy North America (43 billion USD versus 49 billion USD of North America), which has more than double the number of Asian startups. Considering the average funding per startup instead, Asia dominates this ranking with about 248 million received per startup, doubling the American data, which

is in the second position. It is a very relevant data because if comparing it with the other two areas with a higher concentration (North America and Europe), it is possible to see how the average funding is very high. An example taken from the database to support these data is the one of VAYYAR, an Israeli IoT startup which develops solutions dedicated to personal assistance in the Smart Home environment. Vayyar produces different types of sensors for different applications, as for example sensors that detect people in a room, their position and their breathing to send alarms if needed. Moreover, the developed chips communicate with adjustable wave frequencies. This IoT startup has raised around 200 million dollars from investors in its few years of life.

It is important to underline how, among the three most important countries, only Europe does not have outliers. So, there are not funding rounds with important figures. With this consideration, it is possible to give a reason for the Europe third place in this ranking.

So, considering this greater view, there seems that investors are more attracted to Asian and North American startups rather than European ones. Moreover, considering the average funding per startup, also Oceania has a higher value (around 32 million USD per startup) than Europe (only 18.8 million USD per startup) and also it does not have outliers in its data. The other two areas present too low numbers to make more in-depth analysis. From this reasoning, it could be deduced that despite the growing interest shown in the Internet of Things field which is manifested by the number and the growth of startups founded, at the economic level, there is still a very low ability of European startups to attract large investors.

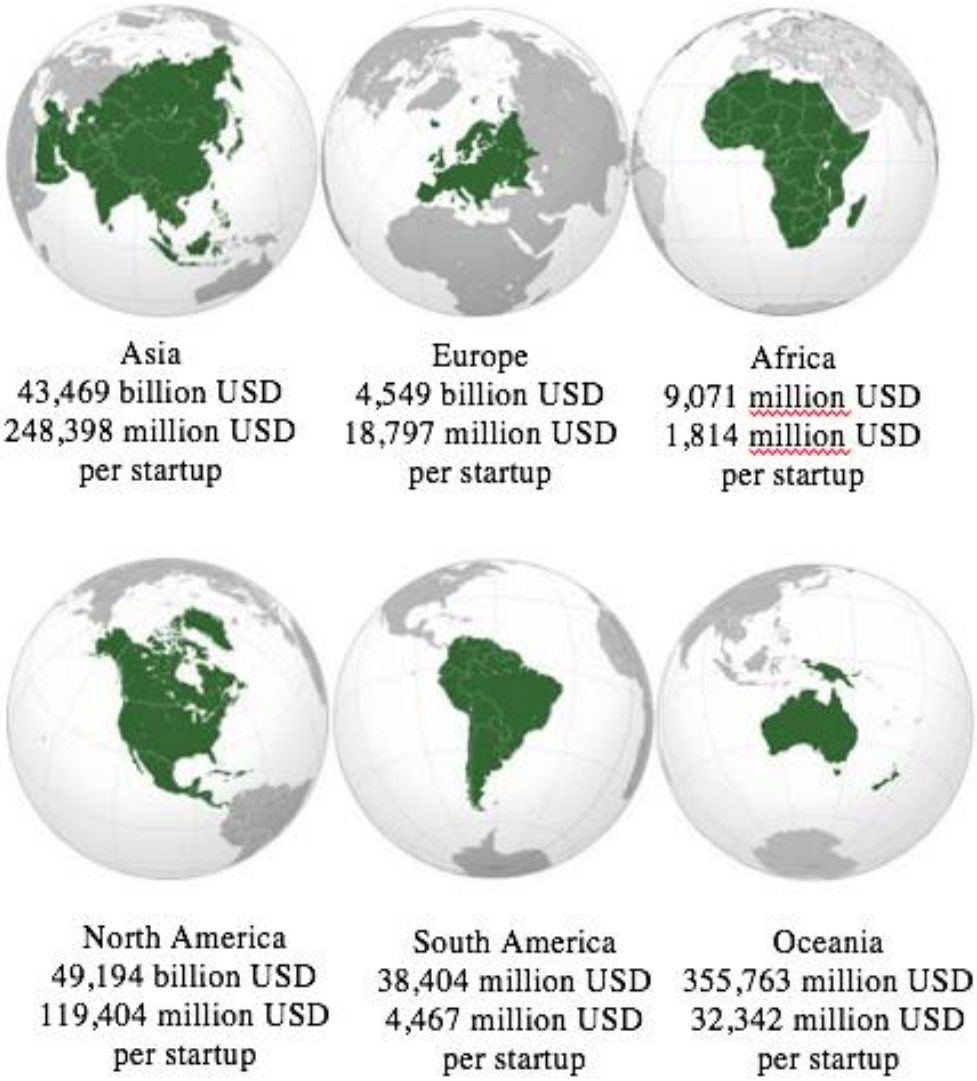

Figure 31: Total and Average Funding per continent of the 854 financed startups

3.3.4 FUNDING IN THE APPLICATION FIELDS

This section is dedicated to the distribution of funding for each field of application. The goal of this analysis is to understand which are the areas of application which receive the higher figures from investors and, consequently, what are the most attractive areas for moneylenders. The analysis consists in the investigation of the 854 startups of the database which received funding, summing the total amount collected by the startups belonging to a specific application field. Then, as done previously, the average sum of investments received by each company mapped for a specific application area was calculated. The results of this analysis are shown in Figure 34. In Figure 33, instead, it is

illustrated the distribution by application field of the 854 financed startups. Substantially the latter reflects the distribution of the 1079 startups seen previously.

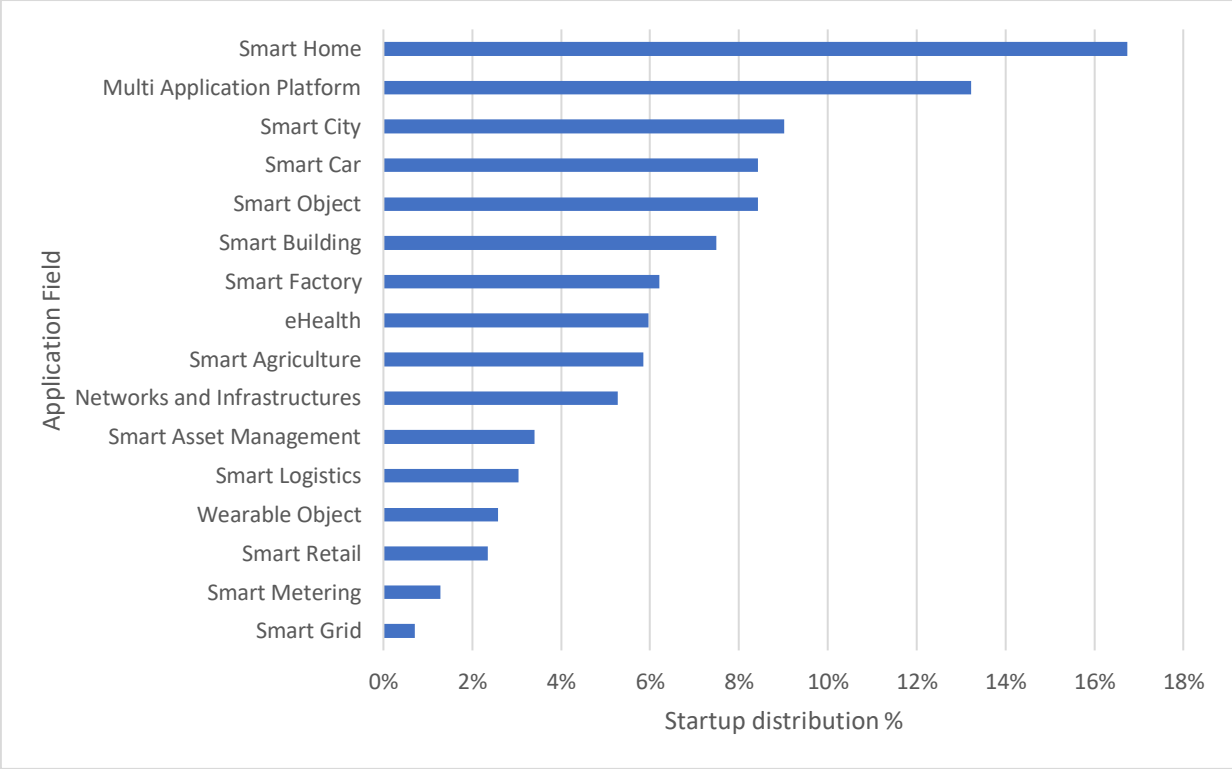

Figure 32: Distribution by Application Field of the 854 financed startups

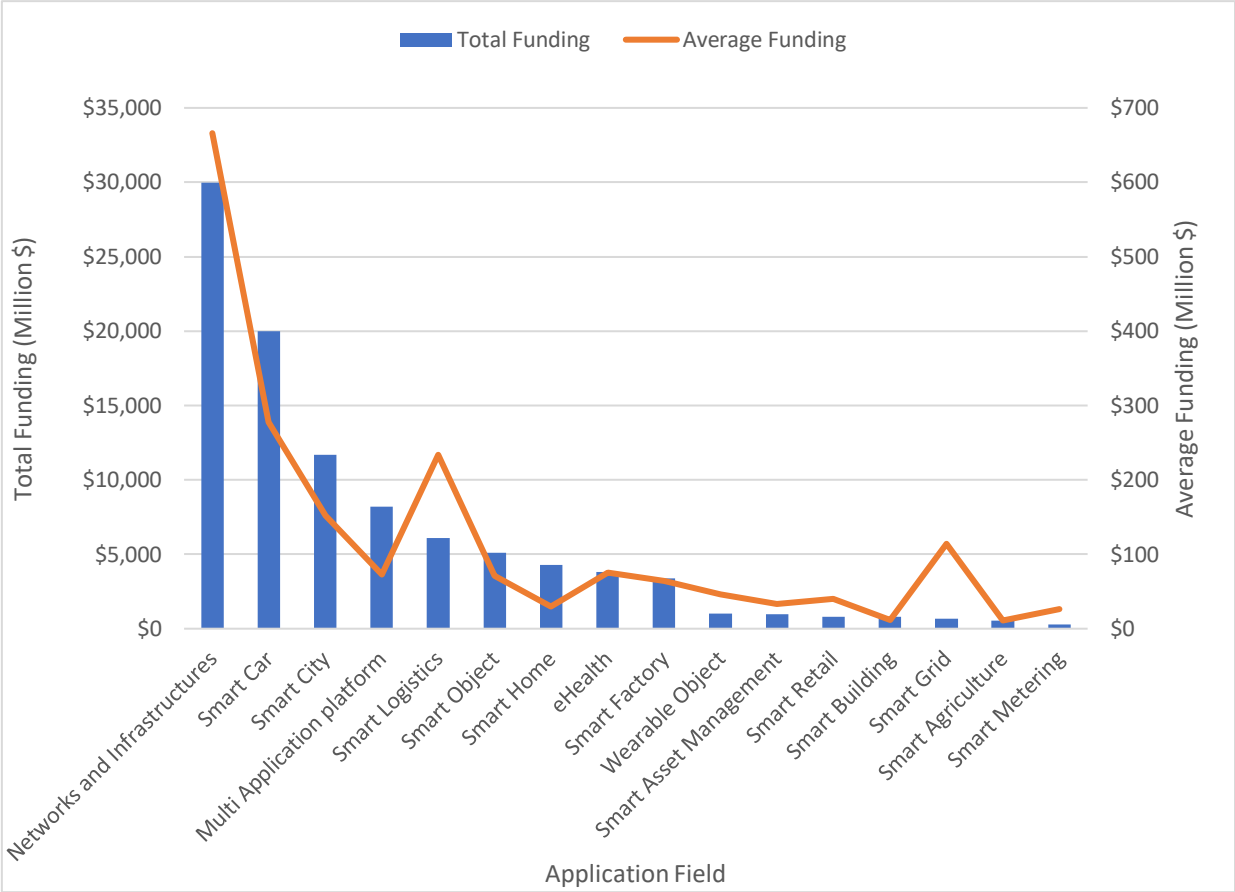

Figure 33: Total and Average funding per field of application of the 854 financed startups

Looking at Figure 34, the first impressing data that emerges is the one related to the Networks and Infrastructures field: although it represents only 5% of the total by number of startups, it is by far the area that has collected the most funding. Furthermore, considering that, having high capitals and few startups, this field of application is the one with the highest average amount of funding per startup (666 million USD per startup against 278 million USD of the Smart Car, the second application field in ranking). It is certainly an application field that offers solutions that require significant capitals to be developed. In this regard, an example of a startup offering solutions in this area and which have collected a total funding amount of around 109 million USD is provided below.

Company Name	**Kineis**
Foundation Year	2018
Headquarter	Ramonville-saint-agne, Midi-Pyrenees, France
Founder	Cristophe Vassal
Business description	Kineis is an independent, private satellite operator. An emerging player in the new space sector, the company wants to lead innovation in global connectivity for the IoT domain. Through its technologies, Kineis works closely with terrestrial IoT operators, current satellite operators and connected object manufacturers, to locate ad collect data all over the globe in all conditions.
Application Field	Networks and Infrastructures
Web Site	www.kineis.com

Table 15: Example of startup in the Networks and Infrastructures field

Again, Smart Car field of application, which is fourth for number of startups representing the 8% of the total, occupies the second position with high figures both in terms of total and average funding received, respectively almost 20 billion USD and 278 million USD per startup.
Opposite is the case for the Smart Home area of IoT application: as it is visible in Figure 33, it dominates the ranking for number of startups but it is only the seventh for total funding amount, with around 4 billion USD. As a consequence, the average funding per startup in this field is very low. To explain this there is to consider the fact that although this is an ever growing and already established field of application, startups in this area do not need too many capitals to realize their solutions and to be competitive.
Considering the total amount of capital received, Smart Asset Management, Smart Retail, Smart Building, Smart Grid, Smart Agriculture and Smart Metering confirm to be the least attractive areas, with figures less than 1 billion.
Analyzing the trend of the average startup funding, instead, it is possible to notice how this follows the one of the total funding, with the exception of mainly two points: Smart Logistics and Smart Grid fields of application. Smart Logistics application field is the third for average funding amount with 234 million dollars per startup while Smart Grid startup receives on average 114 million USD. It is indicative that there are few startups in these areas with high funding amounts per startup: these numbers show how the startups in this area need huge capitals in order to develop their offer, survive and grow. Probably without high capitals these startups are destined to fail.
At this point, it could be interesting to do a more in-depth analysis on Smart City and Smart Home fields, having information and numbers on the different functions of these areas. The situation is shown respectively in Figure 35 and 36.

Looking at the Smart City area it is impressing how almost the total funding amount of this area are concentrated in one functionality, the Private transportation, exactly the 92% of the total. This is undoubtedly the most attractive functionality for investors. This type of sector intends, for example, to implement mainly the E-mobility area, providing solutions about electric cars, electric motorcycles, electric scooter etc. These solutions are becoming increasingly popular, especially in metropolis, and above all considering the problem of pollution caused by the CO2 emitted by vehicles, and, more in general, the environmentally friendly issue. These startups need often a lot of capitals to develop their solutions, considering also the fact that, in some case, they have to provide entire fleets of vehicles, as shown previously with LIME example. Other functionalities, as it is visible in figure, are very low financed.
The situation is similar for the Smart Home area, in the sense that all the funding amount in concentrated, this time, in three main functionalities: Security, Scenario management and Personal assistance, which together represent the 86% of the total funding. In particular, Security functionality receives the 45% of the total, Scenario management almost the 30% and Personal assistance the 12%. Security functionality, which in number of startups was slightly lower than the Scenario management, dominates this ranking, receiving 700 million USD more than the second. In this regard, it is possible to report an example of the application of Internet of Things security functionality by a startup from the database: DOMI, an Italian startup founded in 2016, provides a smart intrusion alarm system. It is a connected alarm that in addition to having an acoustic warning system integrates smart functions such as smartphone notifications and a connected remotely controllable camera.

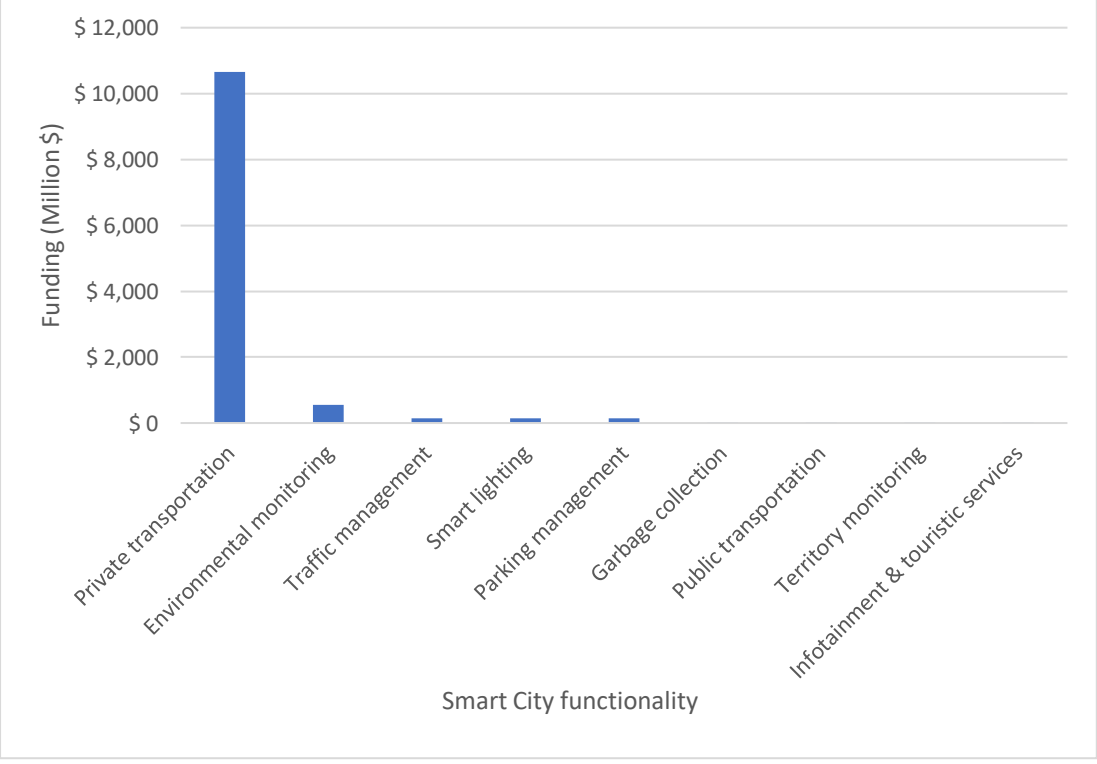

Figure 34: Funding distribution per functionality based on the 143 financed Smart City startups

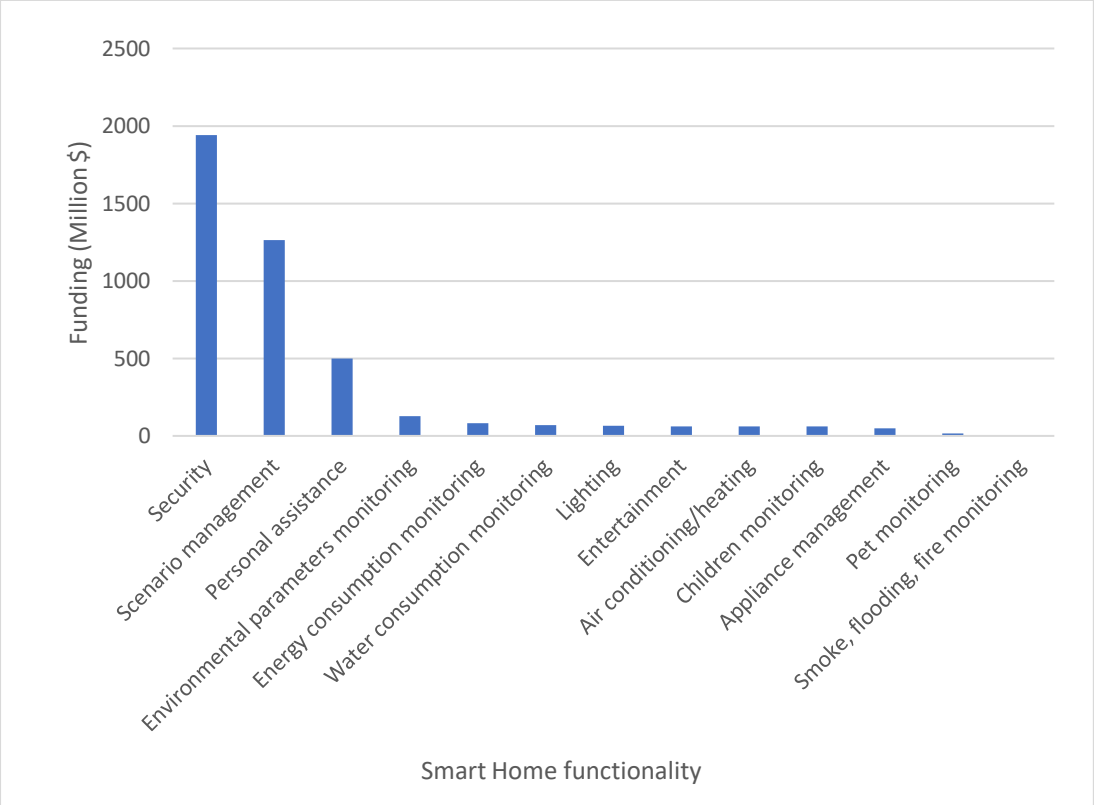

Figure 35: Funding distribution per functionality based on the 115 financed Smart Home startups

CHAPTER 4: ANALYSIS OF THE SUCCESS OF IOT STARTUPS

By analyzing the last funding rounds received by the different startups it is possible to understand their level of growth, how much they are established. Indeed, depending on the kind of funding received it is possible to certify if the startup is in the initial stages of life or if it is ready "to exit" through the acquisition by another company. The goal of this analysis is to verify if there is a kind of Internet of Things technology that is more successful than the others by understanding which are the more established startups, the ones that are at their last stages of life and are ready to be acquired by a third party. The different types of funding received by startups and present in the database have already been described in chapter 3.1. What is important now is to show the different phases of the life cycle of a startup and the corresponding types of financing related to each phase.

4.1 STARTUP: LIFE AND FINANCING CYCLE

It is possible to identify 4 main phases in the life cycle of a startup:

- Pre-Seed stage
- Seed stage
- Early stage
- Growth stage
- Exit stage

It is necessary to make a premise before seeing in detail the different phases of the life cycle: as the startup grows and moves towards the most advanced phases in the life cycle, the financing necessary to survive and develop its business increases.

PRE-SEED STAGE

At the beginning, if a person has an idea and want to launch a startup, he needs money to start the business. The first priority is to rise a capital. A good starting point could be a grant: it consists in money he gets and can use and he does not have to give it back. In fact, the funders consider that money lost. The downside of the grant is that it provides money but not a real support: the entrepreneur is left on his own. So, he has to find even other additional ways to finance the startup. At this stage, what the entrepreneur needs is equities: he loses some control but he gains money, commitment, skills and knowledge. In order to gain equity, at the very beginning, it is necessary to talk about the triple F: friends, family and fools.

SEED STAGE

In Seed stage there is the awareness that the idea starts working. There seems to be a concrete market to serve. In this phase the startup works to refine its business model, works to structure the business plan and take its first steps towards creating an MVP, a product prototype that allows to attack the market, gaining visibility and acquiring customers. To support this initial phase there are:

- Incubators: companies that help in creating the business model around the idea, which usually requires success fees in exchange (if the business is successful a part of the profits or maybe a bit of shares go to them).
- Accelerators: private facilities o universities which, if the idea starts working, help the startup to accelerate it.

EARLY STAGE

In this phase the startup has started the production and wants to launch the business or has already launched it and wants to increase it. So, here there is the transformation of MVP into a tangible product that people can use, especially with a view to large-scale future. In this stage, it is possible to rely on venture capital funds: they are a branch of private equities. They focus on the highest risk companies (startups). They accept a much higher risk for a much lower price, with a much higher expected return. There are 3 sub-categories of venture capital:

- Independent venture capital: they invest just for financial return
- Corporate venture capital: they are spin-offs from well established companies, with the hope of spotting disruption and innovation
- Government venture capital: this is the attempt of government to sustain a startup environment

It is in this stage that is possible to collocate series A and series B rounds.

GROWTH STAGE

Here happens that the startup, which already has a product with its market (product-market fit), grows, increases its turnover and the number of customers. As the company grows, the amount of the loan disbursed increases: the startup finds a structural solidity where it needs additional capital. Here the rounds of series C, series D and so on continue. In this phase cash flow must be one of the most important pillars to guarantee the success of the startup as well as being one of the parameters in which an investment fund analyst will give greater importance.

EXIT STAGE

Finally, there comes a time when the company has grown and has such a value that it can be sold, obtaining an extra yield. This point is the exit phase. It consists in the sale of the startup and it can be done in various ways. The most common types of exit are:

- Being bought by another company (usually bigger, through acquisitions or mergers)
- IPO: Initial Public Offering. Once the startup become listed, it is not a startup anymore.

It should be noted that this last step is optional. In fact, the goal of many startups is not to go out but to become a high-value company in the long run.

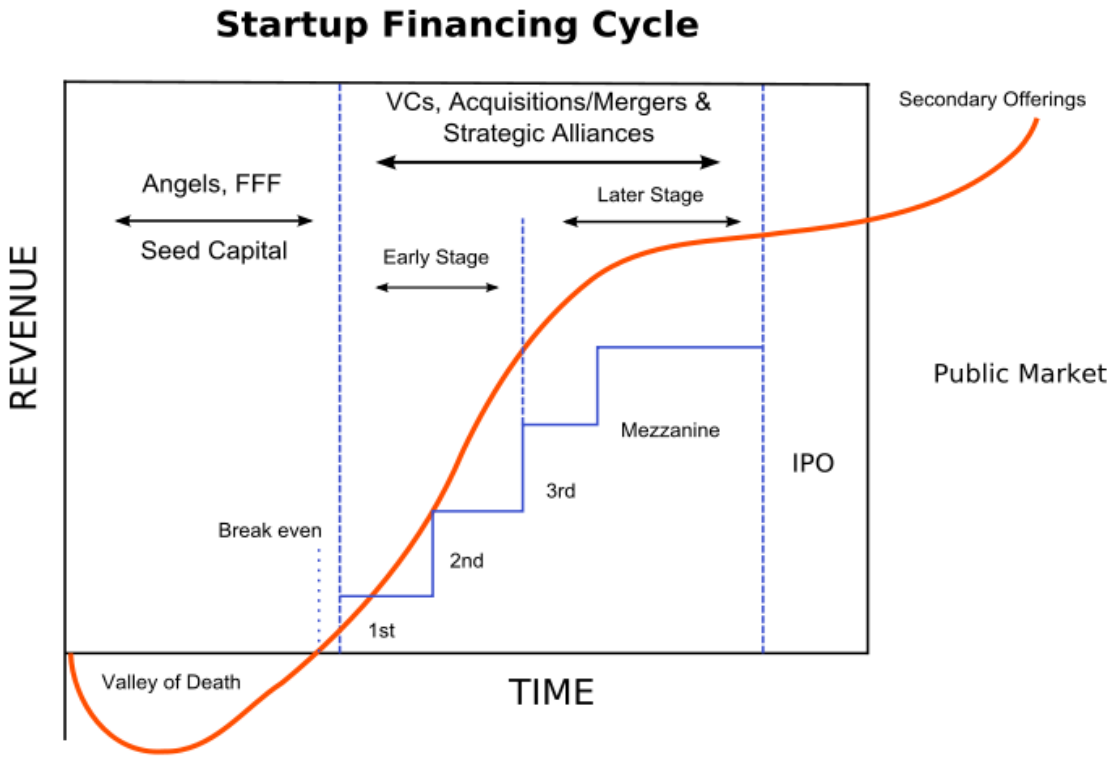

Figure 36: Startup financing cycle

The graph above summarizes what the financial cycle of a startup can be. Some interesting points about it are explained below:

- Most startups (92%) die in the Death Valley phase
- 1st, 2nd and 3rd refers to the round of financing, according to the different stages
- After the early stage, some numbers and something more solid to show are available. This means that will be easier to gain investments. it is also possible to get to round 6, for instance: this means you keep receiving funding because people believe in the startup

4.2 CLASSIFICATION FRAMEWORK BUILDING

After introducing some key concepts and considering what explained in chapter 4.1, it is now possible to build the classification framework. As already said, the goal of this section is to analyze the evolution level of the startups in the database considering the last funding rounds received, focusing the attention on the various typologies of IoT startups. Then, try to understand if some type of IoT startup turns out to reach the later stages of life more easily than others.

The first step consists in collocating the types of last funding rounds to the different life stages of the startups, considering what has been explained so far. Certainly, as explained before in the thesis, not all the mapped startups present financial numbers, and therefore only those with financial information will be able to participate in the analysis. Moreover, there is to consider the fact that not all types of funding are characteristics of a given stage of the startup life cycle. For instance, "Funding Round" is the general term used for a round when more detailed information about the funding type is unavailable and so this will not be considered in the model. Or again, "Venture – Series unknown" refers to an investment that comes from a venture capital firm but where the series has not been specified. For this reason, it is not possible to collocate it in a specific stage.

Taking into account these restrictions, there are 667 startups with the necessary characteristics to be able to participate in the analysis.

Life Cycle stage	Funding Round type
Pre-Seed stage	Angel Pre-Seed
Seed stage	Equity Crowdfunding Product Crowdfunding Seed
Early stage	Series A Series B
Growth stage	Series C Series D Series E Series F Series G Series H Series I
Exit stage	Initial Coin Offering Post-IPO debt Post-IPO equity

Table 16: Classification framework

Above it is possible to see the association between life cycle stages and funding rounds characteristic for each stage. Below, instead, there is the list of "General Funding Round Type", the types of funding which are not specific of a particular stage and so the ones that are not valuable for the framework because they do not give information about the progress of the startup. The startups which has one of these types as their last funding rounds will not be considered in the analysis.

General Funding Round Type
Convertible Note
Corporate Round
Debt Financing
Funding Round
Grant
Non-Equity Assistance
Private Equity
Secondary Market

Table 17: Funding round types excluded from the analysis

Once the model has been built, the next step is to classify the startups in various stages according to the type of last funding received, and split them according to the application field. In this way, it will be possible to have a general view on the situation.

4.3 CLASSIFICATION FRAMEWORK APPLICATION

Above, in the following tables explaining the situation stage-by-stage, the classification framework is applied and a detailed analysis is provided. One dimension shows the phases of the life cycle of a startup with the respective types of financing. The other one illustrates the fields of application of the Internet of Things to which the different startups belong. The cells within the table show the number of startups belonging to a specific application field and which have received a particular type of financing as last funding round. The first yellow line for each stage represents the total number of startups for each application field belonging to the stage. The second yellow line, instead, illustrates the distribution of startups in the various stages of the life cycle, for each area of application. It could be useful to carry out an analysis stage by stage, in order to understand how the situation of each field of application is. To have a general overview of all the stages it is possible to consult the annex at the end of the thesis work.

4.3.1 PRE-SEED STAGE ANALYSIS

Therefore, starting from the embryonic phase of life, the Pre-Seed stage, it seems that more or less all the startups in the various areas are able to overcome this very initial period. In fact, looking at the percentages in Table 18, they are all below 10%, thus indicating a scarce presence of startups in this phase. More precisely, only the 4% of the total number of IoT startups analyzed are in the Pre-Seed stage. The highest values are found in the Smart Logistics, Smart Factory and eHealth areas, with percentages around 10% of the total. However, looking at the percentage values of these areas in the subsequent phases and analyzing the years of birth of these startups, they are more companies just born rather than unable to reach the next steps.

On the contrary, the numbers of Networks and Infrastructures and Multi-Application platform fields should be underlined, with 0% and 2% of the total startups respectively in this phase. These are two important areas of application of the Internet of Things technology, and these data show how here the startups rapidly overcome the embryonic phase. In fact, they need more substantial funding from the very beginning to develop their business. The same is true for the Smart Home and Smart Car sectors, even if the reasons for these numbers may be different from those used for the previous areas. In fact, they too have low percentages of startups in the Pre-Seed phase (2% of the total) and this can be caused by the fact that these are already well established fields and that they manage to easily pass this initial stage.

In this phase, the Pre-seed round is predominant rather that the Angel one. In any case, there are low funding in favor of startups in the Pre-Seed stage. All in all, therefore, the IoT startups considered in this analysis seem to be able to develop their ideas easily, passing the first phase without big problems.

		eHealth	Networks and Infrastructures	Multi-application platform	Smart Agriculture	Smart Asset Management	Smart Building	Smart Car	Smart City	Smart Factory	Smart Grid	Smart Home	Smart Logistics	Smart Metering	Smart Object	Smart Retail	Wearable Object	
Pre-Seed Stage	Angel			1	1		1		2	3		1						9
	Pre-Seed	4		1	1	1	2	1	2	1		1	2		1	1	1	19
		4	0	2	2	1	3	1	4	4	0	2	2	0	1	1	1	28
		9%	0%	2%	6%	4%	7%	2%	6%	9%	0%	2%	10%	0%	2%	6%	6%	

Table 18: Focus on the 28 startups in the Pre-Seed stage

4.3.2 SEED STAGE ANALYSIS

This is the phase in which the idea on which the startup is based begins to take shape. If in the previous phase the percentages were low and did not arouse particular interest, in the Seed stage the situation changes. The percentage values of the various fields of application in this phase range from 25% to 75%, thus showing different situations area by area. First of all, compared to the previous stage, there is a greater presence of startups in this phase of the life cycle: 280 of the 667 startups analyzed are in the Seed stage, more than a third of the total.
Let's analyze in more detail how startups behave in the various areas of application in this phase. In particular, let's start from the areas with lower percentage values which, considering also the low percentages of the previous phase, will be those with greater numbers of startup in the following stages and which do not have great difficulty in passing this phase of life. The lowest percentage is the one of the Multi-Application Platform field, with only the 25% of the total startups in this stage which, together with the 2% of the previous phase, makes it the most successful application field until now. In this regard, it may be interesting to show an example of a startup that offers this type of Internet of Things solution, in order to better clarify what these companies do. The example illustrated below shows a startup taken from the database which actually is in the Seed stage of its life cycle.

Company Name	**Teknoir**
Foundation Year	2019
Headquarter	Greater Houston Area, Southern US
Founder	Jonathan Klein
Business description	Teknoir is igniting the Industrial AI Revolution by democratizing artificial intelligence for machines. It is building an AI IoT platform consisting of all the necessary tools and framework for visionaries to take their ideas from inception and develop them into fully functional AI apps that can be uploaded to a marketplace for distribution, and ultimately deployed to devices in the field – leading to total disruption across industries.
Application Field	Multi-Application platform
Web Site	www.teknoir.ai

Table 19: Example of startup in the Multi-Application platform field

Areas like eHealth and Smart Factory show a low distribution of startups in this phase with 28% of the total and, considering the 9% of the previous phase, they have the same results up to now. Therefore, companies in these fields show a fairly simple trend in overcoming the initial stages of the life cycle by managing to develop their business. The situation for the application of the Internet of Things in the context of Smart Metering, on the other hand, is critical, considering that three quarters of its startups are in this phase. In this case, it must be considered that the number of startups is very low and therefore distribution has a relative importance. It is interesting to note instead that two important areas regarding the application of the internet of things such as Smart Car, Smart City and Smart Home have relatively high concentrations in this phase, respectively 50%, 57% and 49% of the total. In this case the data can be explained partially considering that many of the startups of these areas in this stage are still young. The most preferred way of financing in Seed stage is the Seed funding round, with 270 out of 280 rounds of this type.

		eHealth	Networks and Infrastructures	Multi-application platform	Smart Agriculture	Smart Asset Management	Smart Building	Smart Car	Smart City	Smart Factory	Smart Grid	Smart Home	Smart Logistics	Smart Metering	Smart Object	Smart Retail	Wearable Object	
Seed Stage	Equity Crowdfunding			1	2							3						6
	Product Crowdfunding	1										1			2			4
	Seed	11	13	23	16	11	21	27	39	13	3	46	7	6	19	6	9	270
		12	13	24	18	11	21	27	39	13	3	50	7	6	21	6	9	280
		28%	41%	25%	56%	46%	46%	50%	57%	28%	60%	49%	35%	75%	40%	33%	50%	

Table 20: Focus on the 280 startups in the Seed stage

4.3.3 EARLY STAGE ANALYSIS

With the early stage the initial phase of life is passed. In this phase the startup undergoes the transformation of the MVP into a tangible product. Again, the startup needs higher funding to evolve. The percentage values here are still quite high, highlighting a strong presence of startups in this phase. In particular, 243 startups are in this stage of the life cycle, the 37% of the total. The data in this phase do not offer great hints for analysis as it is a central phase in which all the startups belonging to the various fields of application arrive, some with more and some with fewer startups. But the percentages for every area are between 30% and 40%. The lower numbers are those of Smart Metering and Smart Grid areas of Internet of Things application (respectively 13% and 20%), as they have a greater distribution of startup in the initial stages. Furthermore, as already said for Smart Metering area, also Smart Grid field has low number of total startups thus not giving the possibility of providing a more truthful analysis. On the contrary, Multi-Application Platform area is the one that has the higher distribution in this stage, with the 46% of the total number of startup belonging to this application field, obviously most due to the low presence of these startups in the initial phases.
As for the predominant type of funding received by startups as the last round, the Series A round had 145 uses while the Series B one 95.
In conclusion, it is possible to state that practically all the startups of the different application fields can easily develop the MVP and transform it into the finished product excepts for companies in the Smart Grid and especially Smart Metering areas, which appear to have greater difficulties in reaching this stage.

		eHealth	Networks and Infrastructures	Multi-application platform	Smart Agriculture	Smart Asset Management	Smart Building	Smart Car	Smart City	Smart Factory	Smart Grid	Smart Home	Smart Logistics	Smart Metering	Smart Object	Smart Retail	Wearable Object	
Early Stage	Series A	7	10	30	6	3	15	8	11	8	1	23	4	1	10	6	2	145
	Series B	7	4	14	4	6	1	9	6	10		15	3		13	2	4	98
		14	14	44	10	9	16	17	17	18	1	38	7	1	23	8	6	243
		33%	44%	46%	31%	38%	35%	31%	25%	38%	20%	37%	35%	13%	43%	44%	33%	

Table 21: Focus on the 243 startups in the Early stage

4.3.4 GROWTH STAGE ANALYSIS

Let's enter in the most interesting phase of the life cycle of a startup. If the previous phases are necessary steps in the growth of a startup that wants to offer its product on the market, this stage represents a peculiarity. A stage in which the business, the turnover and the number of customers grow, indicating in a certain way the success reached by the company. Certainly, a step not easily reachable as those described above. In fact, looking at the percentages in Tables 22, figures are quite low, and only the 15.6% of the total Internet of Things startups of this analysis was able to get to this stage. Let's start from the most successful areas of application: eHealth, Multi-Application platform and Smart Factory fields show percentage values above 20% of the total, respectively 26%, 25% and 23%. Therefore, about a quarter of startups in this area reach the Growth stage. They are statistically important numbers, indicating a probability of reaching important turnover of 25% for startups that decide to implement these kinds of solutions. It may be that the success for the eHealth sector in the last year has been favored by the Covid-19 pandemic that has hit the planet, favoring the growth of startups that offer solutions in this regard. In favor of the other two area, it must be considered that large areas need greater funding: it is more likely that either the final stages of life will be reached or the company will definitely fail. In any case, these areas have shown good results in term of numbers from the early stages, consolidating their success here.

Smart Grid sector shows a percentage of 20% but, in reality, it corresponds to 1 startup out of 5, numbers too low to have a certain statistical relevance.

Looking at the lowest percentages, it can be notice the ones of Smart Agriculture (6% of the total), Smart Asset Management (8% of the total) and Smart Home (9% of the total), none of which reaches the 10% of the total. The first two areas are not very surprising, which throughout the course of the thesis work have never shown to be such established or popular IoT fields of application among startups. The presence of the Smart Home sector, on the other hand, causes more sensation even if, has already explained in the funding analysis chapter, the startups in this application field, generally, do not need huge funding to develop their business (it must be remembered that this analysis is based on the last funding round received by startups). The other fields of application are attested with percentages ranging from 11% to 17%, therefore values not relevant and in the average.

In this phase, the most type of funding round used is the Series C round, with a percentage value that overcome the 50%. In any case, the rounds in this area are more substantial, with figures usually exceeding 10 million USD.

In conclusion, it can be said that, considering the analysis made, there are not many startups in the various fields that reach this stage. This can be considered the phase in which the startup definitively affirms itself, achieving excellent results. As seen, the three application fields that have the greatest distribution of companies in the Growth stage are eHealth, Multi-Application Platform and Smart Factory.

		eHealth	Networks and Infrastructures	Multi-application platform	Smart Agriculture	Smart Asset Management	Smart Building	Smart Car	Smart City	Smart Factory	Smart Grid	Smart Home	Smart Logistics	Smart Metering	Smart Object	Smart Retail	Wearable Object	
Growth Stage	Series C	6	4	11	2	1	4	7	3	8		3	3		5	1	1	59
	Series D	3		8		1			4	2		4		1	2	2		27
	Series E	1		2				2	1			2			1		1	10
	Series F			2						1								3
	Series G		1	1														2
	Series H	1									1							2
	Series I								1									1
		11	5	24	2	2	4	9	9	11	1	9	3	1	8	3	2	104
		26%	16%	25%	6%	8%	9%	17%	13%	23%	20%	9%	15%	13%	15%	17%	11%	

Table 22: Focus on the 104 startups in the Growth Stage

4.3.5 EXIT STAGE ANALYSIS

This last stage has a relative importance for the purposes of the analyzes. In fact it is not a mandatory phase or a necessary objective for startups. It is at the discretion of the companies to decide whether to be purchased by third parties and leave the startup world or remain so forever. Companies such as Xiaomi, AirBnb, Spotify and Zalando are still considered startups, despite being ultra-established companies. After having made this premise, let's move on to analyze the numbers of this phase. Only 12 of the 667 financed startups analyzed are present in this stage. Almost all the funding received here are of the Post-IPO Equity type (10 out of 12). The 3 most successful application areas of the previous step are also confirmed in this phase, bringing a minimum number of startups the end of their life cycle. The Smart Home sector, which in any case had shown a low distribution in the previous phase, shows the greatest number of startups brought to the Exit stage (3 startups). This shows how this sector is well established, although it generally requires not huge funding. The other application fields showing startups in this last phase are Smart Asset Management, Smart Building and Smart Logistics.

		eHealth	Networks and Infrastructures	Multi-application platform	Smart Agriculture	Smart Asset Management	Smart Building	Smart Car	Smart City	Smart Factory	Smart Grid	Smart Home	Smart Logistics	Smart Metering	Smart Object	Smart Retail	Wearable Object	
Exit Stage	Initial Coin Offering			1														1
	Post-IPO Equity	2		1		1	2					3	1					10
	Post-IPO debt									1								1
		2	0	2	0	1	2	0	0	1	0	3	1	0	0	0	0	12
		5%	0%	2%	0%	4%	4%	0%	0%	2%	0%	3%	5%	0%	0%	0%	0%	

Table 23: Focus on the 12 startups in the Exit Stage

CHAPTER 5: CONCLUSIONS

The main goal of this part is to summarize what analyzed so far and to answer more directly to the two research questions of the Chapter 2.

About the first research question, which essentially asks what the general situation of the Internet of Things startups is, analyzing the compiled database different interesting results emerge. First of all, considering the geographical distribution of the 1079 IoT startups around the world is resulted that the 97% of the startups are concentrated in North America, Europe and Asia. About the sectors of use of the Internet of Things, startups in the database show a preference for Smart Home, the 15.6% of the total, followed by Multi-Application Platform and Smart City. Going more into detail, considering Smart Home and Smart City areas, the more selected functionalities of these fields are respectively Scenario Management and Private Transportation. A further analysis was illustrated regarding the fields of application of the internet of things, representing the evolution in the period 2010-2020: the first half of the time period analyzed Multi-Application platform is the predominant area of application exploited, while in the second half the focus is shifted on the Smart Home sector. Speaking of Smart Home, it appears to be the IoT area most exploited by startups in North America and Asia, with respectively 19% and 14% of the total. In Europe, instead, the preferred IoT application field is Smart City with 54 startups out of 332.
Regarding the type of offer proposed by startups, the most spread is the one which propose a bundle of Hardware and Software offers: the 33.5% of the total offers proposed correspond to this type of offer. The tendency is to provide the customer with a solution that is as complete as possible. About targets to which the startup offers are addressed, the B2B customer is the more selected with the 46% of the total, followed by B2C with a percentage of 31%.
By analyzing startups from a financial point of view, particularly the loans received by them, interesting data emerge. It is necessary to make a premise in this case: the data have outliers that can slightly influence the results. First of all, investigating on the evolution of funding amounts received over the years, it shows a growing trend. Then, shifting attention to the geographical distribution of funding, North America is still the first in the ranking even if the most surprising data are the Asian ones. In fact, despite having about three quarters of European startups, Asian companies receives almost 10 times the funding amount received by European ones. and again, Asian startups show by far the highest average funding value per startup (248 million USD per startup), doubling the figure of American companies. The last focus is about the distribution of funding among the different areas of application of the Internet of Things. Networks and Infrastructures area is the one that receives the greatest amount of funding, followed by Smart Car and Smart City fields. Considering also the not so high number of startups in this area, it appears to have considerably higher than average funding per startup. Finally, always looking at the trend of average funding per startup, there are mainly two outliers: Smart

Logistics and Smart Grid areas, which show a higher value than the trend line.

Moving on the second research question, after having analyzed in detail the situation in the various stages of the life cycle of the startups belonging to the different application areas of the Internet of Things, let's dedicate this last paragraph for a final consideration on what has been seen, in order to give a more general view.

	Number of startups	Distribution of startups
Pre-Seed Stage	28	4%
Sed Stage	280	42%
Early Stage	243	36%
Growth Stage	104	16%
Exit Stage	12	2%

Table 24: Distribution of the 667 startups by life cycle stage

From Table 24 it is possible to see how most of the startups are concentrated in the three central phases of the life cycle, therefore Seed, Early and Growth stages. In particular, 627 of the 667 startups are in these stages, the 94% of the total. This data is not surprising given that, as has already been explained, the Exit stage is not a necessary step of the life cycle while the very first phase is passed quickly by startups, once the idea is established and they start rising money. The essence of the analysis is therefore concentrated in the central phase. The Seed stage is the most populous phase of the analysis with 280 out of 667 startups, and therefore seems to be the longest. It is undoubtedly a phase that all startups with a valid idea can reach and it is mainly for this reason that it is the stage with the higher number of companies. Even the Early stage is very populated, thus showing how startups belonging to different application fields are generally able to reach this step quite easily in one way or another. The situation is different for the Growth stage, where the numbers begin to decrease compared to the Seed and Early stages. Therefore, it is not so obvious and easy to reach this step and different situations are outlined in the different fields of application. In this sense, it is possible to attribute the term success to the fields of application that present a greater distribution of startups in the final stages of their life cycle, therefore considering Growth and Exit stage, always keeping in mind what has been said so far regarding the very last phase.
Table 25 illustrates the classification of the application fields according to the cumulative distribution of startups in the Growth and Exit stages. Within the four sections of the table the application fields are sorted in descending order, so from the ones who have higher percentages to the ones who have lower percentages. In this way, it is possible to draw up a sort of ranking of the most successful Internet of Things application areas, based on the last funding round received by startups. It is possible to notice how Smart Grid and Smart Building have not been inserted in the table. this is because the sample of startups available for this application area of the Internet of Things is too low (respectively 5 startups for Smart Grid and 8 startups for Smart Buildings). Therefore, the statistical

significance of the numbers available for these two application fields is not sufficient to be able to insert them in the table and determine their success.

Growth Stage + Exit Stage distribution	Application Field
>=20%	Multi-Application Platform eHealth Smart Factory
>=15% & <20%	Smart Logistics Smart Car Smart Retail Networks and Infrastructures Smart Object
>=10% & <15%	Smart City Smart Building Smart Home Smart Asset Management Wearable Objects
<10%	Smart Agriculture

Table 25: Classification of application fields according to the cumulative distribution in the Growth and Exit stages

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ANNEXES

Annex 1: General overview on the application of the classification framework

		eHealth	Networks and Infrastructures	Multi-application platform	Smart Agriculture	Smart Asset Management	Smart Building	Smart Car	Smart City	Smart Factory	Smart Grid	Smart Home	Smart Logistics	Smart Metering	Smart Object	Smart Retail	Wearable Object	
Pre-Seed Stage	Angel			1	1		1		2	3		1						9
	Pre-Seed	4		1	1	1	2	1	2	1		1	2		1	1	1	19
		4	0	2	2	1	3	1	4	4	0	2	2	0	1	1	1	28
		9%	0%	2%	6%	4%	7%	2%	6%	9%	0%	2%	10%	0%	2%	6%	6%	
Seed Stage	Equity Crowdfunding			1	2							3						6
	Product Crowdfunding	1										1			2			4
	Seed	11	13	23	16	11	21	27	39	13	3	46	7	6	19	6	9	270
		12	13	24	18	11	21	27	39	13	3	50	7	6	21	6	9	280
		28%	41%	25%	56%	46%	46%	50%	57%	28%	60%	49%	35%	75%	40%	33%	50%	
Early Stage	Series A	7	10	30	6	3	15	8	11	8	1	23	4	1	10	6	2	145
	Series B	7	4	14	4	6	1	9	6	10		15	3		13	2	4	98
		14	14	44	10	9	16	17	17	18	1	38	7	1	23	8	6	243
		33%	44%	46%	31%	38%	35%	31%	25%	38%	20%	37%	35%	13%	43%	44%	33%	
Growth Stage	Series C	6	4	11	2	1	4	7	3	8		3	3		5	1	1	59
	Series D	3		8		1			4	2		4		1	2	2		27
	Series E	1		2				2	1			2			1		1	10
	Series F			2						1								3
	Series G		1	1														2
	Series H	1									1							2
	Series I								1									1
		11	5	24	2	2	4	9	9	11	1	9	3	1	8	3	2	104
		26%	16%	25%	6%	8%	9%	17%	13%	23%	20%	9%	15%	13%	15%	17%	11%	
Exit Stage	Initial Coin Offering			1														1
	Post-IPO Equity	2		1		1	2					3	1					10
	Post-IPO debt									1								1
		2	0	2	0	1	2	0	0	1	0	3	1	0	0	0	0	12
		5%	0%	2%	0%	4%	4%	0%	0%	2%	0%	3%	5%	0%	0%	0%	0%	
		43	32	96	32	24	46	54	69	47	5	102	20	8	53	18	18	667