Science and Technology Park as an Urban Element Towards Society Scientific Innovation Evolution

Afnan Tuama Almaamory 1*, Ghada Al Slik 2*

1 University of Baghdad, MSc student
2 Professor of theory and conservation of architecture PhD
Department of Architecture, College of Engineering, University of Baghdad, Iraq
*E-mail: Afnanmahdi@coeng.uobaghdad.edu.iq , Ghada.alslik@coeng.uobaghdad.edu.iq

Abstract. The idea of Science and Technology Parks (STP) emerged in the 1950s. The Parks have accumulated several architectural functions, including research centers, scientific exhibitions and innovator residence, etc. As these Parks gradually spread, some of them were linked to university complexes, while others had independent sites. The STP have been linked to the prosperity of society by providing an environment that fosters a culture of innovation and transforming research and ideas based on innovation into a commercially marketed product. However, the functional architectural concept of the STP remained unclear. The objective of this paper is to clarifying the stages of development of Parks architecture, investigating their activities, their linkage regarding planning and design, and the way they act as means to evolve innovation in societies.

Key words: science& technology park, incubator, innovation environment, scientific research

INTRODUCTION
The high increase in the number of STP around the world emphasize the role and important of them for an innovation-based economy. Moreover, they are essential tools for the country scientific and technological development. Its function is not limited to generating and transferring knowledge, but also the STP, as an innovative urban element has an impact on the local and regional environment. The idea of interconnectedness between scientific research and its establishment in an urban site between the university on the one hand and society - industry on the other hand, and its interdependence, with function linked to research had the impact on the theory of (quadruple helix). It enhances supporting the development of STP by innovative interaction among (university, industry, government and society). The paper will clarify the concept of STP and its growing architectural functions and their sites within university campuses and in separate urban context.

1. The Emergence of Science and Technology Parks
The cooperation between universities and industry was first raised seventy years ago by Professor Frederick Terman, Dean of the college of Engineering at Stanford University. He emphasized that
universities are more than just places of learning and considered them: “the main economic influences on the industrial life in the country” [1]. He decisively contributed to the establishment of the first high-tech industrial Park (Stanford Research Park SRP) in 1951 in which the interests of commercial, academic and governmental institutions converged in a synergistic vision for the future. Terman took advantage of the scientific and technical potential of the university and employed them in serve the industry based on research and development.

So we may infer that Terman established a new notion which links the academic side with the practical side. After SRP proved its success, the idea of establishing Parks spread throughout the Unite State, followed by the Research Triangle Park (North Carolina) in 1959 [3].

The spread of Parks was not limited to the United States, but it extended to Europe in the 1960s. The first European STP was Sophia Antipolis in France 1969. It was established by the government in a vital commercial area within the city and is considered to be largest science Park in Europe [1]. Additionally, Britain first Park was Cambridge Science Park which was established in 1971 by the university similar of what of US. In Asia, the experiment of establishing STP in the form of science cities began. So Tsukuba Science City had been established in Japan in the late 1970s.

Thus, the idea of a functional place for STP was crystallized that could be outside from the university frame to another space. The space would complement them with urban functions to meet the need for a complex that connects universities and research centers as a source of knowledge with industry. Thus contributing to stimulating scientific research, developing it and transferring it to Production to serve society and the economy.

This paper will briefly investigate the development of scientific research and its intellectual growth in order to enable to search space environment necessary to carry out all kinds of research.

2. Development of Scientific Research

A historical overview from the eighteenth to the early twentieth centuries illustrate that the pure science paradigm maintained until the late nineteenth century. Thereafter, connection between university and industry scientists began, and scientific practice began to change with the birth of engineering with its academic definition as an applied science. So it started awarding PhDs in this field, so the relationship between science and technology has become two-way. [4]

By the year 1900, a great change had occurred and professional industrial laboratories with researchers working for contracts and wages emerged. After that, research institutes were established outside universities. These institutes were the start of private funding programs for science and research. Gradually, the demand for scientific specializations increased, as well as the industrial demand for scientific knowledge. That led to the focus of the efforts of scientists entirely on research. Sponsorship
projects have also appeared at universities, and it was supported by cooperative funding programs [4]. Since the 1920s, many began to emphasize the term development and discuss the sequential process from basic research to applied research and then to development instead of classifying basic versus applied research. The industry is thus considered part of the national research system. After 1945 development changed from being a sub-category of research to a separate category. At this point it was logical to distinguish between measures of research activity and measures of developmental activity. Instead, officials formulated the acronym R&D, and thus continued to measure the mix of the two activities [5].

After scientific research passed through several stages, a new feature was added, which is innovation. Thus, scientific research comes out of the framework of universities and research institutions and centers are interacting with innovative research and encouraging researchers to work within this path.

The Scientific Research Path Towards Innovation

A “linear model of innovation” prevailed for a long time. This model is based on basic research that is usually carried out by universities. It was mostly with public funding, from which companies selectively pick up some of the outcomes of the basic research. Then transforming them through applied research and experimental development R&D (mostly with private funding) into products [6].

Michael Gibbons 1994 and Helga Nowotny introduced a new mode of knowledge production called the "nonlinear innovation model"[7] for research and innovation (Feedback is “more sophisticated to innovation”) [13]. This theory emphasizes the importance of coupling basic research at the university simultaneously with the commercial research and development applications of companies in the business sectors [6].

This was followed by the emergence of the idea of the Triple Helix in the mid-1990s. The era in which politicians urged universities and industries to work more closely together to commercialize new knowledge for the benefit of society [8]. The Triple Helix concept illustrates innovation dynamics based on the multi-faced interlink ages between the three pillars: government, universities and R&D centers and industry [7].

![Figure 3. Triple helix model](image)

![Figure 4. Quadruple Helix](image)

Then, the researchers added a fourth pillar in the “Quadruple Helix,” which is society. It is defined more precisely as “media-and cultural-based public” and also the idea of a “creative class” (a term suggested by Richard Florida, 2004) [6].

However, some researchers also stress the increasing importance of society and the public respectively in the dynamic innovation process by distinguishing civil society by having new demands for innovative and creative solutions. Likewise, the public represents the skilled talents and the transfer of knowledge needed to create novel knowledge and innovations. Thus knowledge economy is strongly influenced by society [9].
3. Development of the Concept of Science and Technology Park

After adoption of STP in varying regions of the world, concepts and theories about the formation and establishment of STP are related to the main parties. It starts with the concept of the triple helix (Etzkowitz, 1995), which presents the STP as a proactive factor that depends on university and government resources to provide innovation through business actors. It shows how good STPs can represent a worthy mechanism for stimulating the three elements of the helix to drive innovative processes. Then the quadruple helix added society, because the anticipated output from the triple helix activities will be innovative products. It should be linked to the market and society in order to create jobs and wealth, which are the main goals for creating STPs.

Figure 5 illustrates that the STP itself also has to balance the gains from economic development and the need for sustainability over time. It is worth noting that the most important characteristic of STPs is their networks and programs (as Allen described them), which are the mechanisms that they use to achieve economic development gains. At the same time, they represent an important part in achieving sustainability through excellence in a market that in turn leads to attracting and forming a base for its customers. And that through its networks while developing programs to organize relationships between stakeholders. [12].

Figure 5. Science Park’s Environment & its Internal Dimensions [12].

Within this direction, many organizations, networks were formed in the world for STP, including: The International Association of Science Parks and Areas of Innovation, where the official definition adopted by (IASP) in 2002: [2]

“Science Parks are organizations managed by specialized professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions. To enable these goals to be met, a Science Park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin-off processes; and provides other value-added services together with high-quality space and facilities”.

The term contains any kind of high-tech Parks such as: science & technology park, science Park, Techno Park, Techno pole, Innovation center, Research Park [14].

The countries of the world share a basic idea whose content is that the essence of technology development is to create a convenient environment in which innovation thrives [10]. Thus, we can reach a procedural definition:

The Science and Technology Park is an urban environment that includes specialized multi-functional buildings to support R&D. Its aim is to link universities and R&D centers with industrial institutions in order to convert applied research and ideas based on innovation into a marketable product. That will exist in a distinguished environment that stimulates innovation and supports interaction between specialists.
The STP began to be established in two directions:

**The First Direction: Parks Established by Universities:** This can be achieved by expanding university campus or on land belonging to the university. These developments reflect the commitment of universities to participate in wider activities, which provides companies with high-value sites in order to reach researchers and students, such as the Research Triangle Park in California and Cambridge Park in Britain.

**The Second Direction: The Parks Established in the Urban Environment:** That are established by the government or by the participation of the business sector, and the choice of the site location is made according to special criteria in line with the strategies of the master plan of the city. Parks may be developed in urban areas as an important component and pole of growth in the scheme to revitalize areas. An example is the Piedmont Triad Park for Research. [3].

Since the founding of the Stanford Research Park, which was the nucleus of Silicon Valley development, in the 1980s the rapid growth of STPs around the world began as the 'Science Parks Movement'. Ninety-one Parks were created in the United States, compared to 32 between 1951 and 1980. Hundreds of STP have been created in different parts of the world. Their number are still growing in light of the trend towards the need to adopt such STP as an important tool for scientific and economic development [15].

![Figure 6. The number of STPs by country [15.]](image)

According to the UNESCO (2018) survey, there were by 2017, 534 STPs were implemented worldwide, 169 of which were in Asia and the Pacific. Most of the Parks are built in economically developed countries due to the interest of governments in implementing local strategic plans. Almost 80 percent of the countries mentioned in the report programmed to allocate specialized zones, containing STPs, as a part of their industrial policy in twenty-first century. [15]

4. **Science and Technology Park Development**

After the idea of STP was realized and developed, the STP grew towards the following goals: First, the goal of research and innovation for the continuity of science. Second, the goal of community service, which will be on two levels: The first level is the development of individuals and their encouragement of science and innovation through the environment created by the STP. While the second level is industry, in order to meet the needs of society and access to luxury. The third goal is the economy that leads to the provision of capital by marketing research products to increase the wealth of society. It is also linked to the industrial goal and is achieved through the development of industry and its use in...
society. And these goals are the axes linked to each other. STP has grown towards these goals, and with this, function and facilities are established.

![Figure 7. Axis of STP development (Authors).](image)

### 4.1 The First Axis: Innovation
STP provides an environment for innovation that starts with innovative resources, becomes output and ends with marketing [10]. Collaboration networks located in STP are key elements in building an innovation environment. Also, cooperation between research groups is one of most important factors affecting the performance of research projects and provides for the use and exchange of knowledge and various points of view, which contributes to improving their performance. Thus, an atmosphere of complementarity will be achieved for all cooperating research entities [16]. Thus, this fully confirms the importance of physical proximity and interaction in a stimulating and innovative environment. [9]

### 4.2 The Second Axis: Society
The society's need for innovative research and the presence of talent to create knowledge and generate new innovations in society are effective social elements of the scientific innovation process [9]. The quadruple helix also illustrates the important role of society. The focus of community service is based on two levels, one of which is the industrial level and the other is the development of community members towards research and innovation. One of the goals of the STP is to work on developing individuals who are not researchers in an innovative environment that encourages education, stimulates creativity and opens minds through creative spaces, programs, and a variety of methods. As well as scientific exhibitions, training courses and various scientific competitions. In addition, the policy of the STP includes respect for the rights of inventors and scientists. They enjoy full intellectual property rights for patents and the rights remain reserved to them even if they leave the STP [7].

### 4.3 The Third Axis: Capital and Economy
According to Luger and Goldstein (1991), STP can be seen as centers of growth leading to economic development [17]. The STP have major economic impacts, according to an Iowa University RP (2003) economic impact report, the park has an industrial output of nearly $88 million. Also The University of Maryland reported a total budget of $ 1.3 billion for 2017. The presence of STP stimulates the urban community and the surrounding areas will be affected economically. Because it will have a noticeable impact on the development of nearby neighborhood. STP play a role in developing and diversifying the cities tech industry base [3].

### 5. STP Activities and Functions
The functional concept of STP is new to architecture. And as previously mentioned, it began to develop in the fifties of the twentieth century, and over time, the following activities took shape:
Stimulating and managing the flow of knowledge and technology between universities and industry, i.e. by transferring knowledge from its sources to companies.

Start-up support and guidance programs to convert innovative ideas into a marketable product (for innovators and startups) through a set of programs and grants designed to encourage innovation and development.

Exporting technology outside the STP.

Creating an ecosystem to incubate large technology-based companies that are opportunities for development, networking and cooperation.

Providing good office space and the possibility to take advantage of developed facilities and laboratories with all services.

Educational and training programs and workshops, local and international courses, seminars and conferences.

Scientific, financial and economic advisory services and schedule studies.

Opportunities to attract investors.

Enhancing opportunities for communication and cooperation with researchers, inventors, scientists, universities, companies and investors.

5.1 Determination of the STP site location

It is considered a strategic stage of the project. It is distinguished in terms of its quality and symbolism by the extent to which a visual, efficient and fully integrated process is achieved with city functions as a special economic zone [12]. STP are usually found on the outskirts of the city and far from the traditional polluting places of industry. The STP is often found next to universities and prestigious research institutes, and it must have innumerable links with the city. Note that the permanent development of technology may be affected by the master plan of the city. [17] Being in calm and scenic environments is another spatial feature of the STP, which hosts a group of researchers and experts. Because of the accuracy and sensitivity of work, the need for calm doubles. The choice of site location is linked to many factors, government policy, technology development policy, proximity to educational and research institutions, and knowledge base company [18].

Proximity to the knowledge base: The geographical proximity of the university and R&D center is an important requirement and provides strong links between tenants and knowledge institutions, which will enhance further interaction and synergy in research exchange. Some STP are being developed on university campuses to benefit from their services. The proximity between teachers and the technology based company will also enhance its activity, which leads to the creation of job opportunities. [12].

Accessibility: One of the important factors in choosing the site is its suitability for the place in relation to the main roads and highways, easy access to the entrances and exits of the city, the airport, as well as the railways and the main artery of the city. Speed and transportation facilities are important in a knowledge economy.

Clarity: Clarity to the site helps to effectively promote the STP, especially when it is close to a main road. The interest in the site of the STP is an important matter as it must be clearly visible within the urban area as well as it must have a direct connection with the capital.

Area: The area must be large enough to ensure growth needs. When it is considered a good site, the desire of technology companies increases more rapidly than growth expectations. The establishment of the STP must be subject to an economic development plan that defines the areas of activity and use.

Scenery design capability: STP feature beautiful landscapes, making them pleasant places to work. So the place designated for it should be large enough. consideration should be taken to create favorable working places such as rooftop terraces, parks in case of limited area availability .in addition sports and leisure facilities. [12].

5.2 Functional Components
These activities are translated into the following spaces:

First: A relatively large site with privacy within or close to a university or in an urban area connected with one or more universities and industrial companies.

Second: The site includes large open spaces that provide a distinct environment and include:

1. Specialized research spaces: The incubator center and research centers, which are the main architectural component and provide work spaces for researchers with work facilities, equipped laboratories, and other requirements.

2. Spaces to display inventions and innovative ideas.

3. Educational spaces for holding training courses and workshops.

4. Sports and entertainment spaces for researchers and workers and the provision of residential spaces (this is not the basic requirements if the Parks are within cities).

5. Other creative spaces for adults and children.

### Table 1. STP facilities and components (Authors).

| Activates | Facilities | Function |
|-----------|------------|----------|
| Administrative building & public facilities & activates | Administrative building | A building for formal and informal interaction, an environment in which planned for innovation proposes, different types of spaces for co working and individual activity |
| Conference center and meeting rooms | Hub | |
| exhibition pavilions | Scientific exhibitions and trade fairs to display products to attract investors and marketing |
| Museum | To show the technology that the STP has reached & to inspire the creators |
| medical Center | |
| Banking offices | |
| hotels | It is not a basic requirement / but according to STP location |
| residential zone | |
| Research & development specialized facilities & activities | R&D centers | |
| laboratories | |
| Incubator center | To accelerating the establishment and growth of promising tech start-ups |
| Innovation center | To accelerate the pace of innovation and technology |
| Library Specialized | |
| Offices& workshops | |
| Private R&D activities & industrial facilities | Multi occupancy building | Rent an office or floor in the building after passing the incubator stage |
| Buildings or land for rent | Renting an entire building or plot of land by the independent company |
| Workshops | For light industrial purpose |
| Open spaces | Green space, sports centers, restaurant & café |

### 6. Case studies

Two case studies were selected: Stanford Research Park as an example of the first established park, and Qatar Science & Technology Park as an example of a local modern STP.
Table 2. Case studies, Authors based on [19,20].

| Case study                  | Foundation  | Established by         | Area          | Major Area Established by foundation | Companies No. | Employees No. |
|-----------------------------|-------------|------------------------|---------------|---------------------------------------|---------------|--------------|
| Stanford research park      | 1951        | Stanford university    | 3.11 km²      | It, electronic, Biotechnology, Hardware and Software, Aerospace | over 150      | 23000        |
| Qatar Science & Technology park | 2010        | Qatar foundation       | 91.27 hectares| Energy, Environment, Health & Pharmaceuticals, ICT & Communication | 20            |              |

6.1 Stanford research park
SRP is located in the center of Silicon Valley’s business community and it considered the main axis of Silicon Valley formation & development.

The SRP expanded from 0.845 km² in 1953 to 3.11 km² in 2016. Stanford University leased its lands to industrial tech. companies with contracts that extend to 99 years. That has been done with the necessity to preserve its reputation on the condition that the company construct its buildings based on planning and design standards approved by the university [19], such as the proportions of built spaces, heights and green spaces.

The Site Location features:
• Located in the south of San Francisco Bay area stunning nature and large economic activity
• Stanford University’s just 2 miles away
• more than 3 airports around. The nearest one is 11 min/car away.
• It is located on the highway linking cities
• Surrounded by research centres and technology companies
Main movement pattern in master plan:
• The SRP is punctuated by a major movement linking the components of the SRP with each other and with the outside, then linked to highways and main roads of the city.
• The public transport lines pass through the SRP.

SRP is considered as a model of the first generation of STP, which is known as mostly real estate project, although it is based on scientific and technological basis. It is noted that the master plan of SRP was limited to allocating lands for companies and does not include other components such as shared public spaces for interaction between researchers.

6.2 Qatar Science & Technology Park
QSTP is within Qatar Foundation Research, Development and Innovation (QF RDI).
The master plan for QSTP includes 124 hectares of land that integrates with the Education City. The QSTP is located in the main green backbone from north to south, which connects the campus with the courtyards and other spaces in the Education City.

The Site Location features:
- Located in Qatar Foundation’s Education City
- Hamad international airport is 25km, 20 min/car far away.
- It is located on the main road that leads to the city center.

Master plan facilities:
- Incubator Centre 12,000m², including administrative hub and Business Centre.
- Innovation Centre (IC) 3,000m²: offices and inclusive facilities.
- Two tech building 12,000m²: accommodation, offices, laboratories, workshops for companies needing up to 500m² for R&D and commercialization.
- Tenant building 20,000m² each.
- Contemporary architecture suited to desert climate. It provides a landscape environment for pedestrian under the shade of the structure that connects the building to each other and allows free movement between activity axes in building spaces. Green scenery with the sound of water.
As shown in the master plan fig (12), the STP includes administrative buildings, incubator centre and innovation centres, surrounded by rental spaces of buildings and lands, and there are open green internal and external public spaces designed for formal and informal interaction. QSTP is an example of the third generation of STP that have been focusing on the principles of place making and creating attractive environments that stimulate innovation, as well as adding components inherited from the second generation (1990s).

7. Conclusion
By comparing the two study cases through the architectural development of STP, we observed that STP differ today from the model that was adopted in the 1950s. Most of the early STP were viewed as real estate development projects as in the SRP where lands were leased to technology companies to build them according to planning and design criteria for the university. As for the contemporary STPs, of the third generation, focus on place-making principles, built environment and spaces that stimulate creativity. Also it concentrates on architectural components, such as incubator and innovation centres inherited from the second generation that enhance the growth and sustainability of STPs.

The high increase in the number of STP in the world confirms their importance and role. Thus STP projects must be taken into consideration when updating the masterplans of cities and universities. We recommend that Iraqi universities start moving in this direction to ensure development.

We can finally conclude that Science and Technology park are both urban and Architectural new complex function which provide best environment physically and system wise to encourage scientific research and orient it towards the benefit of society, in the same time of encourage the society to initiate innovation ideas and project.

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