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Management of Innovation in a Flat World: Growing Complexity, Globalisation and Citizen Participation

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Abstract: Innovation is not what it was in the 20th century; the classic century of R & D based innovation. The nature of innovation is changing, only in part because different technologies dominate innovation. This paper identifies three main societal trends that are of major importance for strategic management of innovation in industry and for government industrial- and technology policies. These trends are:

- Growing complexity
- Globalisation
- Citizen participation

As a result, innovation strategy and technology policies cannot be determined by ad hoc technology push and market pull factors popping up. Strategic planning, not just of products and technologies but also of sites and alliances becomes increasingly important. Transparency and stakeholder dialogue require new competencies of the technology manager.

Keywords: R&D management, Innovation, Complexity, Globalisation, Citizen participation

JEL Classifications: O32, O31, O35

1. Introduction: Science Based Industrial Innovation in the 20th Century

The relation between natural science and technology has changed dramatically during the 20th century: Nowadays, scientific research is often crucial for new high-tech products but it played only a minor role in 19th century innovation. In the 19th century the natural science departments at universities were generally dealing with phenomena that were interesting but without any practical use.

The first changes in the roles of science and technology took place in Germany. German chemists developed processes to manufacture synthetic dyes based on coal tar. How to do research and how to organize it within the context of industry was an innovation as Meyer-Thurow (1982) points out.

The electrical inventions of Thomas Edison implied the birth of the electric industry, which was supported by research laboratories. The General Electric Research Laboratory in Schenectady, New York became famous by Irving Langmuir's 1932 Nobel Prize in Chemistry. Du Pont also started a chemical research laboratory. It made a fortune by smokeless gunpowder and expanded in fundamental research. Frictions between academic research and industrial research often occurred(see Hounshell and Smith, 1988). The history of Nylon discovery at Du Pont serves as an interesting example of the problems in the marriage between technology and science.

At the end of 1926, Du Pont decided that it would start a fundamental research program. One of the main proponents of this fundamental research program, Charles M.A. Stine, later explained the motives: 'Fundamental research assists one to predict the course of development of chemical industry. Pioneering applied research enables one to achieve certain objectives indicated by fundamental research. Therefore, the continued growth (as distinct from mere expansion) of chemical industry is dependent upon fundamental research. That is the basic philosophy of fundamental research.' Stine (1936) stated that fundamental research also improved industry-university interaction and created consulting specialists for applied research within the company. The main difference to university research would be that *'In university research, the discovery is a sufficient objective in itself,..'*.

Du Pont recruited academic scientist who had great liberty to engage in the subjects they thought to be useful. In 1928, Wallace Hume Carothers, chemist from Harvard University, was enlisted as head of the organic chemistry fundamental research group. Carothers had doubted this step for a long period for industrial research was not high valued by academics. At Du Ponts' Experimental Station, he started research on the macromolecular concept of polymers, a subject of great interest, as it was the focal point of debate in chemistry.

In September 1931, Carothers announced the possibility of obtaining useful fibres from strictly synthetic materials. At the end of 1937, polyamide 6,6 was produced in a pilot plant. At the end of 1938, Du Pont launched it as 'Nylon'. It was an overwhelming success on the market. Carothers did not live to see the success of 'Nylon'. He committed suicide in April 1937, deeply depressed and, although being the first industrial chemist admitted to membership of the National Academy of Science, convinced of having failed as a scientist (see Mulder, 1992).

Scientists like Carothers bridged the gap between academics and industrial technologists. As Harvard president, James B. Conant, said of Carothers' acceptance of a position at Du Pont: '…he had facilities for carrying on his research on a scale that would be difficult or impossible to duplicate in most university laboratories'(see Adams, 1961).

Science proved its value to industrial interests but also to military ones. During the WW II, physicists suspected that Hitler was working on a nuclear bomb. They convinced Einstein to request President Roosevelt to start a research project to develop a nuclear bomb too (see Weart and Weiss Szilard (1979)). In the Manhattan project, top physicists were gathered to build it. Physics lost its innocence in political matters, i.e. as the other natural sciences it lost its claim to be an independent force for the progress of mankind. Both Herken (2002) and Rhodes (1986) state that physicists had not only built the bomb, but had also played a main role in the political decision to build and apply it.

The interwovenness of technology and science is often called techno-science. Van den Daele (1978) indicates that science is no longer accepted as an activity purely directed towards producing objective knowledge, as was the main legitimation for science in the 19th century.

2. Major Changes in Techno-Science in Recent Decades

Three main trends are increasing the challenge of Management of Technology: Complexity of Technology, Globalization and citizen participation. These trends are further analysed.

2.1 Complexity

To state that techno-science is increasingly complex is common sense: phenomena that were not even discovered 50 years ago are utilized in the design of new products. Especially most of our current day information- and communication technologies were completely unknown half a century ago. However, technological complexity is not just growing by the development of new, often more complicated artefacts as such. The complexity of modern artefacts is often due to the use of various knowledge realms, that were unconnected before, and the interconnection to other artefacts:

The car again serves as a good example: In the 1960s, the car body was only made of steel. The car design essentially only incorporated mechanical knowledge. Nowadays, various kinds of plastics have been introduced, some of them reinforced by glass fibre. Aluminium also plays an increasing role. Electronic equipment is applied to control various functions of the car. Wind tunnel experiments have lowered aerodynamic drag, while rubber research and tire design produced much more complicated, but safer tires (Car and Driver, (2016)). The number of scientific disciplines that are used in car design increased a lot. That makes innovation much more complicated. But that is not the only complicating factor. Redundancies in the design have been decreased and therefore every minor change in a detail of the design of a car is far more likely to have consequences for other parts of it. The effect is that innovation is far more complicated: more experts and disciplines are involved, and more adaptations are needed before a design is fit for production.

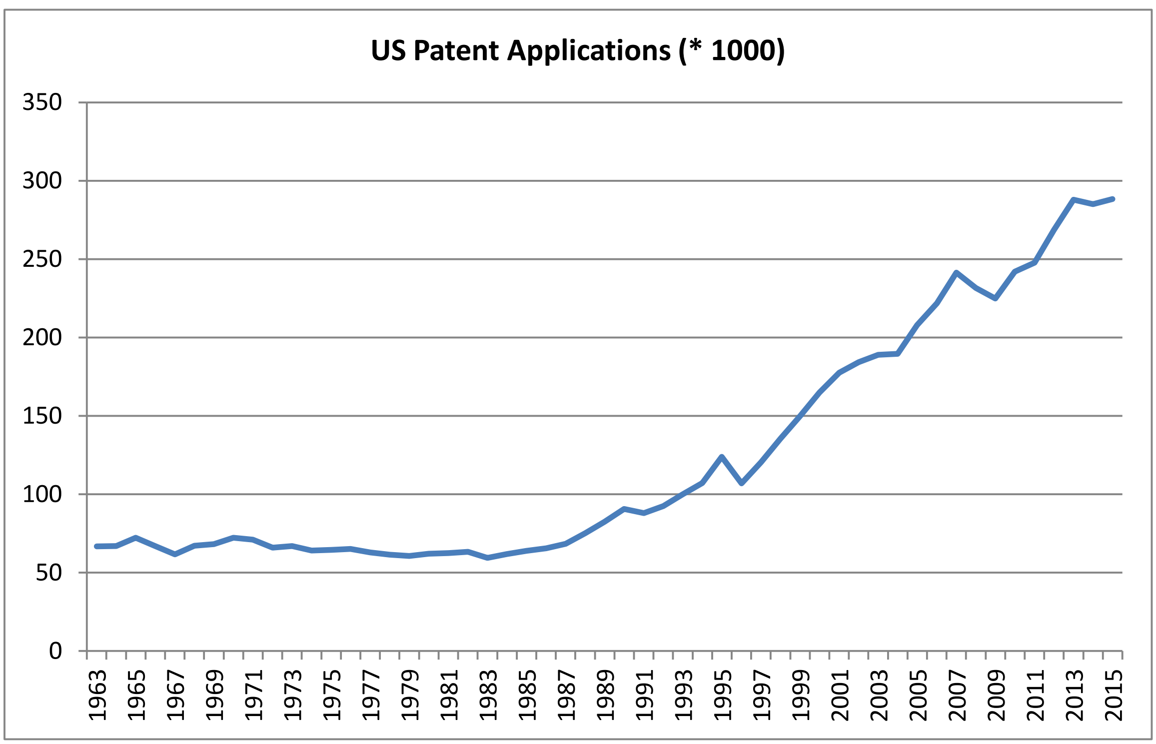

Figure 1. Rising number of Patent applications in USA (Source: USPTO, 2016)

Moreover, world-wide R&D has been growing just as the world wide expenditure on science. This creates an increasing flow of information that has to be tracked by innovating companies. The Internet is a new tool to get this information but retrieving the right information becomes hard by the plethora of untrustworthy information, viruses, hackers and spam.

2.2 Globalization

The innovation process for products of increasing complexity requires considerable more efforts and resources than it did in the past. These increasing innovation costs could best be covered for by increasing the market. As the innovation costs are not dependent on the volume of sales, they become relatively lower when market sales grow. As trade barriers have decreased in recent decades, this created a strong drive for companies to market their products globally. Especially products with low transport costs can easily be marketed worldwide. Products with higher transport costs can be produced in the main regions of the world, according to the main product (and production process-) design. Companies that might be unable to operate worldwide either find overseas partners, merge, or disappear. The result can be observed by every traveller: Some decades ago it was easy bringing home presents to the people back home. Nowadays it is much harder as the offer of presents appears to be identical in every airport of the world.

Company	**Brand**	**Website**	**Country of origin**	**Entrance US market**
Akai		http://www.akaiusa.com/profile.htm	Japan	N.A.
Curtis Mathes		http://www.curtismathes.com/aboutus.asp	USA	1960
Hitachi		http://www.hitachi.com/index.html	Japan	1975
JVC		http://www.jvc-victor.co.jp	Japan	1976
LGE	Zenith	http://www.lge.com/index.do	Korea	1999 (1948)
Matsushita	Panasonic	http://www.panasonic.com	Japan	1975
Mitsubishi		http://global.mitsubishielectric.com	Japan	1980
Philips	Magnavox	http://www.consumer.philips.com	Netherlands	1976
SAMPO		http://www.sampoamericas.com	Taiwan	1981
SAMSUNG		http://www.samsung.com	Korea	1989
SANSUI		http://www.sansui.co.jp/info/index.cfm	Japan	1987
Sanyo		http://www.sanyo.com/home.cfm	Japan	1977
Sharp		http://sharp-world.com/index.html	Japan	1983
Sony		http://www.sony.net	Japan	1961
Tatung		http://www.tatung.com	Taiwan	1979
Thomson	RCA	http://www.thomson.net/EN/home	France	1987(1946)
Toshiba		http://www.toshiba.co.jp	Japan	1976

Data source: TVhistory (2016).

This effect can also be illustrated by the history of the television. In 1950, when only 10% of the US households owned a television set, 33 manufacturers sold the sets on the US market. All of these manufacturers were US companies that were not owned by foreign interests. In the year 2000, 16 manufacturers were supplying TV-sets in the US. Only one manufacturer was still a US company: Curtis Mathes.

The reduction of the number of TV suppliers might be seen as remarkable, but there is a much more interesting phenomenon: In the 1950s and early 1960s, the manufacture of TV sets in all industrialized countries was completely dominated by national industries. Nowadays, the television brands that one can buy in various countries are virtually the same. Except for Curtis Mathes, all brands that are sold in the USA are sold in various parts of the world. A small sample of 3 Internet shops in The Netherlands shows that 10 TV set manufacturers also marketed their products in the USA, while there were 3 more manufacturers (Finlux-Finland, Vestel-Turkey, Orion-Singapore) that were still working at their global expansion. This phenomenon cannot only be observed for TV sets. It applies to many manufactured goods such as cars, radios, washing machines, etc.

Consumers have somewhat les choice of products. But far more important is that most people in the world have more and more identical choices. The world becomes more uniform, and therefore perhaps somewhat less exciting.

This trend is reflected in R&D expenditures. Companies increasingly tend to put their R&D facilities in those places that offer the best circumstances for (scientific, technological development) cooperation. This trend continues, especially in regard to 'emerging markets' (Light, (2011).

The historic R&D home base of a company still plays a role, but is generally also the node that connects the company to its R&D centres in other main technological regions of the world.

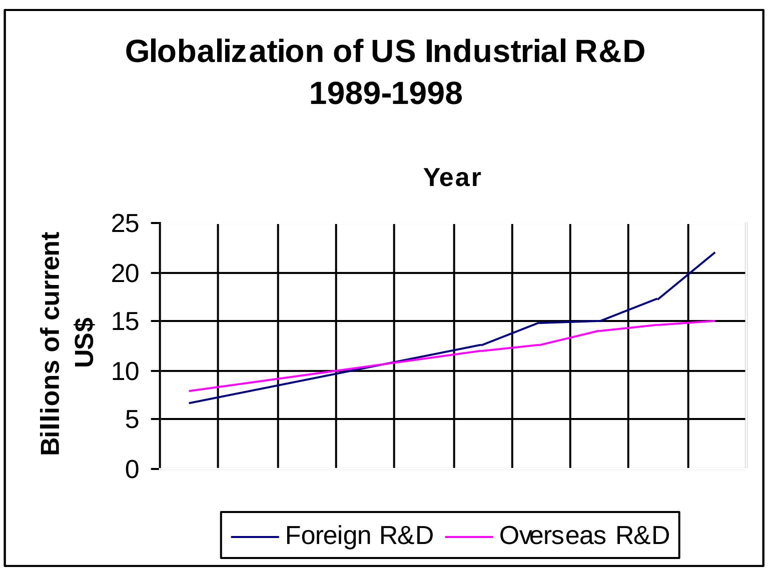

Figure 2. Money spent in industrial R & D, foreign R&D v.s. overseas R&D

Notes: Foreign R&D refers to R&D performed in the United States by U.S. affiliates of foreign parent companies. Overseas R&D refers to R&D performed abroad by foreign affiliates of U.S. parent companies. Data source: NSF (2003).

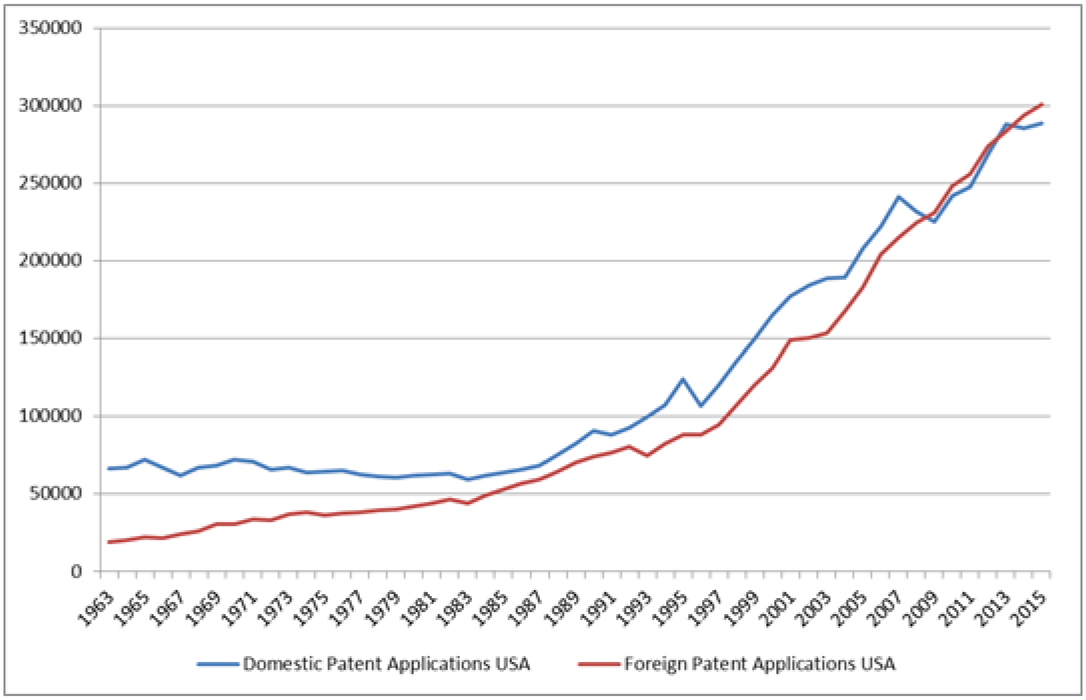

Figure 3. Origin of US Patent Applications (Source: USPTO, 2016)

As corporations tend to operate more and more at a global level, competition increases. The increased competition implies that no company can get away with products that do not meet today's technological standards. More speed of innovation is required. However, as corporate resources are limited, the company needs to focus its efforts. The effect is that companies widen their geographic area of activities while narrowing down the range of products that they make. Large conglomerates, that in the 1970s produced products as varied as coffee, coatings, drugs, steel wire, shipping, and plastics, have now generally focused their activities on only one product sector.

2.3 Citizen participation

The 1960s and 1970s have formed a watershed in the political history of many Western countries. Until the end of the 1960s, the parliamentary system implied that parliaments, and the governments that were controlled by them, had almost absolute powers. The influence of citizens was generally limited to elections. Formally this is still true. However, it can be observed in most countries that various groups of citizens do not accept decisions solely because of their parliamentary legitimation. Large shares of the population of industrialized countries are highly educated. They do not take government actions for granted if their own interests or convictions are at stake. Citizens' protests cannot be neglected by governments anymore, and therefore companies should not only apply for government licences for their activities, but also seek for support within the population.

Participation in higher education in several European countries. Selection of countries based on availability of data. In these countries, the number of students increased by a factor of 4.05 in these years UNESCO(2016).

Table 1. Number of students in higher education in several European countries

	1970	**1996**	**2014**
Albania	25469	34257	173819
Austria	59778	293172	421224
Bulgaria	99596	262757	283294
Finland	59769	226458	306080
Iceland	1706	7908	19099 [1]
Italy	687242	1892542	1872693
Netherlands	231167	468970	793678 [2]
Norway	50047	185320	264207
Romania	151885	411687	578706
Spain	224904	1684445	1982162
Sweden	144254	275217	429444
United Kingdom	601300	1891450	2352932

Before the 1960s, technology was generally regarded to be a positive sum game: the benefits of new technology always exceeded the costs. Therefore the people that tried to stop certain innovations were barriers to progress. This image changed in the 1960s. Some technologies, such as agricultural chemicals, turned out to have far more disadvantages than advantages for society. Nuclear weapons, that were developed to make the world safer, created for the first time in human history the possibility of a total human self destruction. It was often questionable if the sum would be positive. Moreover, the distribution of advantages and disadvantages was problematic: chemical producers and farmers had some benefits but the chemicals destroyed ecosystems from which for example fishermen earned their living.

At the end of the 1960, the US Congress decided to start *Technology Assessment;* to create an office for assessing the (broad) effects of a new technology in terms of costs and benefits.

To assess these effects is rather hard. The direct effects, including unintended effects, are not always clear beforehand, but what about the second and third order effects that are caused by changed patterns of behaviour because of the availability of the technology? People nowadays tend to live at longer distance from their work because of the availability of transport, but could this geographic consequence be foreseen when the car became a widely available means of transport?

> *The intended effect of the anti conception pill was a more reliable and easier control of human reproduction. It permitted people to behave more promiscuous, a second order effect. A third order effect was an increase in sexually transmitted diseases. This caused many people to return to more traditional means of birth control.*

However, it is often hard to predict these causal relations and their consequences in advance. The US Congress adopted a moderate definition:

> *Technology Assessment is a form of policy research, which provides a balanced appraisal to the policymaker. Ideally, it is a system to ask the right questions and obtain correct and timely answers. It identifies policy issues, assesses the impact of alternative courses of*

[1] Number in 2012.

[2] Number in 2012.

> *action and presents findings. It is a method of analysis that systematically appraises the nature, significance, status, and merit of a technological program* (Daddario,1968, p.10).

Also for the private sector, Technology Assessment makes sense. Companies could argue that compliance to the law is sufficient when introducing technological innovations. However, the introduction of new technologies that cause effects to third parties, although legally allowed, will often trigger the introduction of new legislation and/or lawsuits. At the end, this might ruin the business that was intended by introducing the innovation, (Malanowski, et at.(2001)).

Therefore, the public legitimacy of corporate activities can no longer be dealt with by complying with legislation. It also requires taking societal values into account in order to be trusted. Protests against corporate decisions might be supported by local and/or regional governments. Moreover, the citizen might use its role as a consumer to put pressure on companies. The power of the consumer makes even the largest multinational vulnerable. Illustrative is what happened to Shell in the Brent Spar case:

> *In 1995, the UK government allowed Shell to sink an old oil production platform in the North Atlantic. Greenpeace objected and tried to stop it but was removed from the platform. However, Shells' gas stations throughout Europe became deserted places. Various politicians joined actions against Shell. Ultimately, Shell had to change its plans and the Brent Spar was dismantled and re-used in Norway* (De Groot van Embden,2000).

An important lesson from the Brent Spar affair is that the environmental protest does not necessarily have to be right: it is open for debate whether the final solution was better for the environment than dumping the platform on the ocean floor. However, what counts is that Shells' arguments were less credible in the eyes of the public than Greenpeaces´arguments.

3. Dealing with the Consequences

3.1 The world as a global community, global issues, global cooperation

Many corporations must act on a global scale. They therefore must learn to deal with various cultures within and outside their organisation. Complying with the law in each nation is not enough: consumers and employees of the company will protest against actions that they consider wrong: exploitation of workers, environmental destruction, or racial discrimination. Therefore firms need to adapt to local circumstances but also need to develop corporate standards of behaviour.

Globalisation also means that firms need to be present in the main technological hot spots. Although one might argue that it might be most efficient to concentrate Research and Development at one location, it is often not very wise. A research laboratory acts as a node to make contact with a local/regional research community. For a Western company it will be hardly possible to set up cooperation with a Japanese research unit without actually being present there.

3.2 Assessing the consequences of technological innovation

Technology Assessment in the public sector has been carried out for more than 30 years. After the US Congress started its Office of Technology Assessment in 1972 various industrialized nations established TA institutes in the 1980s and 1990s (Smits, 1990). The changes in theorizing on technological change, that is to say the debates regarding autonomous technology or socially constructed technology, did leave Technology Assessment unaffected. Technology Assessment institutes gradually shifted their activities from mere advising parliaments on impacts of new technology, to strategies for steering technology and promoting active participation of citizens in discussions on new technologies (Van Eijndhoven (1997), and Rip, et al.(1995)).

In business, as early as in 1982, Maloney (1982), Fleischmann and Paul (1987), and Simonse, et al.(1989) noticed that Technology Assessments were also made, although these efforts were also criticized as being too narrow minded (Coates and Fabian (1982)). Technology Assessments in business were often more or less extended technological forecasts. Unilever Research director Professor Wiero Beek said in 1988:

> *'For me, the overriding question now is not so much to get TA even better institutionalised in scientific circles (as a scientific discipline, TA, given its subject matter, will always be weak in terms of logical conviction, but to get it better institutionalised in political and managerial circles'* (Beek, 1995, p.84).

Van Ginneken, and Van Hulst (1996) indicate companies chose scenario planning as a main impact assessment tool, probably because this method allowed many people to be involved in the strategy process. The success of scenario planning was that it allowed companies to involve a large part of its human resources to participate in the creative thinking process on the future.

Facing controversial issues, most companies were very careful. Companies with interests in biotechnology took great care. In 1993, Unilever initiated consultations with various consumer and environmental organisations regarding biotechnology. Other companies joined these consultations (Anonymous, (1993)). One of them, Gist Brocades, had developed a biotechnological process to manufacture chymosine, a coagulant to produce cheese. However, the dairy industry refused to use it, afraid as it was to loose its (export) market. Gist Brocades and three other companies joined in another project, which aimed at finding a way out of the deadlock on modern biotechnology and food. The report advised corporations to:

- take the issue of public acceptance seriously and to not leave it to the final R&D stages,
- be more open to the public,
- deal seriously with the public (even if it is 'irrational') and
- be willing to adapt products and processes.

Corporations should prepare for interaction with their environment, optimise learning effects and build up a corporate memory (Jelsma, and Rip(1995)).

So Technology Assessment studies can be important for companies, especially if they contribute to setting up dialogues with citizens (see for an overview of methods by Van Den Ende, et al.(1998))

3.3 Systems innovations need inter-firm and public private collaboration

For innovation, the globalisation process creates a problem: the core business of firms is narrowed down, but the firms operate world wide. Therefore an increasing part of innovations will require various types of technological knowledge that are not available within research & development departments of single firms. Senseo, the coffee machine developed by Philips Electronics and Sara Lee/DE consumer products is a good example of such an innovation: This new way of making coffee comprised a new coffee machine, a new coffee blend, and new packaging for the coffee (Du Chatenier, et al. (2009)).

Inter-firm cooperation is therefore very important. However, setting up a good cooperation is hard: The main factor for success is trust between partners that recognize the values of the mutual contributions and respect mutual interests (EIRMA, (2002)).

4. Conclusions

4.1 The increased challenge of managing innovation

Innovation requires the ability for managing various heterogeneous subjects. Management of Technology is like playing chess against some dozens of opponents simultaneously. Entrepreneurial profit is in fact the reward for contributing to society. Profits that are acquired without a positive contribution to society are generally soon terminated by legal- or consumer actions. But contributing to society is not enough. Being in time is crucial, just as communication with stakeholders is.

Innovation is a challenge for the coming decades, not just for economic growth, but also to enable high standards of living for a growing part of the world population. China and India are rapidly catching up with Western standards of living and other countries will follow. This will lead to a sharp increase in resource consumption, even if the industrialized countries could increase their efficiencies of production. Natural resources are limited and we will be confronted by these limits. Innovation will be a necessity for the future. Meanwhile as is shown in this paper, innovation has become increasingly complex and hard to establish, for individual companies as well as for national authorities. Managing the innovation process is therefore a challenge of unprecedented magnitude.

4.2 The new manager of innovation

The dichotomy of industrial management and public policy has come to an end. The implication is that innovation managers should be educated to be sensitive to public policy issues and public communication. The traditional reaction of industrial firms to public policy issues, creating high level agreements with authorities based on expertise, will not work anymore. Successful firms will have to engage pro-actively in potential public policy issues. Transparency is of major importance to be trustworthy, but is a challenge for the new manager of innovation which still has to deal with competition.

Innovation managers need further professionalization in order to deal with the trends sketched in this paper. Interdisciplinary knowledge of innovation, economics, public policy, communication, systems dynamics and knowledge management will be crucial.

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Biosketch

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He teaches in the areas of industrial innovation studies, Sustainable Development as a challenge for innovation and the impacts of innovation upon society. His current research interests are especially focused on innovation in urban infrastructures.

Mulder chaired the Technology & Society department of the Dutch Royal Institute of Engineers from 1994 to 199haired published various papers, books and book chapters regarding innovation, innovation strategy, sustainable innovation and engineering education for sustainable development.