"Heidelberg City of Science"
Analyses and strategies

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1 Introduction – Challenges of a knowledge society and a knowledge economy for cities

The initial thesis of this strategy paper is: The economic future of the city of Heidelberg lies predominantly in its diverse functions as an internationally renowned City of Science. Leading national or international scientific institutions, world-renowned hospitals, research-intensive and innovative enterprises, and a highly qualified workforce will be the key to Heidelberg's sustainable development and international competitiveness.

The establishment of the IBA (*Internationale Bauausstellung* – International Building Exhibition), along with many more initiatives by the city, shows that a "knowledge-oriented urban development" is one of the strategic goals of urban policy. In order to implement this model of urban development, conditions for cutting-edge research, which help Heidelberg stay attractive to the best scientists and be competitive with international Cities of Science in the future too, must be created or maintained. The emphasis on cutting-edge research is deliberate. Without this cutting-edge research and its excellent hospitals, Heidelberg would not stand out from hundreds of other university towns or scientific locations in Germany, and, thus, would lose one of its most critical unique characteristics.

However, Heidelberg should also pursue a strategy to ensure it has above-average competences or highly qualified decision-makers in areas other than science, i.e., in as many economic, cultural, and social areas as possible. This because a knowledge advantage (over time), high-level qualifications, and international experience and networks are the best insurance against the uncertainties of the future and increase the likelihood that future megatrends, opportunities, and risks can be detected *early enough* as to avoid costly mistakes.

The IBA catchphrase is deliberately "**Knowledge | Based | Urbanism**" and not "Science | Based | Urbanism". The sciences are by far the major driving force, but the significance of the ensuing analyses and findings must be recognized by political and economic decision-makers, and be implemented accordingly. The IBA catchphrase could also be reversed and would then read: "Ignorance and incompetence of crucial decision-makers cause huge financial losses and compromise the sustainability of a city." Nothing is as costly to an organization, business or city, and so severely inhibits its development, as mistakes due to the inadequate qualifications and skills of crucial decision-makers. Theoretically, Cities of Science have the advantage of direct local access to the best technical expertise, the latest scientific findings, and global networks in various sectors. In practice, however, this potential is exploited all too rarely.

A glance back at history demonstrates that political power, technological superiority, and economic dominance have always been based on a "**knowledge advantage**" held by the predominant social systems or territories. That is why there have always been close alliances between knowledge, political power, and economic power for several thousand years now. Cambyses II (558–522 BC) had already established a "center of knowledge" in Babylon, in which the best scholars were gathered to translate then available knowledge into other languages. Many European universities also owe their existence to the political interests of the former territorial overlords. Over the centuries, such centers of knowledge were primarily put in place to consolidate and legitimize the power of the respective political rulers (Meusburger, 2015, p. 19–20). The economic significance of education was recognized as early as the 17th century (e.g., by Philipp Melanchthon). Starting with the second industrial revolution in the latter part of the 19th century, scientific research (especially in chemistry, electrical engineering, mechanical engineering, etc., at that time), technical innovations, and the qualification level of the workforce became the main factors for economic production and competition.

Unlike in traditional industrial society, where new technologies or groundbreaking inventions have established a product life cycle of around 20 to 30 years and, thus, secured a company's or a region's competitiveness for a relatively long time, the product life cycles of new technologies have decreased significantly in a **knowledge society**. Consequently, competitiveness must be repeatedly secured through new scientific findings, new technologies, and a – albeit only short-lived – knowledge advantage.

A knowledge society differs from traditional societies not only in that "knowledge" in the broadest sense – i.e., a highly skilled workforce, professional skills, research, development, and a capacity for innovation – has become the most important production and competitive factor, while other factors such as raw materials, labor, and capital have lost their relative importance. In previous societies only certain elites benefitted from centers of knowledge; in a knowledge society broad sections of the population are in a position to take advantage of the available knowledge and participate in discourses on generating new knowledge (keyword "**citizen science**").

In order to avoid misunderstanding, it should once again be pointed out that it is not just scientific research or advanced technology that is important for a knowledge economy and a knowledge society. Nor should the focus be only on universities or Max Planck institutes, etc., thereby neglecting secondary schools, primary schools, kindergartens or other educational institutions. All levels of education have their own particular features and strengths, are dependent on each other, and should be of a high standard in a City of Science. Therefore, the goal is to strengthen the competitiveness and sustainability of social systems (organizations, institutions, companies) by acquiring high-level qualifications, an early knowledge transfer, and recruiting particularly strong talent in as many economic, cultural, and social areas as possible.

Even companies in the basic economy[1], which cater to the daily needs of the resident population, can only outlive the competition if competent, well-trained, and well-informed decision-makers lead them. This statement may seem trivial, but everyday

1 In the basic economy, one must distinguish between personal services (hairdressers, physiotherapists), whose activities cannot – or only to a small extent – be changed by the vertical division of labor, automation or digitization, and such commercial activities and services in which the trend toward larger units (shopping centers), online retail (travel agencies, hotel reservations, eBay) automation by robots (e.g., warehouse storage), or a greater use of electronics, sensors and laser technology, etc. can no longer be reversed. The earlier decision-makers in the grassroots economy learn about such megatrends and are able to adapt to them, and the greater the expertise they have available to them, the greater their companies' chances for survival.

experience shows that a large number of recently established companies does not make it past the first five years, be it because young entrepreneurs have misjudged their markets, the new technologies they were using were not yet fully developed, the competitors were more qualified, or company founders, due to knowledge gaps, made mistakes that were not financially viable.

The boundaries between economic sectors (occupational groups) in a knowledge society or knowledge economy will have to be much more permeable than they were in a traditional industrial society. Company founders who do not hold a degree, or businesses that previously had nothing to do with science, will have to rely on specialists in computer technology, electronics, robotics, laser technology, optimization and simulation, and geoinformatics, as well as experts in the humanities, the social sciences, and economics for *timely* knowledge acquisition or advice. Compared to 2016, electricians, plumbers, mechanical engineers, or printers in the year 2050 will require different qualifications in order to be economically competitive. They will only acquire a minor part of the skills they will need later on during their professional careers at a vocational school or in an apprenticeship, and they will be required to constantly expand their skills and competences or to adapt to structural changes.

Whenever the significance of science for economic development is discussed in public, most of the time the main focus is erroneously on just the natural and life sciences, or high technologies. Mistakes in politics, management, and the economy, which can result in billions of euro wasted every year, are very often not due to technical shortcomings but rather the result of a lack of knowledge and skills on the part of the stakeholders in the fields of the humanities, the social sciences, and economics. Whoever wants to assert themselves in a globalized economy, and this challenge will increasingly affect small businesses in the future, also requires adequate knowledge of the culture, history, geography, politics and languages of those countries and markets in which they want to succeed. Scientific studies have shown that cultural misunderstandings are among the main causes of the failure of **joint ventures** by German companies in certain countries (e.g., China). Chinese, Japanese, and South Asian studies, the Heidelberg Center for American Studies, geography, ethnology, history and political science at Heidelberg University – to name but a few subjects – have a high level of competence and central networks in the countries concerned. The region's economy could also benefit from this.

Whoever makes far-reaching political decisions on **science and education policy** should know how cutting-edge science and the labor market for highly skilled and low-skilled workers function, and which factors influence the educational attainment of the population. Not only technical expertise but also knowledge of the humanities and the social sciences is indispensable for risk assessment in various sectors too. The processing costs, fines and compensation in the amount of tens of billions of euro, which German automotive companies and banks recently had to shoulder and are expected to continue paying, were largely due to the inability to assess risks, identify correlations and interactions, and estimate possible (unintended) consequences of their own actions, i.e., a lack of skills or knowledge deficits in the humanities, the social sciences, and economics.

The economic reasoning used thus far is indeed quite suitable to convey the benefits of science for the city of Heidelberg to sections of the population with limited scientific knowledge, but the cultural, social and political dimensions of knowledge are just as, or maybe even more, important in the long term.

Despite their very intensive public relations work, the scientific institutions and the city of Heidelberg have not really succeeded in making the existing local knowledge pool from internationally renowned scientific institutions available to the majority of local companies, political and cultural institutions, or committed citizens. This also applies to many other university cities. The so-called “silo mentality” of a fragmented society still dominates in the majority of university cities, and often a city and its scientific community merely “coexist”, rather than directly “cooperate”, with each other. This is no criticism of the city administration or its urban policy, because this “silo mentality” is also pervasive in scientific institutions and, usually, could previously only be overcome when all parties participating in a cooperation or a joint strategic goal had determined it to be a win-win situation (e.g., in the Excellence Initiative).

Thus, keywords are the exchange of ideas, knowledge transfer, interaction, mutual trust, and discourse on a level playing field. A city can benefit from the knowledge pool of its scientific institutions only when firstly, it itself has highly skilled workers in many areas who know what to do with the available knowledge and secondly, there is trust and intensive communication between the relevant political, scientific, and economic decision-makers.[2] Cutting-edge science can then only flourish when the majority of the population and the municipal council understand its issues.

However, the transfer of higher level knowledge from A to B is not as easy as neo-classical economic literature suggests (see Jöns, Meusburger & Heffernan, 2017, for a relevant criticism of older models of communication). This is why mediators and “bridge builders”, who facilitate or make possible this communication process between different groups, are also needed. In addition to the existing, proven platforms such as the “Heidelberg economic talks”, the open days at scientific institutions, the makerspaces, the lunchtime lectures at St. Peter’s Church, the “Medicine in the evening” lecture series, the *Haus der Astronomie* (House of Astronomy), the events organized by the IBA, the “field labs” of the Urban Office, the around two dozen museums of scientific institutions, the numerous public events held by the university, and many other events that have long been offered, even more platforms and discussion groups, which can contribute to improving the knowledge transfer, building mutual trust, and developing joint strategies between the city, the economy, and science, should be created and in part institutionalized. In such a manageable, “small” city as Heidelberg, this should be much easier to achieve than in significantly more anonymous metropolitan areas like Berlin or Munich.

Each city that defines itself as a **City of Science** or strives to become one must answer two critical questions, namely:

- What can various institutions do for their enormous scientific potential to be used more effectively by stakeholders in the local economy, administration, culture, and politics, or for the knowledge transfer between the scientific institutions and the various social stakeholders to be more effective?

- How can the city contribute to ensuring that its renowned scientific institutions maintain their leading international position 50 years from now too?

There are several and, depending on the local situation, different answers to this question. In principle, a City of Science can only successfully develop in the long term and hold it’s own with the fierce international City of Science competition if two basic conditions are met.

2 Since the early 1980s, certain sections of Heidelberg’s city administration have repeatedly benefited from the contributions of environmental physicists, biologists, geographers, geoinformatics specialists, sociologists, psychologists, and representatives of other disciplines to assessments and discussion and planning processes. Interaction and cooperation could still be more intense yet.

- Firstly, the urban population must be aware of: the economic, cultural, and other benefits of the local scientific institutions; the number of primary and secondary jobs, as well as the purchasing power that are created by the scientific institutions;[3] the benefits of the excellent healthcare provided by the hospitals; the extent to which educational and other cultural institutions can benefit from the presence of thousands of scientists and students; and the extent to which the city's international reputation is influenced by the scientific institutions.

- Secondly, the population must be informed on how cutting-edge research works and what it depends on, that internationally renowned top scientists come to Heidelberg and attain above-average achievements, and about what could contribute to top scientists avoiding Heidelberg and favoring another City of Science in the future. If this knowledge is not available to broad sections of the population, a city would not be able to hold it's own in the increasing competition between cities for highly qualified scientists. Without the support of a clear majority of the population, a city cannot become a City of Science; it then remains merely a location of science[4] with an uncertain future.

3 Although numerous studies on the significance of universities for the development of the regional economy have already been published (Bathelt & Schamp, 2002; Blume & Fromm, 1999; Breznitz & Etzkowitz, 2016; DIW econ, 2013; Drucker & Goldstein, 2007; Rosner & Weimann, 2003; Stoetzer & Krähmer, 2007; among others) along with several studies on the significance of scientific institutions for Heidelberg's economy – most recently by Glückler & König (2012), Glückler, Panitz and Wuttke (2013), Töpfer (2013), and ISW (2016) – knowledge of the interrelationships between science and the economy and on the economic impact of expenditures by scientific institutions still needs much improvement in very large parts of Heidelberg's population.

4 The differences between a scientific location and a City of Science are presented in chapter 4.

2 How does cutting-edge research work?

Whoever has followed the public debate – e.g., at town meetings, at municipal and district-council discussions, in letters to the editor, and at events of political parties – about the university, the hospitals, DKFZ (German Cancer Research Center), EMBL, or especially the Neuenheimer Feld complex in Heidelberg in recent years, has to admit that some policy makers, interest groups, and committed citizens still have a considerable deficit in information about how **cutting-edge science**[5] works, its required conditions, the economic, social and cultural benefits of internationally competitive scientific institutions for Heidelberg's population, the benefits to Heidelberg from its hospitals and their leading positions in several areas, and the competition conditions that will be critical for a (future) knowledge-based society.

If these information deficits influence political decisions, there is the risk that conditions for the sciences will deteriorate and that the international competitiveness of Heidelberg as a scientific location will decrease in the medium and long term.

2.1 On the hierarchization of scientific institutions

A frequent mistake in daily political discussion is to only pay attention to the presence of scientific institutions and to overlook the fact that universities have different functions, international reputations, dependencies on local conditions, and location requirements. These differences should not be tabooed, since they have a large economic impact on the respective cities.

There is evidence of a hierarchy or **university ranking** ever since the Middle Ages. It has never been stable for long but has constantly changed in the course of time, be it due to external political influences or due to the internal development of the universities. Taylor, Hoyler and Evans (2010) as well as Hoyler and Taylor (2012) among others present evidence for such changes in the natural sciences (see Fig. 1). Meusburger (2011), Meusburger and Schuch (2010, 2011), Wolgast (1986, 1987), and many other authors analyzed the fluctuations in the development of Heidelberg University's scientific reputation in the course of history. Statistics by the *Deutschen Forschungsgemeinschaft* (German Research Foundation, 2015) demonstrate that there are constant shifts in the German university ranking.

The differentiation and hierarchization of the university system will increase even further, both nationally and internationally. At the top of the pyramid are a few research universities and non-university research institutions that enjoy an excellent, international scientific reputation, have extensive research funds, are able to attract the best talent worldwide, and represent a very important economic locational factor for their university region. At the base are (small) universities that have little research funds, are not able to

5 It is very important to take into account the various functions, levels, and standards of scientific institutions. Internationally renowned scientific institutions have completely different requirements in terms of locational factors and conditions from institutions that are not exposed to the fierce international competition for research funds and world-renowned scientists. This statement should not be misunderstood as a value judgment; rather, it should help avoid political mistakes.

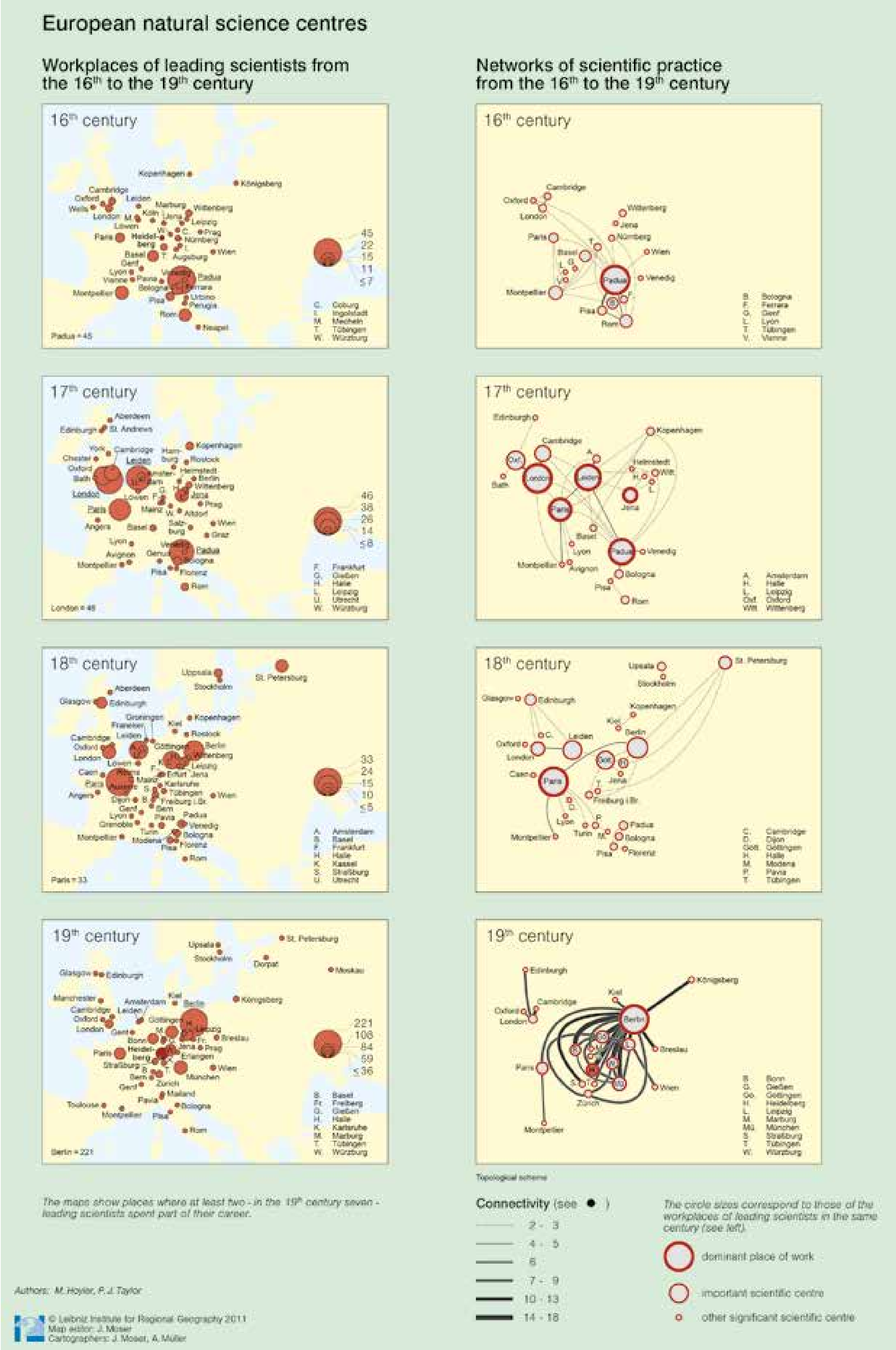
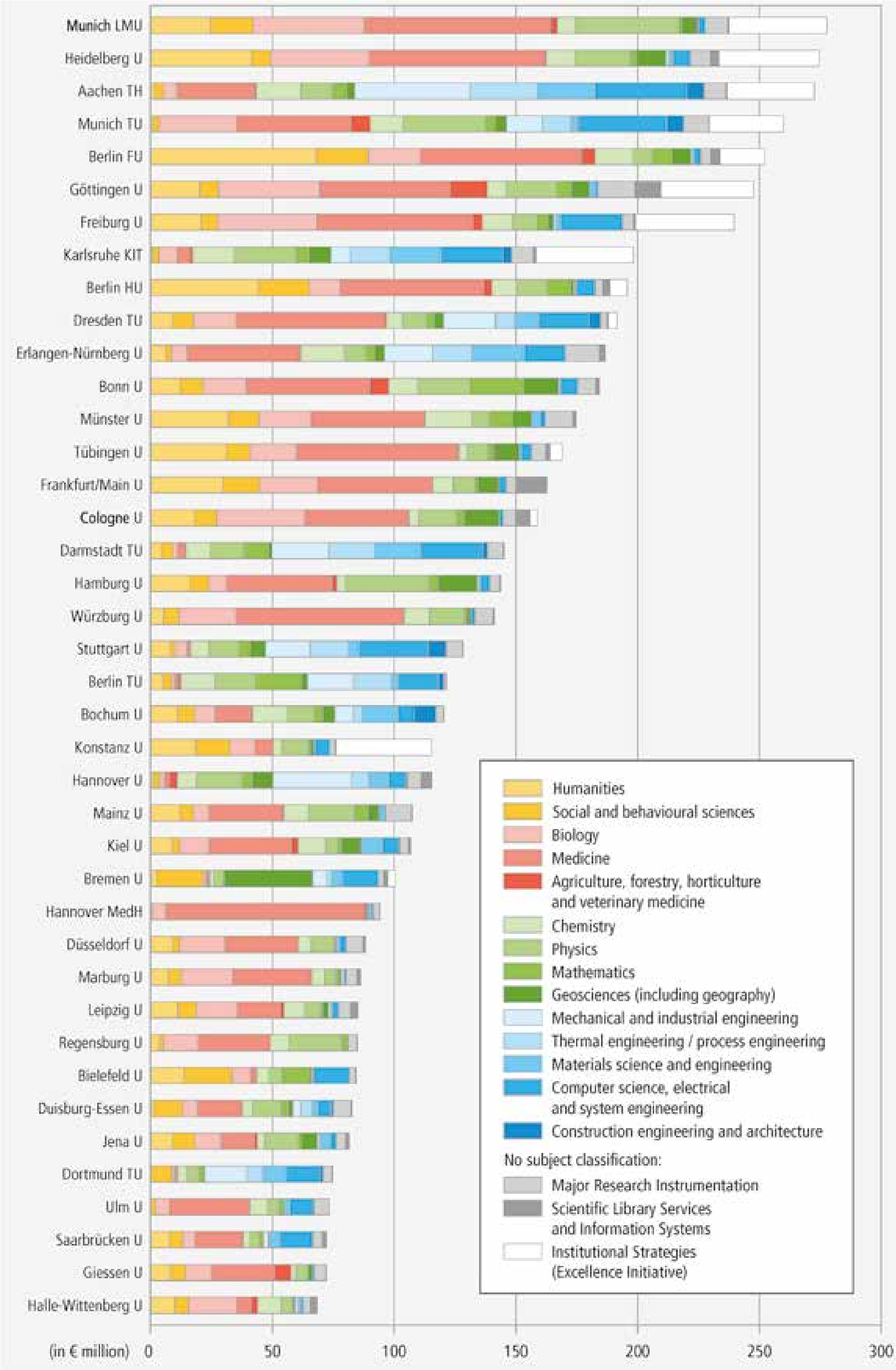


Fig. 1: The European centers of natural scientific research between the 16th and the 19th centuries.
Source: Hoyler and Taylor (2012, p. 77). Reprinted with the permission of the rectorate of Heidelberg University.



[1] Only the 40 leading recipients (higher education institutions) of DFG awards are presented here.

Note: Corresponds to Abbildung 3-3 of the DFG Förderatlas 2015.
Data basis and source: Deutsche Forschungsgemeinschaft (DFG, German Research Foundation): DFG awards for 2011 to 2013. Calculations by the DFG.

Fig. 2: The ranking of German universities based on funding granted by the DFG.
Source: Deutsche Forschungsgemeinschaft (2016, p. 36). Reprinted with the permission of the DFG.

engage highly qualified scientists, are not entitled to submit applications to the *Deutsche Forschungsgemeinschaft* for research funds, primarily teach, have no right to award doctorates, and receive students from a relatively small catchment area.

A few figures briefly demonstrate this hierarchization of the German university system. Between 2011 and 2013, 210 of the around 420 German universities[6] received funding from the DFG: 99.5% of research funds went to universities and 0.5% went to universities of applied sciences, pedagogical universities, and music and art universities. The 40 universities that were most successful at securing third-party funds from the DFG (Fig. 2) received 86.6% of the entire DFG funding in the period 2011–2013. Heidelberg University is second, just below LMU Munich, in this ranking. Heidelberg is third in terms of the Leibniz Prize winners; it is noteworthy that 72.2% of the Leibniz Prize winners accounted for only 18% of the German universities (*Deutsche Forschungsgemeinschaft*, 2015, p. 58–61). Of the around 420 German universities, 230 still do not have the right to award doctorates, which of course also has a negative effect on research performance (*Deutsche Forschungsgemeinschaft*, 2015, p. 33).

Among the world's top 100, only three to four German universities appear in the world's top 100, based on the year of reference and the ranking method (Heidelberg has been consistently the best German university in the Shanghai ranking for the last three years; it is second best in other rankings).

However, these rankings are only for universities. Were the Max Planck institutes, EMBL, DKFZ, HITS, and other research-intensive institutions in Heidelberg to be included, the Heidelberg scientific location would be significantly further ahead in the international ranking. Heidelberg has the added advantage that not only Baden-Württemberg but specifically the region between Frankfurt and Karlsruhe – as measured by several indicators, e.g., the proportion of employees in high-tech industries, the number of scientists in 1,000 jobs, patent density – is one of the strongest research and innovation regions in Europe.

Of course, it is legitimate and even encouraging to consider scientific knowledge acquisition not just from a competition standpoint, especially since the statistical indicators used for rankings never represent the entire truth, and because the acquisition of scientific knowledge can hardly be measured quantitatively. However, as soon as the allocation of resources is based on the attractiveness of scientific locations or on the high quality of research and teaching, indicators are construed, achievement is measured and compared, and scientists and students "vote with their feet", resulting in such hierarchical structures as that illustrated in Figure 2. A sport analogy may be used to clarify the discrepancy between pure knowledge acquisition, or education for its own sake, and competition in research and teaching. One can play soccer in tens of thousands of places in Germany and become a member of more than 5,700 football clubs. But only 18 of the more than 5,700 German soccer clubs play in the first federal league. A predominant number of clubs plays in lower regional or district leagues. And a federal league club that plays in the Champions League has a completely different impact (e.g., awareness of the city, tax yield, purchasing power, job creation) from that of a club playing in the sixth league.

As already mentioned, university ranking is not set in stone. Some universities rise, others fall. The TU Dresden rose from 35th in the "first half of the 1990s" to 10th in the 2011–2013 reporting period of the DFG ranking of granted research funding (*Deutsche Forschungsgemeinschaft*, 2015, p. 61). The history of science also includes many examples of specific cases of outstanding scientific achievement in peripheral universities that

6 A three-year average of the total number of universities is quoted here, since this increased during the survey period. There were 445 universities in Germany in 2014.

were not so well funded. For example: As is generally known, Robert Bunsen made his major scientific breakthrough at the University of Breslau (today Wrocław). Only with an extraordinarily generous job offer did the grand duchy of Baden succeed in bringing him to Heidelberg, which he then turned into a world center for chemistry for several decades. Other scientists too, who only later became famous, started their scientific career in peripheral, small universities: for them, these were merely "entry or interim universities" that they left once they accepted an appointment at a prestigious university with better conditions.

Since the mobility decisions of internationally successful scientists are significantly influenced by the diverse financial and organizational conditions, the various knowledge milieus, and different scientific reputations of the specific universities (Jöns, Meusburger & Heffernan, 2017; Meusburger, 2011, 2016), the issue of knowledge milieus will be addressed in further detail.

2.2 On the significance of knowledge milieus

2.2.1 Deficits in previous discussions

Many studies – economic cluster research among others – have made the mistake of focusing too much on the presence of institutions and of underestimating the significance of technical skills, the scientific reputation of stakeholders, and knowledge milieus, and the complexity of the transfer of high-level knowledge[7] from A to B. **Clusters and innovation or technology parks** were expected to have an automatically positive impact, so to speak. However, a cluster of mediocre stakeholders will also attain only mediocre achievements and a cluster without the required resources cannot compete with other clusters. Several municipalities in Germany established technology parks in the 1980s and 1990s, in the hope that knowledge and qualifications would automatically flow from A to B, triggering economic dynamism and securing sustainable, highly qualified jobs. Very few of these early technology parks were successful and achieved their goal. Most failed because the local conditions hindered such knowledge transfer and the concept of knowledge spillover – knowledge transfer from A to B – was based on naive assumptions. Merely setting up a science park is not enough: the success of a science park primarily depends on the qualifications and competences of the responsible stakeholders, and on the local conditions.

Some of these misconceptions have arisen because adherents of the cluster theory have made no distinction between **knowledge** and **information**, and between the various categories and levels of knowledge, and have underestimated the obstacles that hinder the mobility of higher level knowledge. There are only two ways to transmit specialized (high-level) knowledge from A to B: either there must be highly qualified stakeholders with the necessary prior knowledge[8] to understand and apply the supplied information at location B; or stakeholders who have the specialized knowledge must relocate from A to B – however, they will only do this if the conditions at B are favorable and if there is a specific knowledge milieu in which they can perform their research.

7 Knowledge can be differentiated not only in nominal categories (e.g., implicit and explicit knowledge, codified knowledge, and tacit knowledge) but also in ordinal categories. Common knowledge, which is widely available and easy to understand, is different from higher level knowledge due to the several years of study, extensive professional experience, or decades of research necessary to acquire it.

8 Several years' study or 10 years' practical research may be required to acquire this prior knowledge. Certain scientific publications by theoretical physicists are understood by only 200–300 peers.

Similar mistakes have been repeated in the 2000s, with the concept of creative industries (creative class, creative economy). Richard Florida's theses (2002, 2005) were strongly criticized by experts in creativity research, in the geography of knowledge, and in other areas. But the promise that cities can trigger creative processes, attract the creative class, or even create creative products through planning initiatives (e.g., low rent, tolerance of minorities), was so attractive and seductive, that many cities followed this path without verifying whether they at all have the necessary conditions for creative milieus. Unfortunately, Florida used the term "creative" in a completely different way, as it is commonly used in psychological creativity research (Amabile, 1983, 1988; Amabile et al., 1990, 1996; Boden, 1994, 2004, 2010; Csikszentmihalyi, 1988; Funke, 2000, 2010; Holm-Hadulla, 2010; Isaksen, 2010; Paulus, 2000; Simonton, 1975, 2000, 2010; Sternberg, 2010; Sternberg & Lubart, 1999; Weisberg, 1999; etc.).

From a scientific point of view, the question of whether a person, a process, or a product can be defined as creative can only be settled "in retrospect", once the results are available. However, Florida and his followers predetermined that certain occupations belong to the creative class and others do not. Thus, "creativity" degenerated into an empty catchword. How methodologically questionable the definition of the **creative economy** is can already be evidenced by the fact that the definition used by the Centre for European Economic Research differs from that used by the Conference of Economics Ministers, and both definitions have little to do with how creative people, processes, and products are defined in the psychological creativity research (for details, see Funke, 2000, 2010; Meusburger, 2010). The criticism of Florida's concept is not purely academic theoretical discussion. Rather, it should contribute toward local politicians not overestimating the economic return of the creative economy. Of course, creative artists and young inventors must have experimental spaces and "makerspaces" at their disposal, and lateral thinkers should be tolerated, but Florida's allocation of specific occupational groups to the creative economy is very problematic.

In conclusion, one can say:

The presence of specific institutions in a city does not yet mean that they will have the expected (promised) positive impact on the economy, culture, and society, or that they will be able to compete both nationally and internationally. Rather, it is the local conditions as well as the qualifications and interactions of the stakeholders operating locally that are critical to success.

2.2.2 How significant are spatial contexts and knowledge milieus for research and knowledge acquisition?

The views that generating scientific findings is location independent, that face-to-face contact is of no great importance for scientists because they would communicate primarily by email, and that relocating parts of the university to Patrick Henry Village would not be detrimental were repeatedly expressed in the public debate about Neuenheimer Feld, the Patton Barracks and Patrick Henry Village. Since a few Heidelberg local politicians express these arguments openly too, they must be taken seriously.

Whoever still adheres to the long refuted notion that scientific achievement is *not* affected by knowledge milieus, the research infrastructure, the local contact potential, and other spatially varying factors but can be produced anywhere, may answer the following questions:

- Why have so many chemistry, physics, medicine, and economics Nobel laureates in recent decades each performed their research at the same universities? Why have certain universities never in their long history produced a Nobel laureate or another internationally renowned scientist?
- Why are the doctoral students of certain supervisors, institutions, or faculties much more scientifically and professionally successful than those of others?
- Why were innovative research topics or new methodological approaches developed repeatedly at universities A and B rather than at universities C or D?
- Why were intellectual booms at Heidelberg University repeatedly superseded by phases of intellectual stagnation?

These questions suggest that research and learning processes, as well as the intellectual development and professional career of (young) scientists, obviously do not only depend on the personal qualities of the stakeholders but can also be structurally influenced by a variety of external factors. The **significance of the environment** or milieu for creative processes and scientific careers has been demonstrated by numerous studies in creativity research (Amabile, 1988; Csikszentmihalyi, 1988; Meusburger, 2010; Williams & Yang, 1999) and in the history and geography of science (Livingstone, 1995, 2003, 2010; Meusburger, 2000, 2006, 2008, 2016). It is clearly not enough for scientists to be gifted, creative, and highly motivated, and to have original ideas. They also need the environment and local conditions that would enable them to realize their ideas. Obviously, it is easier to produce outstanding research results, to embark on a successful scientific career, or to establish a successful start-up under certain conditions as opposed to others. Overall, there is a large number of external factors that could influence creativity, research processes, the academic careers of scientists, and the scientific reputation and attractiveness of a location. Altogether, these mutually influencing factors result in local conditions that can be described as an action context, a knowledge environment, or a knowledge milieu. A knowledge milieu is the result of systemic interdependencies that are relevant to a specific location (in a particular scientific institution) for the generation, application, and diffusion of knowledge.

One can distinguish between internal and external conditions. The ***internal* conditions** – the working conditions at the research institutions – are mostly the responsibility of the institutions (universities, hospitals, etc.) themselves. Among the many influencing factors, the appointment policy, the quality of the research infrastructure, the research and teaching quality standards, the available research funding and human resources, organizational structures (working environment, autonomy of young scientists), career advancement, local role models, or membership in major networks play a critical role.

However, universities and other scientific institutions do not act in a political, economic, and social vacuum, but are involved in political and economic power structures and, therefore, also depend on ***external* conditions** that are influenced by political decisions at the federal, state, and municipal levels. These external conditions are critical for those scientists wanting to stay longer in Heidelberg. Global top scientists are pleased if: they find that Heidelberg has high quality housing; their children can attend a municipality-funded day-care center or kindergarten on campus; there is an international (English-language) school in Heidelberg; and their families can reside in a tolerant city with a high quality of life and a very low crime rate. These soft locational factors are given very high priority, especially by foreign scientists. Were Heidelberg not an international and cosmopolitan city, other events that are highly regarded in the sciences, e.g., the "Laureate Forum" funded by the *Klaus Tschira Stiftung* and attended by Nobel laureates and students from around the world, would also not take place in Heidelberg.

What constitutes a knowledge milieu? The single most important element of a knowledge milieu is the local ***stakeholders***, with their technical and social skills, their professional experience, and their international networks. These stakeholders include not only scientists and students, but also all occupational groups that can contribute positively to a knowledge milieu.

In order to attract renowned stakeholders to Heidelberg and retain them for a long period of time, one must offer tangible and intangible conditions that are attractive to them and that will enable them to achieve their goals. It goes without saying that there are different requirements for ***internal*** conditions, based on scientific discipline. An experimental physicist requires different conditions from those of a theoretical physicist, a biologist different ones from those of a specialist in German studies, and a doctoral student different ones from those of an established top scientist. These details will be developed further in chapter 2.5.

However, many elements of a knowledge milieu are also influenced by federal (research programs), state (higher education acts, core university funding), and municipal[9] (policies of urban planning, traffic management, schools, etc.) **political decisions**. Both in the intellectual booms that have made Heidelberg world renowned and in the dark phases of the university's 630-year history, the political decisions of the Elector and later the grand duchy of Baden, the State Government of Baden-Württemberg, and the city of Heidelberg have always been a major contribution, to a greater or lesser extent. Ideally, the external conditions help at least those scientists who stay longer in Heidelberg to develop a local identity and an emotional bond with Heidelberg, and to also get involved with "their city" beyond their scientific work.

What are the effects of knowledge milieus? The influence of local conditions or a knowledge milieu on scientific achievement should not be understood in terms of a direct cause-and-effect relationship (if A, then B). Rather, the knowledge milieu is a local potential or offer that some stakeholders benefit from and that others, however, perhaps overlook, ignore, or cannot exploit due to a lack of qualifications. Therefore, the interaction between stakeholder and milieu is always critical. Whether these interactions work, and how, can only be determined in retrospect, on the basis of achievements, professional careers, or (auto)biographies (cf. Meusburger, 2016). Good or bad conditions do not result in *all* the scientists working under these conditions attaining achievements, good or bad.[10] Some scientists are crushed by a negative environment (a poor working environment, lack of resources, unfair criticism); others are not. Some scientists attain outstanding scientific achievements under positive conditions; others do not. Rather, the central question is whether the same scientists would have attained even better scientific achievements, reached their goal faster, secured more research funds, perhaps researched other topics, or attracted better doctoral students under good conditions.

9 The *Stifterverband* competition for German science has clearly shown that there are astonishingly big differences between German university cities – in terms of the willingness of local politics to do something for "their" scientific institutions, or in terms of knowledge – in the importance of the scientific institutions for the economic, cultural, and educational development of the city and the region (Stifterverband für die Deutsche Wissenschaft, 2011).

10 The history of science includes many examples of scientists who reported outstanding findings and research results, even under difficult conditions.

2.2.3 Knowledge milieus are constantly evolving

Unlike campus buildings, a *knowledge milieu* is not entrenched or stable, but constantly evolving. It must constantly renew itself from the outside if it is to maintain high scientific attraction. New initiatives are mainly derived from: the appointment of new professors; new doctoral students, postdocs, visiting professorships, and other forms of academic mobility; new research projects; new research infrastructure; and new networks and collaborations. This constant dynamic provides both opportunities and risks; it can accelerate both the upward spiral of an institution's scientific reputation and the intellectual decline.

Why is the mobility of scientists so important? Firstly, the technical skills, methodological knowledge, networks, and original ideas that are expected of scientists can seldom be acquired at a single location. Secondly, mobility stimulates new ways of thinking, leverages new networks, leads to new scientific collaboration, and can contribute to avoiding "intellectual inbreeding". Thirdly, the likelihood that a scientist has high potential is significantly greater if several different universities with strict selection procedures attest to their scientific achievements than if the scientist completes all levels of their career at a single university and only the same professors attest to their scientific quality.

The history of science demonstrates that a *top-class* knowledge milieu is very sensitive to external political and economic influences and that mistakes made by scientific institutions and local politics can damage the reputation of a location relatively quickly. Negative external or internal influences do not necessarily have an immediate effect. Rather, a deterioration in the conditions and the reputation of the location leads to the replacement of renowned scientists by less qualified peers in the next appointment procedure, because the location is no longer attractive to top scientists. Thus, the scientific reputation begins a "**downward spiral**" that can also have serious negative consequences for the economic dynamism of the city (e.g., job availability, purchasing power, federal financial compensation, taxes, etc.) in the longer term – because the majority of the attractive and financially sound research projects, which bring money and highly qualified jobs to the city, can be secured only by researchers with a high international reputation.

Top scientists or exceptionally talented students can choose the best university locations (worldwide) – they are not dependent on Heidelberg. Therefore, something must be done to attract them to, and keep them in, Heidelberg. Should the critical conditions for research in Heidelberg deteriorate, scientists, at least those who have a good international reputation and have not yet exceeded the upper age limit, will quickly leave. This renewal of knowledge milieus operates mostly on the **Matthew principle**: "For whoever has will be given more" or "birds of a feather flock together". The better the scientific reputation of a scientific institution, the more can it act as a magnet for top scientists and students. Once it has started a downward spiral, it is difficult to stop.

The scientific **reputation** of a location can significantly contribute to attracting renowned scholars. In order to reduce complexity, individual stakeholders' or institutions' earlier top achievements are often transferred to the location or to the relevant milieu where the achievements were attained. Based on past experience, the projected reputation on the institution or the location leads one to expect future, above-average scientific achievement, due to the applicable quality standards or scientific and cultural standards, and the working conditions. Affiliation with a prestigious institution and the symbolic significance of location also constitute a part of the personal identity and the self-esteem of many stakeholders. This reputation of a location can also be positively or negatively influenced by local political decisions.

2.3 On the significance of spatial proximity and face-to-face contact in cutting-edge research

How important is spontaneous personal contact between scientists in various disciplines in the digital age? In Heidelberg, individual members of the municipal council and of district councils have several times publicly stated that spatial proximity between cooperating scientists no longer matters nowadays, because scientists are globally networked and would primarily communicate online. Thus, research institutes could easily be relocated, without any detrimental effect, if there is no local space for expansion. This view – at least with regard to top scientists in basic research – is neither consistent with the international state of research on creativity and knowledge milieus, nor with the personal experience of the scientists in Heidelberg who were interviewed for this study. The amount and significance of spontaneous (unplanned) face-to-face contact has probably never been so great for top scientists as it is today.

However, one should distinguish between basic research and targeted applied research, and between the various levels of research. In **basic research**, creative processes or groundbreaking scientific findings can neither be planned nor "decreed" from above. The history of science and the (auto)biographies of famous scientists (e.g., Nobel laureates) demonstrate that many outstanding scientific achievements or groundbreaking discoveries in research were accidental, sometimes caused by "failed experiments" in the laboratory (Thomas, 1955), and very often in spontaneous, unplanned contact with representatives of other disciplines. Science thrives on human contact, the exchange of ideas, analogical reasoning, role models, criticism, and coincidences. The possibility of spontaneous contact with top-class scientists in various disciplines at a single location is of paramount importance for basic research. However, the odds of such valuable chance encounters are not uniformly distributed across a country or a city. Rather they are concentrated at a relatively small number of locations that have the potential of high levels of contact on a large variety of topics.

Several internationally renowned scientists of natural and life sciences have only accepted an appointment in Heidelberg or rejected one at other universities because there is no other location in Germany – and also very few worldwide (Cambridge, Harvard, MIT) – with the density, quality, and diversity of scientific institutions, the excellent research infrastructure, and the outstanding scientists in such a small area as that of Neuenheimer Feld. Without the potential for high-level scientific contact and the research infrastructure in Neuenheimer Feld, Heidelberg would have not participated in many research clusters, special research areas, EU projects, ERC grants, national research centers (e.g., National Center for Tumor Diseases, pediatric oncology), and business partnerships.

The fact that most research funding does not "automatically flow" into scientific research projects but is awarded through fierce national and international **competition**, and that only the best scientists are in a position to secure approval for such research projects, is often overlooked in public debate. The basic facilities financed by the state can secure routine research but cannot perform cutting-edge research. Whether Heidelberg is one of the most expensive research infrastructures available nationwide or whether investment should be made in other cities depends on a few dozen top natural and life scientists. Whether the Heidelberg City of Science annually receives several hundred million euro in additional research funding and also several hundred highly talented young scientists performing research locally, or whether this funding should go to other scientific locations depends on a few dozen top scientists.

The success in the nationwide "BioRegio" competition in 1996, which brought €26 million in funding to Heidelberg; the successes of establishing the National Center for Tumor Diseases (NCT) and the Heidelberg Ion-Beam Therapy Center (HIT) – the first of its kind worldwide – in Heidelberg; winning the Leading-Edge Cluster Competition in 2008, which brought around €80 million to Heidelberg (€40 million from the state and €40 million from the private sector) until 2013; and, last but not least, winning €700 million in funding (with a total project amount of more than €2 billion) in the “Healthy Living and Active Ageing” funding competition in 2014 as BioRN, a member of the InnoLife Consortium, comprising partners in nine EU countries, together with the many special research areas which also each bring in several million euro, would have been impossible without the world-famous scientific **reputation of the Neuenheimer Feld campus**. Hence, the differences between “cutting-edge research” and “average research” are not only academic but are also reflected in the amounts of available investment, material, and human resources, and are, therefore, extremely important to the economy, culture, and society of the city of Heidelberg.

Of course, Berlin and Munich also have outstanding research facilities, but these are spread over several, sometimes distant locations, as in the case of the life sciences. In order to meet an important contact from another institution in Berlin or Munich, one would often have to travel one to one and a half hours by train – in Neuenheimer Feld, one would be within a five to 10-minute walking distance of the desired contact. Therefore, the probability of a chance encounter with scientists from other faculties or research areas in Heidelberg is quite clearly much higher than that in Berlin or Munich. Due to this fragmentation of life sciences across several locations, Munich or Berlin have already lost leading-edge cluster competitions or national research centers to Heidelberg. International experts who decide on awarding research funds or research centers are very well familiar with the excellent research conditions in Neuenheimer Feld. Neuenheimer Feld is a world-famous “brand” in the **natural and life sciences**, for which Heidelberg is envied.

Spatial proximity, or a spatial concentration of scientific institutions is, e.g., in the case of the life sciences, also indispensable for specialists in several disciplines who have to interpret clinical pictures of patients. It is almost perfect that pediatric oncology, the pediatric hospital, the Tumor Center, and DKFZ are (or will be) within walking distance from each other in Heidelberg. The fact that biologists, physicists, mathematicians, chemists, computer specialists, etc. are also primarily needed in cancer research apart from physicians is often overlooked in the public debate. Medical laymen too could understand the negative consequences were the German Cancer Research Centre (DKFZ) located in Neuenheimer Feld, the National Tumor Center in Patrick Henry Village, and pediatric oncology in Patton Barracks.

Heidelberg, together with Munich, is also the largest and most important **physics and astronomy** location in Germany. Many of the younger and newly appointed physicists view the current fragmentation of physics and astronomy in Heidelberg in Neuenheimer Feld, the Philosophenweg (Philosophers’ Walk), the Königstuhl (two locations) and in Mönchhofstrasse as detrimental to Heidelberg. A survey of the scientists in Neuenheimer Feld has shown that some groups of researchers already feel that relocating workplaces by a few hundred meters from their central office is grossly detrimental, because this hampers spontaneous contact with colleagues and the random submission of suggestions, and because the affected scientists constantly feel that they are no longer “in the thick of the action” and that they are missing something important. Of course, one should not generalize. Therefore, a relevant distinction is made in chapter 2.5.

The humanities, the social sciences, and economics are generally not so dependent on expensive laboratories, research equipment, and experiments; even the competition for third-party funding plays a somewhat lesser role in most of their subjects. However, they also benefit greatly from the fact that almost all contact to all other subjects of importance to them takes place in the Altstadt (Old Town) or Bergheim, within five to 10 minutes’ walking distance. Anyone walking along Heidelberg’s main street at specific times of day can hardly avoid bumping into scientists of other disciplines.

2.4 To what extent are digital communication media expected to change the significance of the different kinds of contact, the local contact potential, and spatial proximity?

Digital communication and networking, as well as the exponential rise of mass data to be evaluated have doubtlessly fundamentally transformed scientific work in the last 20–30 years. Many archive resources, documents, and publications are now available in digital format, so that one must no longer travel to other cities to refer to them, as in the 1990s. Digitization and modern digital **communication technologies** have today made routine some activities that previously required certain qualifications and personal contact. Of course, the largest part of routine communication requires no personal contact but can be done over the Internet or the telephone.

Modern digital communication technologies have mainly streamlined access to "hard" and other freely available information. However, access to information still doesn't automatically mean that the available information is understood, accepted, and adopted. The generation of new scientific findings and their acceptance by peers represent a laborious and time-consuming process, based mainly on the direct communication (co-presence), observation, and critical discussion of the results. Face-to-face contact is generally preferred for conversations about sensitive topics.

As opposed to the predictions of "false prophets", digitization in top-class research has not led to the decentralization of top scientists' jobs. On the contrary, science hot spots increasingly attract research-intensive companies. The trend that research-intensive companies in basic research now, more than ever before, seek *spatial* proximity to leading international science centers,[11] e.g., Harvard, MIT, Cambridge, etc. by relocating to specific research departments in these "centers of knowledge", has not only been observed in the United States but also in Europe. Why else is BASF, itself a leading worldwide scientific center for chemistry, employing more than 6,000 scientists, interested in the "industry on campus" concept? Why is it important for BASF to use a joint laboratory with university chemists in Neuenheimer Feld in the context of the Carla project? Why are research-intensive companies seeking proximity to major universities and face-to-face contact with scientists, when they have good digital networks and, allegedly, worldwide access to all knowledge – as claimed by some Heidelberg local politicians? How does one explain the fact that globally networked scientists with worldwide research collaborations are seeking proximity to scientists in other disciplines locally in Heidelberg?

In order to answer these questions, one must understand how cutting-edge science and creative processes function, and the kinds of contact that are required or preferred for the various purposes. For decades, organizational research has differentiated between **routine, planning, and orientation contact**, as well as between direct contact, in which people meet personally (face to face), and indirect contact, where no personal presence is required and communication occurs through letters, emails, and other communication technologies. Since routine activities are regulated by best practice, production processes, and administrative rules – hence, with a low degree of uncertainty – **routine contact** (with the exception of very few professions) can usually occur through indirect contact: via letters, telephone calls, emails, or other forms of digital communication.

11 The term "center" is often misunderstood. In this case, it is not defined in terms of topography (the middle of an area) but in terms of organizational theory. The center of a social system is wherever its highest authority is located. Therefore, the center of a science, a research topic, or a network, is located wherever outstanding top scientists work.

The need to meet personally significantly increases in the case of **planning contact**. However, such contact does not occur by chance. Rather, the time and place of the meeting, the agenda, as well as the number of participants are usually already known before the meeting. Routine and planning contact is mostly about hard data, clear objectives, and a more or less defined discussion process. Since planning contact is organized in a timely manner, such contact may occur in very different places.

High-quality **orientation contact**, however, has a completely different function from planning and routine contact. This is mostly about the early acquisition of *soft* information and serves to "hear the grass grow", to learn at an early stage what others are planning, the direction a development could take, where opportunities and risks arise, where and when new sources of research funding open up, sources of danger that threaten a project, who is interested in similar research questions and where, and who might be a potential cooperation partner or competitor. Here, vague suggestions, rumors, chance observations, who talks to whom, or the facial expressions of persons could provide valuable information about future developments, research programs that have not yet been officially announced, imminent coalitions and resistance, and new data sources among others. Such *soft* information that is obtained by unplanned orientation contact can not only significantly improve the chances of success for scientists or institutions competing for research funds, but also lead to new associations, to analogical reasoning, to the identification of interrelationships, as well as to new literary and methodological knowledge.

Research about organizations and office-locations have since the 1970s (Goddard 1971; Goddard & Morris, 1976; Goddard & Pye, 1977; among others) demonstrated that the proportion of orientation contact to total contact in large organizations increases with: the stakeholder's functional position or decision-making power in a social system; the degree of uncertainty about future developments; and the importance of mutual trust in problem-solving or decision-making. These findings can be partly transferred to scientific work.

Orientation contact, personal trust, and chance encounters between researchers, especially in the initial phase of a creative process (an innovative research project) and in very dynamic and uncertain stages, also play a critical role in the sciences. Trustworthy personal contact is particularly important if scientists come from various disciplines (scientific cultures) or if there is a risk that project documents or research findings are made available prematurely to competing research groups. The necessary mutual trust for joint research projects can develop only in the context of personal contact.

Unexpectedly for some, for several reasons, a trend toward spatial concentration exists even in **e-science (computationally intensive science)**, working with high-performance computers and unimaginably large amounts of data. Firstly, computing power has increased at a much faster rate than the transmission speed of data networks in recent years. In other words, the currently available networks are too slow in relation to computing power. Due to the high cost of mainframe computers[12], it will only be possible to carry out specific projects at three to five locations in Germany – or maybe at only one location in Europe in the case of extremely large amounts of data – in the future. Besides, in e-science – where results can be displayed in just a few graphics due to extremely high computing power – one requires scientists in several disciplines and a different kind of intuition to that required for classical disciplines in order to interpret the graphics.

In summary, one can state that the high density of top-class research infrastructure and the short distances between world-renowned scientists can be considered Heidelberg's biggest advantages and are key reasons why Heidelberg is still competitive in the international competition for top scientists.

12 The quip "the best mainframe is the one you must not operate yourself" is circulating among computer specialists.

2.5 The significance of spatial proximity is no dogma but depends on several factors

The principle of "spatial proximity" should not be regarded as dogma. The necessity and significance of spontaneous, face-to-face contact varies according to the discipline and the life cycle of a research topic. In the initial or critical phases of a research process, there is a greater need for face-to-face contact than in a phase in which the research processes are already largely regulated by routine or can follow models. There is much greater demand for high-quality, personal orientation contact in basic research than in applied (industrial) research, which has clear objectives or is regulated by specific routine procedures, rules, and standards. The history of science provides several examples of applied industrial research also functioning very well at peripheral locations, particularly when it presents a clear technological advantage over competitors. There are also examples where leading high-tech companies or highly sensitive projects in the arms industry deliberately favored peripheral locations, because they made secrecy easier.

Factors such as the stakeholders' autonomy, the uncertainty over achieving the goals, the stability or dynamics of the environment (e.g., the degree of competition), as well as the research topic, among others, play a role in the case of the question: How dependent are scientists or research projects on the **contact potential** of the location? One could somewhat overstate that top achievements in basic research, which must constantly move with the international "research frontier" in terms of research questions, methods, and theories, are usually in the overlapping area between several disciplines and have a high degree of uncertainty, are very dependent on a "top-class" potential for face-to-face contact with other disciplines, and, in some disciplines, are only possible in a few locations due to the expensive research infrastructure required. This local contact potential will of course not be required daily, but only at specific stages of the research process. It is critical that it is available when needed.

Applied research, which has a precisely defined, practical goal in a clearly specified area (e.g., to increase the performance of a battery), can also be carried out on a new campus in the open countryside, far away from the next university. Similarly, institutions that focus on teaching and that carry out relatively little research or, from an international perspective, only "routine research", have relatively low need for the location's contact potential, so they often base their location selection on other criteria (traffic conditions, real-estate prices, available land, etc.).

So, when it comes to new locations for research institutes, research-intensive companies and start-ups, or an increase in the land used for scientific purposes in Heidelberg, the different kinds of science, with their different orientation, planning, and routine contact dependences, or different requirement for spatial proximity and local conditions, must be considered. In principle, the following questions should be answered:

- Which international, cutting-edge research workplaces must certainly remain at **Neuenheimer Feld** because only there do they have the infrastructure and the necessary contact potential to be competitive in international research? The research infrastructure in Neuenheimer Feld had a value of around €3.5 billion in 2015. Neither the city nor federal, state, or private entrepreneurs would be capable of funding such a research infrastructure at Patrick Henry Village off the cuff. Therefore, due to the necessary contact potential and the required research infrastructure, the jobs of top scientists in certain disciplines and in highly specialized hospitals can only be located in Neuenheimer Feld in the long term.
- What kind of research activities can be relocated to the innovation park at **Patton Barracks** or later at **Patrick Henry Village** – be it because they no longer need daily contact with other groups of researchers, since they have already progressed along

the process chain (product life cycle), or because they have become autonomous due to other reasons? As previously mentioned, these two locations are particularly suited to targeted (applied) research, e.g., Organic Electronics, and to other research collaborations between science and industry.
- What kinds of research-intensive jobs can be established at any other location in Heidelberg or in the metropolitan area without compromising their research performance?

It would be very unwise to fragment or to distribute across various locations well-functioning research networks due to lack of space. Neuenheimer Feld, Patton Barracks, and Patrick Henry Village are not interchangeable, they will not compete against each other but they will complement each other.

Some parts of the **technology park** could also be relocated to other locations in Heidelberg without detrimental effects. However, very research-intensive start-ups in the natural and life sciences require the proximity to expensive laboratory facilities, as well as spontaneous face-to-face contact with the biologists, physicists, chemists, physicians, mathematicians, and experts of bioinformatics in Neuenheimer Feld, at least in the initial years, until their products are ready for production.

There are also subjects such as geography and psychology, which have such broad research topics that they have to compromise in terms of location. Physical geography requires links with the earth sciences, physics, chemistry, and geoinformatics. In contrast, human geography is rather linked with the social, economic, and political sciences, the South Asia Institute, the Heidelberg Center for American Studies, as well as history, English, Romance studies, and ethnology. Fragmenting geography across three locations in Neuenheimer Feld, Altstadt, and Bergheim would be a whole lot more detrimental to this subject than the fact that Neuenheimer Feld does not have high contact potential for all of geography.

Fig. 3: Patton Barracks as a location for a future innovation park (science park) (photo Kay Sommer).

Fig. 4: Patrick Henry Village as an experimental site for urban development in a City of Science (photo Kay Sommer).

Fig. 5: The Neuenheimer Feld campus. Copyright: Lossen photography/heidelberg-images.com. Reprinted with permission.

2.6 What requirements must be met for a new campus for basic research to be competitive internationally?

Of course, we can now raise the question of whether a highly attractive campus for the natural and life sciences could also be created outside of Neuenheimer Feld and deliver international top achievements in basic research. The Neuenheimer Feld campus had once also started from scratch, in the open countryside; and the concentration of non-university research institutions (EMBL, Max Planck institutes) on the Königstuhl represents an internationally renowned research environment for basic research whose reputation and resources attract scientists worldwide.

The answer to the above question is: "In principle, yes. But only under certain conditions." Briefly mentioned, the two most important requirements are:

1. Success is more likely if a completely new research area that does not yet exist in Heidelberg and that benefits several subjects were to be established at a new location, than if the new location were to include only work areas that have no further available space on the existing campus, existing research collaborations were to be fragmented, and the new location were not able to provide the same research infrastructure, the same contact potential, and the same reputation as the current location.
2. The new location must have substantial financial resources, offer an outstanding quality research infrastructure in a relatively short time, achieve critical mass and technical diversity relatively quickly, and quickly earn a good international reputation from the outset, because top scientists will come to this new location only if the conditions and the research environment here can seldom be found elsewhere. EMBL and the two Max Planck institutes for nuclear physics and astronomy met these requirements at the Königstuhl. EMBL was established and financed by 10 European states in 1974. In 2016, it was financed by 22 member states, two associated countries and four candidate countries. EMBL is Europe's molecular biology flagship, with 80 independent groups of researchers currently working at the five locations at Hinxton, Grenoble, Heidelberg, Hamburg, and Monterotondo. The fact alone that 28 states participate in financing EMBL testifies that this hot spot of molecular biology is a unique institution worldwide that is of great benefit not only to Heidelberg University and DKFZ, but also to universities and Max Planck institutes throughout Germany. HITS at Schloss-Wolfsbrunnenweg too is particularly attractive to scientists because it has much to offer that is not yet available in this form at the university and the Max Planck institutes.

2.7 Why does Neuenheimer Feld too require space reserves for developments over the next decades?

In order to determine and justify the future space requirements of Heidelberg's scientific institutions, distinction must be made between short-term and long-term requirements, and between the various types of scientific institutions. The short-term requirements are already relatively well justified today and have a timescale of up to 20 years. The long-term requirements will be determined primarily by new, still-unforeseeable developments in the sciences.

As opposed to universities of applied sciences or universities that are not research intensive and focus on teaching, the space requirements of a research university depend less on the trend in **student numbers** and more on the research quality and third-party funding. It is true that additional space requirements at a university of applied sciences, a university of education, or a (small) private university arise primarily from an increase in student numbers and that such universities are very much affected by demographic change in Germany because of the predominantly regional or national student catchment areas. However, Heidelberg University is much less dependent on demographic change. A large number of disciplines have a *numerus clausus*; the number of applicants for many institutes is five to ten times the number of available places and, especially in the case of doctoral students, a significant proportion of applications (in some subjects up to 40%) are foreign.

Therefore, research-intensive universities will be much less affected by demographic change in Germany than universities of applied sciences and Heidelberg University of Education, for instance.

New space requirements at internationally renowned research universities and non-university research institutions primarily arise from two developments: **scientific success** in acquiring new research projects; and the **introduction of new key technologies**, new laboratory and analytical methods, new medical treatments, new methods of microscopy and image processing, etc.

Anyone involved with the history of science and that of the economy, is aware that entirely new research areas, technologies, and analytical and treatment methods that revolutionize the sciences and healthcare, and require specially equipped laboratories, new large-scale equipment, additional personnel, and new safety regulations constantly emerge at specific intervals. Nobody could predict the significance of spectral analysis, cancer research, the computer sciences, molecular biology, astrophysics, materials research, nanotechnology, bioinformatics, geoinformatics, or pediatric oncology, to name but a few. Such revolutionary developments will occur in the future too. Although they cannot be predicted, they will surely eventually occur and Heidelberg must at that time be able to provide future, new technologies and analytical, research, and treatment methods at a suitable location. Those Cities of Science that can participate in this new development from the outset will retain their competitiveness and reputation, while those locations that lag behind due to lack of space or funds, or for any other reason, will lose a part of their scientific attractiveness and international reputation.

Heidelberg University is a good example of additional **space requirement** not being primarily caused by an increase in student numbers. The number of students at Heidelberg University has for many years fluctuated between 30,000 and 33,000, which the University does not plan to increase. Although the number of students has not increased, the total number of scientists (only full-time posts) at Heidelberg University (including medical faculties) increased from 3,960 to 5,630 between 2006 and 2014. Purely statistically, this increase corresponds to the number of scientists of a medium-sized University. The successes of the Excellence Initiative alone increased the university's core number of scientists (i.e., without the medical faculties) by328 between 2005 and 2014, which is approximately the number of employees at the SRH University. There have been similar developments at EMBL, DKFZ, and several Max Planck institutes.

(Additional) space requirement at a research university and a hospital center of international stature is primarily a question of the quality of scientific research, medical care, and the amount of third-party funding.

Should the research quality significantly decrease in the future – i.e., Heidelberg would not be as successful in competing for talent, research funds, and investment as in the last 10–15 years – or the population no longer value having one of the two best medical care centers nationwide on its doorstep, the scientific institutions would require even less space. However, several hundred million euro less in annual funding would flow into the region.

A city that claims to be a City of Science must be prepared for such future changes by allowing scientific institutions the necessary freedom and development opportunities. It was only possible for Heidelberg to become a leading City of Science because of state and local politicians, in addition to outstanding scientists, who, in times of critical scientific change, established very wise and far-sighted policies that allowed for the disciplines' necessary expansions. Without this foresight of former local politicians, neither would the hospital area in Bergheim nor the campus in Neuenheimer Feld have been achieved, and EMBL too would have not been established in Heidelberg.

The additional area required in the coming decades primarily depends on the research standard or the international reputation of the scientific institutions, as well as the amount of research and investment funds flowing into Heidelberg. The dense occupancy of the existing Neuenheimer Feld campus will be possible for a few more years, but will soon reach its limit. This is no promising alternative for the long-term development of the natural and life sciences, as well as the hospitals in Neuenheimer Feld.

3 What are the urbanistic demands of a campus?

Urban aesthetics, high quality architecture, good internal networking, clever localization of places of communication, good transportation links, appealing parks, high urbanistic demands in campus planning, and the urbanistic integration of a campus indisputably contribute to the attractiveness of a location, at least in the European tradition. In terms of urban aesthetics and scenic beauty, few university cities have been praised as much as Heidelberg in past centuries (Meusburger, 2011, p. 24–26, provides an overview).

Urbanistic concepts should take into account the functional requirements, needs, and priorities of the scientific institutions. The fact that various disciplines and diverse research cultures require different spatial concepts, that international cutting-edge research has specific needs, that natural sciences require very different conditions than those for the humanities, and that models from the United Kingdom or the United States cannot simply be transferred to Germany are rarely the subject of discussion in the "pure doctrine" of urban planning literature. What makes a big difference is whether universities are funded by the state (federal state) or by tuition fees, real estate, and other revenue streams. What makes a difference is whether the universities themselves are the landowners, or whether the campus real estate belongs to the federal state (*Bundesland*). German universities are not property developers that make financial profit from apartments on campus; the land where they are located or want to build does not belong to them. There are three particular wants or **suggestions for campus planning** from the perspective of scientific institutions.

Firstly, the planning process should be based on tangible, scientific-institution specific but very different needs and functional requirements, along the lines of: *"Medicine should help the patients and not the doctor's image."* No architect ever thought of planning a factory without first asking the customer about the products that would be manufactured there, the internal production processes, the required degree of flexibility, the safety regulations to be observed, where the access roads should be, and what they think the ideal factory should look like. In this case, it is obvious that the very different needs of "customers" are of paramount importance in planning. Why should this be any different for a campus for scientific institutions? Why don't some planners first determine the requirements and priorities of the scientific institutions before planning a campus? Why does one so often find sweeping statements about *the* campus or the indiscriminate adoption of contemporary models (e.g., a functional mix) in urban planning literature? Some urban planners are well aware of these deficits. Recently, on the occasion of an IBA event, there was a call for a shift in campus planning from the former "simplicity" to the new "diversity".

Secondly, planners should distinguish more strongly between campus type, size, and location: *the* campus does not exist. Arguably, one must be able to distinguish between a dozen different types of campus in order to accurately meet the needs of science and gain acceptance of one's planning concepts.

- A university campus dominated by the humanities and the social sciences can be approached differently from a university campus that primarily accommodates the natural and life sciences, where working with sensitive and delicate measuring instruments, diverse radioactive sources, and other dangerous/contaminating substances requires that various safety regulations be observed.

- A functional mix on a campus could work much better were the campus to have 500 ha of building area in reserve rather than a land reserve of only 2 ha.

- A campus that is integrated into an urban area or immediately adjacent to it should be approached differently from a campus that is several kilometers away from the nearest residential area and, therefore, has to also provide apartments, shops for daily needs, and specific services. Neuenheimer Feld, in its current expanse, is certainly no campus that should be "upgraded" with additional apartments, but rather a special-use area. Therefore, as in any other urban district, further development or connection measures are necessary. However, were large land reserves to become available in the future, a moderate mix with residential functions could be very attractive.

Thirdly, campus planning should allow for a large degree of **flexibility** due to the uncertainty of future scientific developments and requirements. Once plans have been defined, it should be possible to change them as required. Figures 6 and 7 show the Neuenheimer Feld campus plans in 1932 and 1972. It is understandable that the 1932 plan could not be achieved. However, in retrospect, the fact that only a small part of the 1972 plan was constructed (only the parts colored dark red in the illustration were actually built) was a stroke of luck, because a few years later not only had the very different challenges of the hospitals and the natural and life sciences to be addressed, but also the concepts that the architects favored had again changed (cf. Stroux, 2011). Flexibility, or the capability to respond to new developments and challenges, is of especially high priority in the sciences.

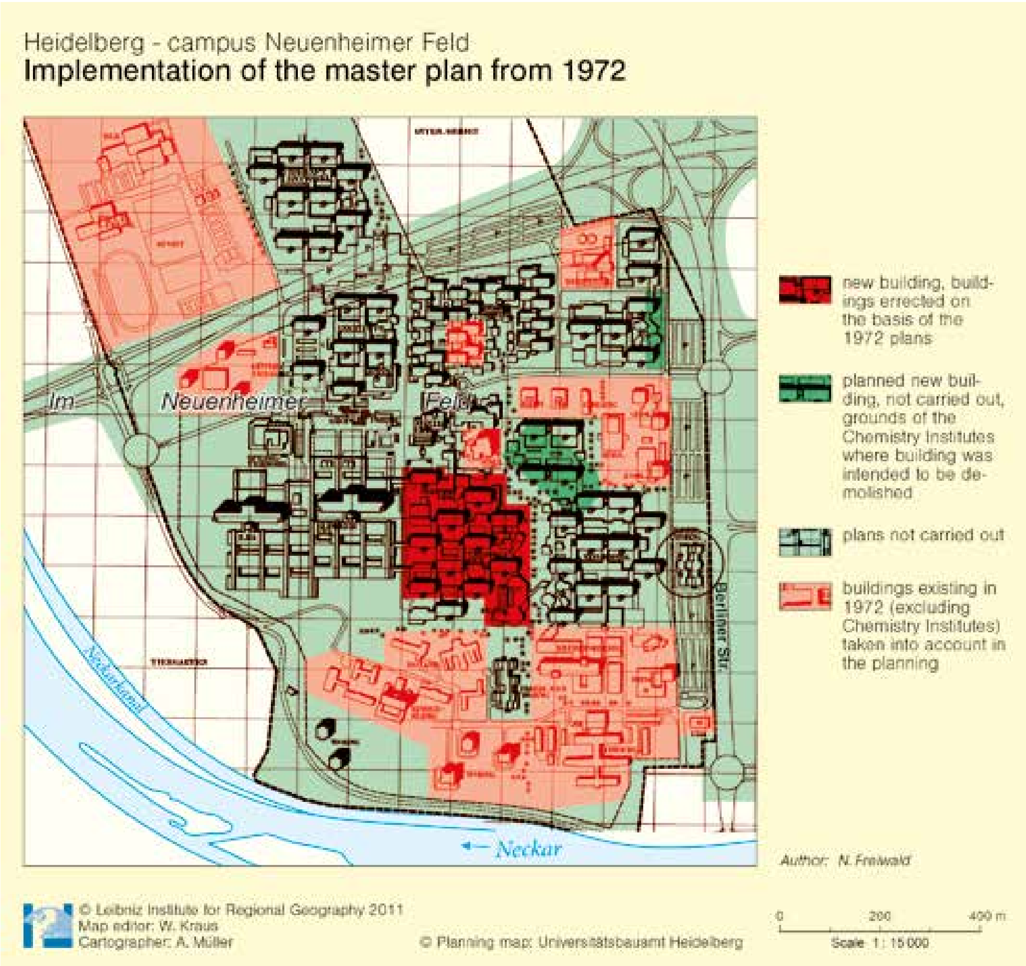


Fig. 6:
The Neuenheimer Feld campus plan in 1972.
Source: Freiwald (2012, p. 331).
Reprinted with the permission of the rectorate of Heidelberg University.
See also Freiwald (2007).

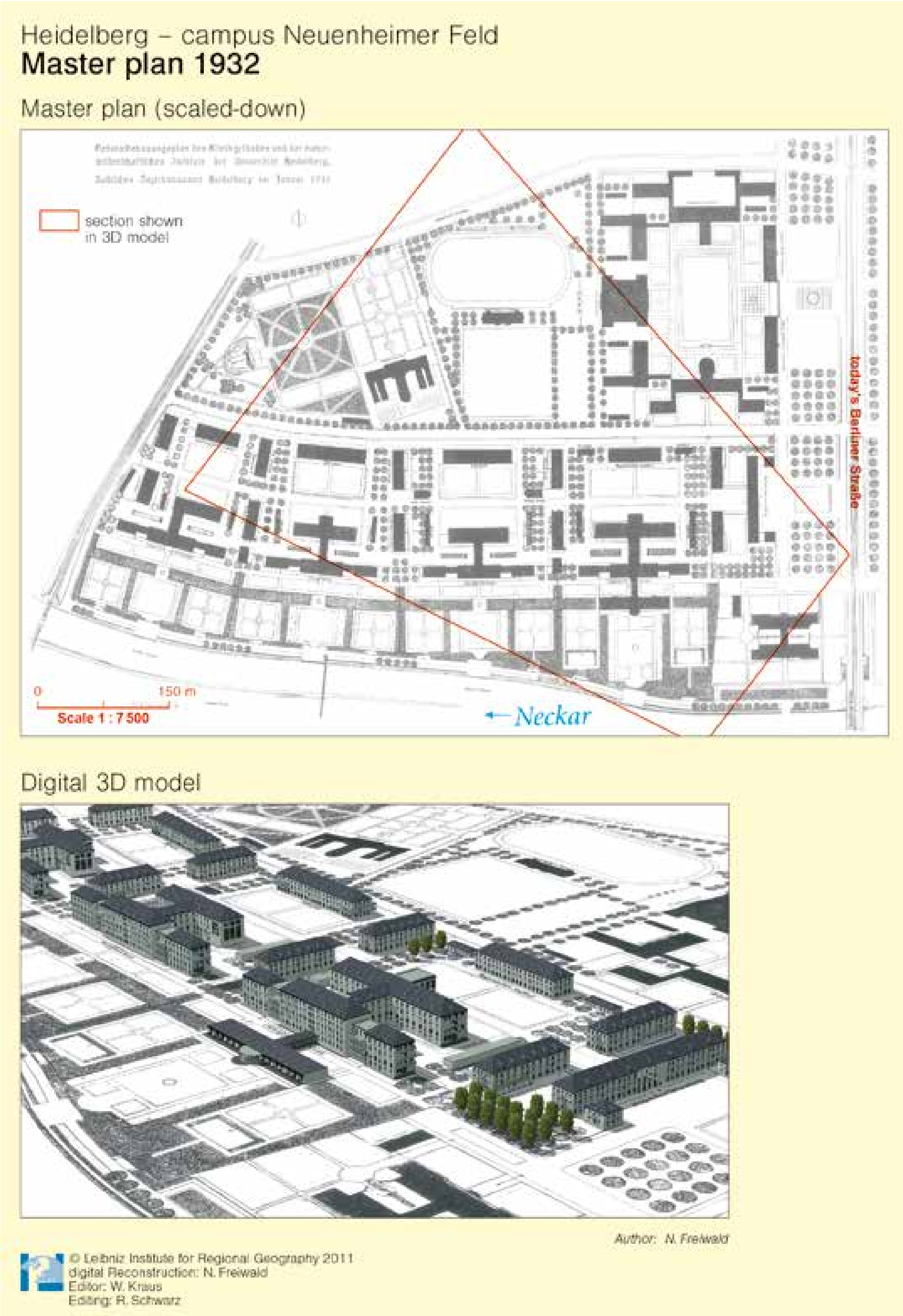


Fig. 7:
The Neuenheimer Feld campus plan in 1932.
Source: Freiwald (2012, p. 330).
Reprinted with the permission of the rectorate of Heidelberg University.
See also Freiwald (2007).

Although the Patton Barracks and Patrick Henry Village conversion areas can accommodate specific non-university (applied) research institutions and research-intensive start-ups and companies – they represent a valuable enrichment of Heidelberg's location qualities – in the long term, these additional areas will be insufficient to maintain Heidelberg's international leadership as a scientific and hospital location for decades to come. There must also be the option to expand into the Neckarbogen (arc of the Neckar river) and/or Handschuhsheimer Feld in the future.

4 Conclusion: Is Heidelberg already a City of Science?

Several authors (Kunzmann 2004; Matthiesen, 2006, 2007a, 2007b, 2013; Stifterverband für die Deutsche Wissenschaft, 2011; among others) have addressed the differences between a **City of Science** and a **location of science**. There are also a large number of publications on the subjects of "entrepreneurial science", "Can Silicon Valley be repeated elsewhere?", "How will the relationship between science, the economy, and politics (triple helix) evolve in the future?", or "How can scientific findings be transformed into innovation?" that are of fundamental importance for a City of Science (Dzisah & Etzkowitz, 2012; Etzkowitz, 1997, 2002, 2008, 2013; Fromhold-Eisebith, 2010; Goldstein et al., 1995, 2004). The findings of most of these papers state that "**science alone is not enough**". This emphasizes the importance of the relationships between stakeholders from science, politics, and the economy – thus, the triple helix (Etzkowitz, 2008).

What defines a City of Science? The following excerpt from a publication of the Stifterverband für die Deutsche Wissenschaft (2011, p. 19–21) is a good summary of the differences between a location of science and a City of Science:

> *"Cities of Science specifically use the knowledge (science) factor for a knowledge-based strategy for the future. This means that, in addition to the requirements of a location of science (universities, research institutes), well-functioning networks between science, the economy, and the city, in which all partners are on an equal footing, do not lose their own identity and visibility, and are well aware of the cooperation benefits for all involved, are an important prerequisite. This targeted cooperation is based on a jointly formulated and driven strategy from which all will benefit. A successful concept does not only distinguish itself through the optimal utilization of universities' expertise for location development, for instance, but rather from the fact that science, the economy, as well as the city will benefit significantly from the exchange processes between all partners. Without tangible added value for everyone – e.g., the creation of specific scientific and economic infrastructure, or help in securing funding – networks will soon start showing signs of collapse. Rigid structures are required to ensure sustainable strategic cooperation: on the one hand, goal specifications that transpose rather loose transfers into binding, cluster-like structures, and on the other hand, a firmly institutionalized network node that manages these structures. A City of Science, in our opinion, distinguishes itself by participating in this management or even leading it. Institutional and human-resource continuity thereby ensure trustworthy networking and broad acceptance by all participating partners. Ideally, the Town Council proclaims the importance of science for municipalities by council decision….*
>
> *Project-related structures for the conception and implementation of an event model for scientific communication, initiatives for jointly marketing the university location, or projects to further develop a cluster, for instance, supplement this fundamental level. These activities are integrated into the overall strategy, contribute to the attainment of the jointly formulated cooperation goals, and are accompanied by an internal and external communication strategy….*
>
> *In our opinion, citizen acceptance is another feature that distinguishes a City of Science from a scientific location….*
>
> *Only if the municipality – council, administration, and citizens – actively supports its scientific institutions in networking with other social areas (also beyond the economic area), can it justify calling itself a "City of Science". Without the active participation of the city and urban society, we would be dealing with "only" a good or less good scientific location."*

Heidelberg has already made good progress as a City of Science but is still short of the ideal City of Science. The fact that 91% of all respondents of the "Heidelberg Survey 2015" rated Heidelberg University and other scientific institutions "very good" (47%) or "good" (44%), is positive. Respondents with a university degree rated this at 97% and those with a secondary school-leaving certificate 78%. Of all respondents, 94% were of the opinion that the city benefits "very strongly" or "strongly" from the presence of the university and other scientific institutions in the city (Stadt Heidelberg, Amt für Stadtentwicklung und Statistik, 2016, p. 35–36).

The scientific institutions have on many occasions over the last few decades had significant support from the local and regional **economy** too. The economy is aware of the importance of the scientific institutions for Heidelberg's location qualities and that it also benefits internationally from the name Heidelberg. Heidelberg University's application in the first Excellence Initiative was enthusiastically promoted by the most important companies in the metropolitan area: their letters of intent, their affirmation of Heidelberg as a scientific location, and the already existing scientific collaborations left the expert group of the Excellence Initiative with a very good impression. Last but not least, Heidelberg is in the fortunate position that several philanthropists (patrons, foundations) promote science, education, and culture to an extent that is nowhere else seen in Germany. This example demonstrates the positive impact that the emotional attachment of key people to their city and their scientific institutions can have.

Heidelberg's **city administration** has supported or even encouraged many projects by scientific institutions. Decision-makers at the technology park gave significant impetus to the establishment of the BMBF leading-edge cluster Organic Electronics in Heidelberg, for instance. The city of Heidelberg also made a preliminary financial contribution to this project within the framework of a metropolitan area initiative. The economy too fully supported the scientific institutions' application. Rector B. Eitel and former SAP member of executive board C. Heinrich *jointly* presented and defended the application for the BMBF leading-edge cluster at scientific and political committees in Berlin. Therefore, this project achieved the ideal of the triple helix (Etzkowitz, 2008) at a municipal level.

Not least, the efforts of urban policy in education and culture, the high standard of Heidelberg's schools, the exclusivity and internationality of the cultural program, the well-developed childcare, the Welcome Center for foreigners, the relatively low crime rate, and other initiatives of the city contribute quite significantly to Heidelberg's positive image and appeal for international scientists. The city's various activities in improving the infrastructure (including a fiber optic cable to Königstuhl, etc.) are also highly appreciated by the affected scientific institutions.

Apart from that, interviews with Heidelberg's university rectors, heads of non-university scientific institutions, and representatives from the economy have shown that the majority of respondents would like to see more commitment to the City of Science and especially to cutting-edge research on the part of urban policy. It has been suggested that urban policy should develop and adopt a **mission statement for a City of Science**, which should also be the basis for future urban development. The heads of scientific institutions also expect decision-making processes affecting science to be expedited as a result of a joint mission statement for a City of Science.

Almost all interviewed decision makers from science and the economy have also expressed a desire for the **visibility** of science in Heidelberg to be increased through various initiatives. With its unique history of science, Heidelberg could attract wealthier guests not only through tourism but also through improving the city's visibility, thus strengthening many residents' – especially the newly arrived – identification with their city.

The city administration would welcome a single strategic entity for scientific institutions per location, which would be its contact for medium and long-term planning projects. One could look to the city of Cambridge as an example: there is a pro-rectorate specifically for campus planning and urban development issues.

Meanwhile, many cities have realized that knowledge (science) is a “job machine” as well as a locational and competitive factor. Therefore, they increasingly employ “science” as an element of the city’s image or marketing. Since the Stifterverband für die Deutsche Wissenschaft introduced a competition for the “**City of Science**” award in 2005, 46 cities have applied and 17 cities have won the award. It is not the scientific institutions that were evaluated but the urban policy and city administration initiatives for their scientific institutions. The reasoning of the Stifterverband was: Only if the municipalities – municipal council, administration, and citizens – actively support their scientific institutions in networking with other social areas (also beyond the economic area), can they justify calling themselves a “City of Science” (Stifterverband für die Deutsche Wissenschaft, 2011, p. 21).

In one of its published studies, the Stifterverband für die Deutsche Wissenschaft introduced each of 16 of the cities that have won the City of Science award so far (Stifterverband für die Deutsche Wissenschaft, 2011). Indeed, these cities have employed very different strategic and operational initiatives to improve their profile as a City of Science. However, by and large, four different strategic approaches or profile features could be distinguished: the event approach (Brunswick, Constance, Jena, Kiel); the image approach (Aachen, Oldenburg, Rostock); the cluster approach (Münster, Munich); and the structural approach (Bremen, Magdeburg). Strong networking was of paramount importance in Essen, Hamm and Lübeck.

A city like Heidelberg will certainly succeed in further improving its own profile as a “City of Science” by employing original initiatives.

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