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1995

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citation for published version (APA)

van Geenhuizen, M., & Nijkamp, P. (1995). *Technology transfer: how to remove obstacles in advancing employment growth*. (Research Memorandum; No. 1995-28). Faculty of Economics and Business Administration, Vrije Universiteit Amsterdam.

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Serie Research Memoranda

Technology Transfer:

How to Remove Obstacles in Advancing Employment Growth

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Research Memorandum 1995-28

vrije Universiteit *amsterdam*



**TECHNOLOGY TRANSFER:
HOW TO REMOVE OBSTACLES IN ADVANCING EMPLOYMENT GROWTH**

**Marina van Geenhuizen
Peter Nijkamp**

Research Memorandum 1995 - 28

**TECHNOLOGY TRANSFER:
HOW TO REMOVE OBSTACLES IN ADVANCING EMPLOYMENT GROWTH**

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July 1995

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Paper for the seminar “Innovation and **restructuring** as a challenge for regional development policy”, Warsaw, 14-17 September 1995.

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ABSTRACT

It has become increasingly evident that technology is a **major determinant of the** competitiveness of cities and regions nowadays. The availability of new technology essentially reduces the amount of uncertainty with which **companies** deal in their daily operations. In addition, new technology is a basis for the establishment of new **companies** and the restructuring of old **ones**. It therefore, **may** essentially **influence** the development direction of urban and regional **economies**.

First, this paper **will discuss** a communication approach to technology transfer. This approach pays attention to barriers and the removing of barriers in communication **processes** underlying technology transfer (Section 2). Next, in an empirical part, the paper **will** focus on experiences in technology transfer through **academic** transfer institutes (Section 3) and science parks (Section 4). This analysis is **based** on a blend of empirical studies in Europe and the United States. The paper **will** conclude with an examination of practical issues concerning obstacles to technology transfer (Section 5). To this purpose it **provides** an evaluation **framework** for the assessment of potential **success** of new science parks, namely by **means** of the so-called 'Pentagon of Concerns'. It **will** be **discussed how** this evaluation framework **can** be operationalized by **means** of multi-criteria analysis.

1. Introduction

Europe is currently facing an unprecedented disappearance of **many** man-made political borders. Whereas the European Union is undertaking further steps towards its integration, Eastern Europe is going **through** a process of transformation in which **closer** linkages are being sought with nations of the European Union. Whether these **developments** lead to an open society for the **benefit** of **all** actors involved remains, **however**, to be seen.

Vanishing borders **mean** the opening of regional economies to new networks and new **social** and **economic** influences, introducing particularly an increased competition between regions and between cities (cf. Cheshire and **Gordon** 1995). **Such** a competition creating win-lose situations, **may** imply the increase of regional disparities in **employment** levels and welfare. High levels of unemployment are apparent in **all** large cities in Western and Eastern Europe, but it is particularly evident in countries facing an **economic** transformation which **causes specific** industries to close down. The **latter** process is not **sufficiently** compensated by the establishment of new activities, leading to a net loss of jobs (Gorzalak et al. 1994; **Jackson** et al. 1995). Unemployment in Eastern Europe is of great concern, particularly because it strongly **affects** young people (Kabaj 1995). In the most worse scenario for European regions, the opening of regional economies leads to the emergence of a 'Golden Curtain', dividing the **rich** West from the poor East (Gibb and Michalak 1994).

It is increasingly realized that the actual **competitive** advantage of city regions in the European Union is brought about by the local presence of science and technology, particularly in research laboratories and enterprises (**Hingel** 1993). Both in Western and Eastern Europe, the **economic** base of cities is being transformed **from** commodity-based activities in the production sector to knowledge-based activities in the knowledge sector (or broadly, the service-sector). Science therefore, should be regarded and treated by urban planners and politicians as a source of **economic** power (Knight 1994). **Accordingly**, it is a major challenge for European cities to formulate **policies** for enhancing and valorizing their knowledge cultures and transforming knowledge into local **economic** development.

The current 'national systems of innovation' in Eastern Europe are still **very**

much influenced by the peculiar features of the communist past (Freeman 1994). First, there was a relative weakness of R and D and **innovation** on the **enterprise level**. Innovation and R and D were traditionally found in **branch level institutes**. A **second** feature was the relatively large contribution of the 'Academy' system to **basic and applied** research. Consequently, there were no strong links between knowledge **sources and enterprises**. A third factor was the **almost** entire isolation from the world **economy** and Western technology sources for decades. Nowadays, the university and its new **generation** of young engineers and scientists form the greatest hope for the future development of technology and innovation in Eastern Europe (Freeman 1994).

It has become increasingly evident that R and D in the European Union is strongly **concentrated** in a few 'islands' in **each** country. Research laboratories and **enterprises** in these few 'islands' work intensively together in highly **exclusive** networks (Hilpert 1992; Hingel 1993). Due to a long history of separation, R and D 'islands' in the European **Union** are not **very well** linked up with Eastern Europe. What **makes** this situation worse nowadays is that **financial** limitations prevent Eastern European scholars from participating in international research networks (Dyker 1994).

Fast-growing 'high tech' regions have increasingly attracted attention from policy makers and planners as models of industrial revitalization. By **means** of promoting links between universities and industry, and establishing science parks and incubation **centres** **many** planners have sought to replicate the **success** of these regions. Northern **California's Silicon Valley** and Boston's Route 128 are the most celebrated examples of **such** regions (Saxenian 1994).

This paper **will** investigate the potential role of universities and other research institutes in the commercialization of technology and concomitant employment growth. To this purpose it **will first discuss** a communication approach to the analysis of technology networking in the next **section**.

2. A Communication Approach

Technology transfer **can** be **defined** as bringing technology to market. A relatively new approach regards technology transfer as a **specific process** of **communi-**

cation, subject to various types of barriers (cf. Williams and Gibson 1990). In an actor-oriented communication approach, one **can** distinguish senders and receivers of **information**. Communication encompasses the following stages (cf. Ouwersloot 1994; Kamann 1993):

information: selection of **message** by **sender**

representation: production of a signal that uses a certain **coding** and vehicle of communication

transfer of the signal

interpretation: decoding of the signal into a **message** by the receiver

reception of the **message** by the destination.

It **needs** to be emphasized that the above linear model is a simple one. In reality, communication is **often** an **interactive process** including various feed-back loops between receiver and **sender**. In this respect, communication **can also** be conceived of in terms of **convergence**, in which senders and receivers communicate interactively with the purpose of reaching a particular **convergence** point **where** both agree (Rogers and Kincaid 1981).

In communication on technology different vehicles **may** be used (Dosi 1988; Geenhuizen 1994), namely:

human capital (this concerns ideas, expertise, **skills** and routines residing in employees and managers)

- **written** language (e.g. data files, manuals, specifications, **scientific** journals)
- **oral** language (**on-site** instruction, audio representation, etc.)
- hardware (**such** as **devices**, equipment, materials)
- **tacit** or visual representation (transfer by observing, doing and imaging).

Communication is subject to influences that **may** prohibit a smooth flow of information. Barriers to communication are indicated by discontinuities in the intensity of information flows in **time** and **space**. **Such** barriers have a widely different **origin**, dependent **upon** the perspective used **such** as spatial interaction (networking), innovation

diffusion, and particularly communication (cf. **Brown** 1981; **Davies** 1979; **Geenhuizen** 1994; **Kamann** 1994; **Nijkamp et al.** 1990; **Suarez-Villa et al.** 1992; **Williams and Gibson** 1990). Analytically, a distinction **can** be made between the **nature** of the **tech-** nology itself, characteristics of senders and receivers as actors in communication, **institu-** tional **factors**, and **time** and space (Table 1). Some barriers **are inherent** in the **nature** of communication and networking. A common example of this type of barriers is the general **inertia** of networks, in view of extension with new **participants** (cf. **Håkansson** 1988). Barriers **may also** be **imposed**, for example, in order to **protect** information (sources) against **access** (**first** stage of communication). In the following part of this **section**, we **will discuss** a few important barriers in more detail.

Barriers in the **first** stages **may** follow on from low skill levels of senders and receivers, for example, with **regard** to the identification of communication **needs** and supply, and image **building** toward potential communication partners. In addition, the **nature** of the technology itself **may well contribute** to friction in communication. In innovation diffusion theory, it is emphasized that the **higher** the complexity and **cost**, the more **time** it takes before the technology has reached **all** potential adopters.

A **further** important source of barriers is the institutional framework, evident in certain **law** and regulatory regimes. One particular aim of barriers in this respect is the protection of information for **economic** reasons. For example, patent protection prevents dissemination and use of technical information in order to guarantee **the patent holder** an **exclusive** use of **the** technology for a certain period. Further barriers to communication have a socio-cultural background and affect both **senders** and **receivers**. Language is far the most important barrier here, preventing an adequate **coding**, decoding, and reception of messages. Language barriers include spoken, **written** and computer language, as **well** as the vocabulary used in communication. Vocabulary **barriers may** follow from different development stages of the technology involved (**basic** and applied), and **from** different organizational cultures of senders and receivers (**Kamann** 1994; **Williams and Gibson** 1990).

Many researchers have chronicled the **influence** of geographical space (see **Charles and Howells** 1992), both at the **micro-scale** (within a building, on a **site**) and the **meso-** and macro-scales. Within this framework, spatial isolation over a long **time** is regarded as a common source of socio-cultural barriers, reflected in different **dialects**,

lower educational levels, and different ways of 'doing things' . In recent **times many** spatial barriers have lost their **importance**, but the concomitant socio-cultural barriers still **persist** on their original level.

To conclude, a large variety of potential barriers **may hamper** communication. Among them socio-cultural barriers seem to have increased in **importance** (cf. Gertler 1993; Lundvall 1988).

Table 1 Influences on communication with regard to technology transfer

Technology	Type of vehicle (medium) used Cost of technology Complexity of technology (Perceived) benefit of technology (profits , competitiveness)
Sender	Skill to identify demand Marketing and image building skills Skill to code message and to use information vehicles and media Organizational culture and vocabulary
Receiver	Receptiveness to information (demand) Skill to identify supply Skill to build the appropriate image Skill to use information vehicles (media) and to decode signals Organizational culture and vocabulary Capacity to take risks (through size , corporate position)
Institutional Framework	Market (de)regulation Trade system and fiscal tariffs Secrecy and intellectual property protection Systems of standardization and certification of products
Space	Culture and language Political borders and bridges Natural barriers and bridges Spatial communication networks Network capacity Physical distance City-size distribution
Time	Network capacity Time zones

We now turn to an exploration of intermediary institutes which aim to bridge barriers in technology transfer between universities and the business world.

3. **University Transfer Institutes**

University transfer institutes aim to bring **demand** and **supply** of academic knowledge together, particularly **when** no established relationships are at hand. It **needs** to be emphasized that **many** other forms of transfer **may** occur at the **same time**, such as joint research of **academics** and industry groups.

In the Netherlands, a system of **academic** transfer institutes was **founded** in 1981. In the **first** years, the system has been **fully** subsidized by the **central government**, but **after** 1986 subsidies were decreased and at the end **terminated**. **Since then**, these intermediary institutes took different development paths (Geenhuizen 1994). Some of them focused on the attraction and **legal** establishment of university contract research. Others have kept a broad perspective, **also** paying attention to the **needs** for knowledge among small and medium-sized enterprises (**SMEs**) in the region. Since the late **1980s**, a **second** development was the decrease of the amount of transfer **projects carried out** by transfer institutes. This decrease was associated with the emergence of new types of knowledge sources and intermediaries since the late **1980s**, **such** as transfer agencies of **higher** educational institutes and regionally **based** innovation **centres**.

From the above it **can** be concluded that the concept of academic transfer **centres** in the Netherlands has been subject to different interpretations, whereas **also** the position of these **centres** in the market has **changed**, leading to some loss of activity.

A slightly different intermediary institute is the (American) technology licensing office (**TLO**) (**Parker** and Zilbermann 1993). This institute is specialized in patenting and licensing of **academic** innovations. We **will** now focus the remaining **section** on the **TLO** of **Massachusetts** Institute of Technology (**MIT**) (Cambridge) which is **often** associated **with** a **strong** high-technology development in the Boston Area. To give an indication of the **growth** of **firms** and employment: about a half-dozen new **companies** are formed **around MIT licenses each** year; MIT personnel and technology are involved in around

640 companies located in the **state** of Massachusetts, while these **companies employ** over 200,000 Massachusetts residents (1988) (**Preston 1992**).

The MIT Technology Licensing Office manages the patenting **and licensing** process for MIT and a number of associated **institutes** (**Preston 1992; TLO 1994**). Through the TLO, inventions are brought to market, including activities **such as the** evaluation of invention disclosures, **filing** of patents, and identification of companies interested in licensing. Under licenses companies are granted rights to MIT patents in return for their **commitment** to develop the inventions into **products** for the market. The major work of MIT TLO is to bring inventions, **venture** capitalists and companies **together**, by using highly specialized networks. MIT TLO does not **provide venture** capital itself, nor does it **provide specific** facilities for start-ups **firms**. **Such** facilities are supplied in the market in the Boston area.

Royalties derived from licenses are shared between inventors (one third), central MIT (one third) and the MIT department **where** the invention has taken **place** (one third). This allocation of royalties guarantees a personal reward for the individual inventors involved, which is an important tool in advancing an entrepreneurial spirit at universities.

MIT TLO is staffed with Licensing **Officers**. Most of them have technical **backgrounds** (**often** engineering) and have spent more than ten years in industry, working in product development, marketing **and/or** business development. **Each** of the License **Officers** manages individual inventions **from** beginning to end. This includes **managing** of literature searches, market assessment, decisions on patent **filing**, marketing of the technology to potential licensees, negotiation of license agreements, and **monitoring** of licensee performance.

The **success** of MIT in patenting and licensing in collaboration with local (regional) business depends strongly on the qualification of its Licensing **Officers**. **Through** experience in industry they understand the process of bringing new technology **to market**. In addition, their educational level is **rather** high (Ph.D. or M.B.A, sometimes with **legal backgrounds**). They have **also** developed a strong problem **solving** attitude **and** excellent communication and negotiation skills.

Further success factors of MIT TLO **can** be summarized as follows:

A huge stream of good technology **produced** by MIT scientists, as **well** as an

entrepreneurial spirit in the faculties.

Clear and consistently applied **policies** and **rules** that separate **scientific** (educational) interests from commercial interests.

- Strong support for technology transfer from the **upper** administration of MIT.
- A **simplified** invention disclosure and review **process**, in order to smoothen the path for scientists to submit inventions for patenting.
- Straightforward licensing procedures, without long **lasting** steps and complexity. Most agreements **can** be signed in the Technology Licensing Office without **further** review.

An entrepreneurial climate in the Boston Area which **can generate economies** of **scale** and scope. For example, 'seed investors', **consultants** and **executives**, local incubation sites, '**venture** forums' and related business networking clubs are abundantly available.

The above clearly applies to conditions in the US. Europe **however**, has a different business climate and different attitudes towards business in **academia**, leading to lower **firm** birth **rates** among **academics**.

With **regard** to the business climate one **can** observe the following differences. In the US, **firm** ownership is **much** more **often** shared among a team of people than in Europe. A **small** team offers the advantage of complementary skills, risk sharing and smaller vulnerability (aside **from** the disadvantage of conflicting interests). A **second difference** is concerned with the acceptability of failure. Failure in Europe **may** be a catastrophe in the **career** of a **person**, mainly because of stigmatization. In the US, this is not the case. Instead, starting a new future from scratch **after** failure is socially **very well accepted**.

In view of attitudes in the **academic** world towards business, the following differences need to be mentioned. Close academic - industry links are **much** more popular in the US than in Europe. In Europe, being involved in business as an **academic** has the negative connotation of **having** moved away from 'pure' (**basic**) science. This view is associated with an **absence** of 'role models' in Europe, i.e. examples of **extremely** successful university professors in business. Numerous 'role models' in the US make starting an own business socially more **acceptable** and **attractive** here than in Europe.

Furthermore, in the US it is **much** more common among bright **graduates** or Ph.D.'s to start an own business based **upon** ideas (inventions) developed during study. In Europe, **such academics often** start a **career** with large, established **companies**.

Most of the above discrepancy cannot simply be removed by **means** of policy measures. Various suggestions **can** nevertheless, be given in order to influence the entrepreneurial climate in Europe at universities and **higher** educational institutes (Charles and Howells 1992; Geenhuizen 1994):

Make starting an own business popular in universities, and devote a part of the curriculum to entrepreneurial skills.

Establish new innovation awards and make them **well** known in **academia** and the business world.

Give successful **academic** entrepreneurs strong attention in the media in order to **create** 'role models' .

Develop a package of measures which enables the part-time move of **academics** towards own business without the (immediate) loss of established rights (e.g., pension rights, upward move in the **university** system).

Undertake public (**academic**) initiatives in order to offer a better supportive organization for **academic** spin-off, including the supply of 'incubator blocks', **and** secretarial and management (**legal**) services.

The **latter** suggestion brings our attention to science parks as a local planning tool. Science parks **will** be the subject matter of the next **section**.

4. Science Parks

Science parks are among the most popular **local** (regional) development tools currently in use in Western Europe, the United States and increasingly, Eastern Europe **and** the Pacific Rim. The vast majority of science parks has been established since the early 1980s. **However**, particularly the **ones** that have attracted **much** attention are clearly older, **such** as Stanford (1952) and Research Triangle (1959) in the United States,

and Cambridge in the United **Kingdom** (1972) (cf. Currie 1985; Geenhuizen 1986; Gibb 1985; Luger **and** Goldstein 1989; Schamp 1987). Aside **from** 'euphoria', an increasingly critical view on achieved results of science parks has become evident in the course of **time** (cf. Bozzo et al. 1992; Luger and Goldstein 1991; Massey et al. 1992). This **section will first discuss** the concept of science parks and the variation evident in the **implemen-** tation of this planning tool. Then, attention **will shift** to results of science park **develop-** ment.

Science parks are conceived of here in a narrow sense. By using the United **Kingdom** Science Park Association definition (Dalton 1992), science parks **can** be described as property based initiatives which:

- have formal and operational links with the university (or **higher** education institute)
- are designed to **encourage** the foundation and growth of knowledge-based business
- have a management **function** actively engaged in the transfer of technology and business skills to residents on **site**.

Initiatives to the establishment of science parks are **usually** taken by different actors. Aside **from** universities, one **can** observe participation of local (**regional**) governments and development agencies, and various private actors **such** as **real** estate developers, investment banks, and large **firms** investing in accommodation (laboratories) (Nijkamp et al. 1994). While **such** a multi-actor situation is desirable regarding the need for different **inputs** in the establishment of the science park organization, it has **also** the danger of diverging **interests** and goals. Universities **usually** aim at knowledge transfer for commercial reasons (sometimes by raising money from premises). Image **building** in order to attract excellent students and **staff may** be a **further** aim of **univer-** sities. Local (regional) governments, **however**, are **often** most concerned about **employ-** ment growth, improvement of local images, and increase of the technology level in the area. **Again**, different goals **can** be identified for private actors, **such** as **profit maximiza-** tion, improvement of image toward society, **and access** to technology.

There is a large differentiation between science parks regarding the accomodation

and premises offered. Science parks usually **provide facilities for newly established firms** (eventually **academic spin-off**) by **means** of 'incubator blocks'. **Many of them also provide** premises and buildings for older **firms** in a park-like lay-out. **By means** of 'incubator blocks' conditions are created which **advance the survival of newly established firms, such** as cheap rent, flexible rent **contracts** and flexible **space, and a range of** supportive services, for example, secretarial services, managerial assistance, **and (easy access to) venture capital. After** a few years of residence in 'incubator blocks' surviving **firms** are expected to move into the park or elsewhere in the region.

The type of residents aimed at **may also** be different, witness for example, **academic spin-off, regional companies, and R and D laboratories of multinationals.** Common selection criteria for residents include a high technology character (e.g. evident in the amount of R and D) and relationships with the neighbouring university. The tightness in use of these criteria is **however,** different between science parks.

A **further** differentiation is evident in the location of science parks, for example, in **economic core areas** and peripheral regions. **Such** different locations **may** lead to divergent aims of science parks and different conditions for their growth. Regarding the **latter,** we **mention** a different embedding of science parks in regional-economic policy, differences in **cost** of premises, differences in investment incentives and (European) subsidies on **infrastructure,** and a different **traffic infrastructure.**

Much of the above indicated differentiation is evident in the application of the science park concept in the Netherlands (Table 2). Notable differences are the type of **university** involved (both universities of technology and **general** universities with a focus on humanities), regional location (**both economic core** regions and peripheral **areas**) and **size** of the parks (small-scale 'incubator blocks', as **well** as large-scale developments with a **diversified** accommodation).

There is **also** a remarkable variation in number of **firms** and employment growth **between** Dutch science parks (Table 2). For example, Enschede performs better than Leiden in **view** of number of **firms,** witness 102 in twelve years and 25 in nine years, respectively. Leiden **however,** aimed at the attraction of a few relatively large (foreign) **companies from the** beginning. Regarding their short **time** of **existence,** both Groningen **and** Wageningen **seem** to be relatively **successful** in attracting employment, witness a good 400 jobs in 4 to 5 years. This is strongly in contrast to Nijmegen.

Table 2 Science Parks in the Netherlands (1993)

Town and uni- versity (a)	Region (b)	Starting year	Size (ha)	Firms	Jobs
Enschede (T)	P	1981	18.5	106	1,115
Leiden (G)	C	1984	30	25	640
Groningen (G)	P	1988	60	51	460
Nijmegen (G)	1	1989	1.5	25	100
Wageningen(A)	1	1989	5.5	39	400
Amsterdam (G)	C	1991	20	20	150
Delft (T)	C	1992	30	15	27

a. T = University of Technology, G = **General** University, **A** = **University of Agriculture**.

b. Regional location in the Netherlands: P = Periphery, 1 = Intermediate location, C = Core (Randstad).

Source: Adapted from **Bartels and Wolff (1993)**, p. 1039.

In **general**, the picture seems to be that the **pace** of employment growth on **site** is **quite** slow in the early years (Moore and Spiers 1986). Indirect employment effects **may** follow on **from** local forward and backward linkages, and various multiplier effects in the region. And again, **evidence** suggests that **much time** is needed before a system of local and regional linkages is **well** developed. The **time profile** is **thus** one of decades **rather** than years before self **sustaining** growth on a significant **scale** occurs.

When considering impacts of science parks, various methodological issues arise. These issues **will** be **discussed** in the next **section**.

5. Evaluation of Science Park Developments

There are **many** reasons why ex *post* **success** of science parks cannot be **assessed** without **difficulties** (Geenhuizen 1994; Luger 1992). These **difficulties** are associated

with the following circumstances:

different external **influences** on science park growth, **such** as macro-economic conditions and military spending programs in the area (cf. Saxenian 1994);
lack of reference values in view of various stages of park growth and **lack** of consensus about **such** values among different actors;
 shortage of required data;
 problem of counterfactuality.

An important factor that **hampers** the evaluation of success is the normative **nature** of success, implying the availability of reference **values (standards)**. A **standard** growth trajectory of science parks **has** not yet been **defined, mainly** because of an expected differentiation between the development stages of science parks (Luger 1992). It seems to be that success must be measured in different ways over these stages. In addition, due to the multiple **actor (objective)** situation consensus about the **definition** of success is **often** absent. **Success can** be measured in terms of networks established on **site** (cf. Longhi and Quere 1993), new **processes and products** created in the region, direct and indirect employment growth, etc.

A **further** important methodological problem in the ex *post* measurement of success is counterfactuality. This problem follows on from the **fact** that 'outcomes' are observed in situations **where** parks exist. The question then is what would have happened in the region without the park (zero case). A proper solution would be a quasi-experimental approach, in which **control** groups and pre- and post-test observation are used similar to classical experiments in medical science (cf. Luger 1992). A **further** solution would be the use of in-depth, quantitative case studies in order to estimate indirect **effects**, following **from** induced start-ups and migration **from** the park, and from multiplier **effects**.

When we **come** to a summary of **findings** from various ex *post* evaluation studies (**with** previously mentioned shortcomings), the conclusion **sofar** is not unambiguous. It **tends** to **an avoidance** of high expectations about outcomes, be it in terms of **employment**, new **firm formation**, synergies between **academics** and business, or local **technology** transfer (Bozzo et al. 1992). **However**, the performance of science parks seems to

improve over **time**.

In the remaining **section** we **will discuss** an ex *ante* evaluation framework for science parks initiatives, based **upon** practical experience listed in the literature (cf. Bolis et al. 1994; Bozzo et al. 1992; Geenhuizen 1986, 1994; Gibb 1985; Luger and Goldstein 1991; Massey et al. 1992; Nijkamp et al. 1994; Premus 1986; **Preston** 1992; Segal et al. 1985). The evaluation aims at a **comparative** analysis of alternative plans with a **ranking** of plans as the end-result. The analysis is multi-dimensional in **nature** by using various different evaluation criteria.

The evaluation criteria rest on the so-called Pentagon model, representing the **decisive** factors in regional development in a **competitive** network **economy**. **Accordingly**, the success of **winning** regions depends in particular on the following classes of factors:

hardware, such as a good transport and communication system, and availability of land;

software, such as particular qualities of the labour force (highly skilled, **dedicated**), local population (entrepreneurial spirit) and output **markets**;

orgware, such as supportive services, and government **policies** favouring entrepreneurship and favouring knowledge as a resource;

ecoware, for example, in terms of residential and cultural amenities, and creativity networks;

finware, such as various forms of loans and **venture capital**.

The most important critical success factors in science park development are consistent with the above classes of the Pentagon model. The factors include the science park (university) itself and the region of location as follows:

1. A science park design which is **attractive** and which is consistent with apparent **demand** (hardware).
2. A region with a population **receptive** to technical progress and with a **sufficiently** developed knowledge **infrastructure** (software).
3. A university with large potentials for commercialization and an **active** **identifi-**

cation (activation) of these potentials (orgware).

4. Contractual arrangements at the university enabling a part-time shift of staff to business (orgware).
5. Easy access for start-ups to supporting services (orgware).
6. Excellent science parks managers (particular in communication) (orgware).
7. A region (city) **well** endowed with high quality residential amenities (ecoware).
8. Easy access for start-ups to **venture** capital (finware).
9. Low **needs** for a profitable exploitation of the park during the first years (finware).

The above factors **indicate** the vital role of particularly orgware in science park development. In addition, **many** factors are associated with conditions for **communication** and networking.

Next step in the operationalization of the evaluation framework is to find valid indicators for the above factors. Various suggestions for operational variables are given in Annex 1, but it **needs** to be emphasized that there is a problem of data availability. Data problems **may** be solved by **means** of assessment by researchers and (for particular cases) by experts. In addition, the measurement level of the variables **may** be different, for example, binary, ordinal and cardinal. **Such** a situation **can however**, be handled in particular designs of multi-criteria analysis (MCA) (Nijkamp et al. 1990).

Multi-criteria techniques enable to **evaluate** a discrete number of alternative options (plans), by **means** of explicitly formulated criteria. It allows for a different weighting of scores on these criteria, dependent **upon** the **scientific relevance** and interests of various actors in the planning **process**. It **needs** to be emphasized **that** MCA is only a supportive tool aimed at **making** new information available to the **benefit** of decision makers.

The use of MCA in the evaluation of science parks is not entirely new. Some interesting experiences have recently been achieved in a cross-national **comparative** study of various high-technology developments (**Bolis** et al. 1994). The results of this evaluation are summarized in Annex 2.

Many issues in science park growth are not **clear** yet because a short **time** of

existence has prevented a thorough investigation. **Time** is now coming that research **can** be done in a **systematic** way, for example, by **means** of ex *post* **quasi-experimentation** and by using the results as an input to ex *ante* evaluation for new science park plans.

6. Concluding Remarks

Universities are major sources of inventions that **can** be commercialized and concomitantly, **contribute** to **economic** growth. The **process** of bringing inventions to market is **however**, fraught with **many** obstacles. This paper has discussed the way in which patented technology is brought to market by Massachusetts Institute of Technology (MIT) in the Boston area. A striking feature of MIT is its strongly developed network which involves **all crucial** actors in technology transfer, namely scientists, **companies** and **venture** capitalists. Whether the model of MIT **can** be replicated elsewhere is dependent **upon** the local (regional) entrepreneurial culture and industrial networks. Therefore, a wise **policy** in advancing technology transfer would be to give attention first to local barriers. A **second** step would then be to adopt **selected success** features from the MIT model which clearly fit local **circumstances**.

Science and technology **can** no **longer** be neglected by local **planners** as a major source of competition in a knowledge-based **economy**. Within this framework, the paper has focused on university science parks as a local planning tool. It has become evident that expectations on employment should be modest, at least for the first years. **However**, carefully planned science **parks** embedded in a comprehensive knowledge policy, **may** have good outlooks for growth. This paper has discussed a preliminary set of **success factors** in **such** a careful planning. There is, **however**, a need for a more elaborate analysis which should be achieved in the near future following the maturation of large numbers of science parks.

Acknowledgement

This analysis has benefited from interviews with Mr. L. de Lange (General Manager of Zemike Science Park in Groningen (NL)), and Dr. Christa **Jensen** (License **Officer** at MIT TLO) and John **Preston** MBA (**Director** of Technology Development at MIT, Cambridge US).

Annex 1 **Operational variables in MCA of science parks**

Hardware

1. type of science park design (layout); realistic match between accomodation (buildings) and **demand** based on a feasibility study .

Software

2. share of skilled technicians in economically **active** population; share of pupils selecting beta **subjects** in secondary school; number of research institutes and R and D departments per 1000 firms in the region.

Orgware

3. number of patent applications per 1000 university researchers; cornrnunication between science park **officers** and research departments about inventions to be expected .
4. package of (**legal**) arrangements concerning pension rights, insurance, upward promotion in university, etc.
5. service package including secretarial, **legal**, management (business plan) and marketing support.
6. science parks managers excellent in personal cornmittment, cornmunication and networking, and problem-solving .

Ecoware

7. share of medium and high segment in housing stock; amount of green area in living quarters; intemational schools, etc.

Finware

8. number of **venture** capital firms per 1000 firms in the region; **access** to **venture** capital firms via the science park.
9. a **financing structure** of the park that avoids the need for a profitable **exploita-tion** during the **first** years.

Annex 2 Summary of 'Knowledge Transfer and Science Parks' (Bolk et al. 1994)

This study aims at a cross-national ranking of **selected** high-technology **developments** in various countries. The evaluation is based **upon** eight criteria as follows:

1. university propulsive role (existing/non-existing);
2. promoting **actor**, regarding type (public/private) and spatial framework (e.g. **local - national**);
3. origin in the region, e.g. a new development (city of science) or an old pole;
4. connection with universities (existing/non-existing);
5. developed sectors on **site** (high-, medium- and low technology);
6. intermediary between university and business world (existing/non-existing);
7. type of funding sources for start-ups (**public/private**);
8. type of funds for technology policy (**public/private**).

An interesting methodological aspect of the evaluation is the use of different scores (for the same criteria) in two tests (t1 and t2) and different weights (for the same scores) in two **scenarios** (s1 and s2), leading to four rankings. The aim of this approach is to test the sensitivity of the ranking to priorities given to 'knowledge transfer support factors' and 'financial factors'. The four rankings are:

	t1-s1	t1-s2	t2-s1	t2-s2
Cambridge (UK)	1	2	1	2
TP Milano	2	7	3	7
RA Trieste	3	4	2	4
BIG Berlin	4	10	4	10
Sophia Antipolis	5	3	5	3
TP Plan Japan	6	1	6	1
Heriot Watt Edinburgh	7	12	7	12
TP Bari	8	5	8	5
Stanford California	9	16	9	16
TIP Berlin	10	14	10	14
Rhone Alpes France	11	11	11	11
Aston Birmingham	12	6	12	6
Route 128 Boston	13	8	13	8
Montpellier France	14	9	15	9
STP Torino	15	13	14	13
Research Triangle	16	15	16	15

The rankings **indicate** a different role for 'knowledge support factors' (emphasis in scenario 1) compared with 'financial factors' (emphasis in scenario 2). **However**, the rankings in the two **scenarios** are certainly not **reverse**, witness a certain overlap between developments (parks) with a low ranking and the **ones** with a high ranking.

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