LEARNING FROM THE PAST: INNOVATION EVALUATED BY STRATEGIC NICHE MANAGEMENT METHODOLOGY

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ABSTRACT

The leading question in this paper concerns the reasons that may stimulate or hamper a wider diffusion of innovative technologies in the construction industry. The Strategic Niche Management (SNM) approach provides an evolutionary framework that is supposed to give a better insight into the reasons why new technologies may be successful or fail even though they promise superior performance compared to incumbent technologies. The SNM approach has been applied in a number of cases of innovative energy and transport technology solutions. The findings will be discussed by thriving on the theoretical backgrounds of the SNM approach and on literature describing the application of the SNM methodology in energy and transport technology cases as well as on the conclusions of the study on the application of it on the wider diffusion of an innovative prefab building system in the Dutch construction industry.

Keywords: *construction industry, diffusion, innovation, prefab building system, strategic niche management*

INTRODUCTION

The construction industry everywhere still faces problems and challenges: globalisation, increasing competition, evolving new technologies, population growth, urbanisation, extensive need for housing and the need to reduce pollution substantially. A considerable variety of technologies has been developed and became available in the global market over the last decades. Innovations could help solving (some of) the problems faced by the construction industry. However the diffusion and implementation of new technologies is progressing slowly in the construction industry. Construction is deeply embedded in local laws, regulations, institutions and not in the least place in long -established professional practices. Many technological opportunities are under-utilized. This happened to be the case with prefab steel housing systems in the Netherlands as well. In the quest for meeting the housing needs at a good pace the use of certain building materials such as steel as well as prefabricated building systems appear to have beneficial properties. Prefab steel structures have been developed and applied reasonably successful in de US, France and Japan. In contrast the prefab steel based housing systems in the Netherlands -developed after World War II- hardly took off. By application of the ideas of the Strategic Niche Management (SNM) methodology we make attempts to discover the reasons for this. In this paper we describe our study of the innovation trajectory of the Polynorm prefab steel system. The results were expected to be useful to find better ways of introducing and diffusing promising technological opportunities and thereby alleviate problems in the construction industry.

THEORY / METHODS

Extensions of the neoclassical theory (e.g., new growth theory) as well as alternative approaches have emerged over the past decades, in attempts to explain the phenomena of innovation, including the broad field of evolutionary economics. The evolutionary concepts have been applied in a diversity of attempts to improve the understanding and explanation of the rate and direction of technological developments. Also the Strategic Niche Management (SNM) approach rests on an evolutionary framework. It is supposed to give a better insight into the reasons why new technologies may be successful or fail even though they promise superior performance compared to incumbent technologies. The SNM approach thrives on the idea of technological niches and the possibility to manage these (Schot & Rip 1996). The core concepts in the evolutionary framework are innovations and technological regimes within innovation systems. *Innovation* refers to the *invention* - i.e. the development of new technologies (products and production processes) and knowledge- as well as to the *diffusion* (acceptation, adoption) and *implementation* of these. Inventions can either be the result of local R&D efforts, or they can be acquired from abroad through international technology transfers. After their introduction, the innovative technologies can be diffused within a community or between communities. A successful diffusion is taking place as soon as the invention is selected, accepted and implemented by companies or institutions, or by people by means of which the technology is dispersed into society. This spread is accomplished through human interactions; communication between members of a social system (Rogers, 1995). The more companies, institutions or people adopt the technology, the more widely it is diffused. Innovation or technological development takes place in on-going cyclic processes (Egmond 2001). The innovation cycle is on going, because new needs keep on emerging in every modern society, be it because of changing rules and regulations, demographic changes, technological changes, or other developments. *Diffusion* can be measured by the rate of adoption of (new) technologies. A technology is more beneficial to more people if the ones benefiting from it can understand and adapt it to their (local) needs. Thus the technologies most adapted to local circumstances are the ones that are adopted most widely in the innovation system.

An *innovation system* is the network of interrelated individuals, organizations and enterprises who share a common field of knowledge and interest in a certain domain. (Malherba 1999) It is the social organizational environment in which innovation takes place. The actors can be found at 1) international –; 2) national- ; 3) sector-; and 4) company- or project level. They behave following a certain Technological Regime.

A technological regime (TR) is seen as a social construct -a pattern- made of knowledge, rules, regulations conventions, consensual expectations, assumptions, or thinking shared by stakeholders in an innovation system, which characterize professional practice and which guide the design and further the development of innovations (Kuhn 1962, Dosi 1982, Nelson & Winter 1982) Innovation theories point at *technological regimes* as key elements in diffusion, acceptation and application of new technologies. The theories also state the importance of gradual TR changes through interactive learning processes to maintain competitiveness as well as of the importance of the development and supply of complementary inventions, such as for example a need for institutional adaptations -in management, organization and the overall innovation system in which firms operate- when new technologies are to be adopted and implemented. Douthwaite (2002, p 75) stated in line with the above "Adapting the parable of the seed & the sower, a technology, however good it is technically, will only be adopted and prosper if it falls on fertile ground." Thus an implementation and diffusion of an innovative technology will be successful if it fits in the prevailing and adaptive technological regime that characterizes the professional practice of actors in the innovation system. A *regime shift* is a significant, profound and irreversible change from one fundamental view to another, a different model of behaviour or perception (Nelson & Winter 1982).

The SNM approach distinguishes a technological network, analogue and next to the social network in the innovation system. The technological network is the network of technologies in a certain domain in which the technologies serve a certain function. Nodes of the network are technologies. The position of a technology in the network is its technological niche in the domain. The idea of a technological niche means that a certain technology exists -or is developed- alongside other technologies, whilst it serves a specific limited domain of application. A technological niche is different from a market niche. The market potential - expected rate of return on investment- plays a role in technological niches. Like markets, technological niches are carried by networks actors (innovation system - the institutional framework-) and by a set of assumptions and expectations (technological regime). Promising innovative technologies are often undersupplied by the market because of high uncertainty, high up-front costs, or because the technical and social benefits are insufficiently valued in the market place. The SNM methodology promotes an interaction between the Actor and the Technology network. SNM aims for *interactive learning* and *societal embedding* of an innovative technology to bridge the gap between innovation and diffusion. From historical evidence can be learned that innovative technologies often received some kind of protection and support from certain actors (niche managers), usually in the form of stimulating a particular market demand or by technology development programmes, which create a market niche for a fledging technology. Different actors in the innovation system may be the niche manager: policy makers, a regulatory agency, local authorities, a citizen group, private company, an industry organization, or a special interest group. The niche manager may be a person or a (newly founded) organization. Governments generally have a special role as a facilitator to stimulate that the diffusion and implementation takes place.

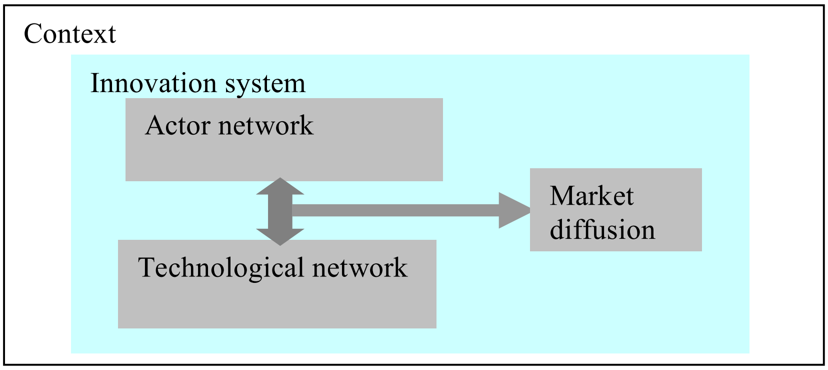

Figure 1. Theoretic Framework

The SNM methodology includes a number of sub-studies i.e. the analyses of (a) the properties of the innovative technology compared to the existing ones in the technology network by using the Technology Mapping Methodology (Egmond 1999); (b) the actor network, its prevailing technological regime and potential niche managers by using the social network analysis methodology; (c) the current promoting or constraining factors of the context and the innovation system, that affect the adoption, implementation and further diffusion of the innovative technology in question. Based on the results of the analyses it will be possible to identify adopter groups and get a better idea of important market requirements as well as to identify a potential Niche Manager. By feeding back of the gained insight, strategies can be determined, that can be followed to stimulate the adoption, implementation and diffusion of innovative – and promising- technologies.

The SNM methodology has been applied, verified and improved in various cases in the transport and energy sector, which acknowledge its validity. (e.g. Kemp et al., 1998, 2001; Hoogma et al., 2002; Lane, 2002; Raven, 2005; Geels and Raven, 2006) From all these studies can be learned that the interaction between the Actor Network and the Technology Network are important in the innovation trajectory. In his studies Raven (2005) distinguished three interrelated interaction processes that lead to successful adoption of an innovative technology, which in fact come down at (1) *strengthening the ties in the Actor Network* and *changing the Technological Regime* by (2) "*Voicing and shaping*" the perceptions, expectations and valuation of the technology and (3) *learning processes* which enable a better insight and understanding of the technology (social embedding).

RESULTS AND DISCUSSIONS

An innovative technology for residential construction in the Netherlands in the past

The case study

Subject of the case study is the Dutch Polynorm building system developed in the period 1943-1952. It was a remarkable innovative construction technology, which comprises a lightweight prefab modular steel system composed of parts and elements that were to be assembled on-site into a variety of housing units. Although the Polynorm building system seemed reasonably suitable to provide a technological solution for the Dutch housing shortage in the prevailing situation at that time, it did not take off. Many data were collected by staff and students at the Eindhoven University of Technology, which we used in our study.

Context

The Polynorm system was developed to meet the extreme housing needs in a context of a severe scarcity of materials and financial means after World War II in the Netherlands. After the war the annual demand for housing increased tremendously to approx 70.000 units per year, due to the war destructions, the construction stop during the war in 1942, and an explosive growth of marriages and births after the war. However, the investment capacity for housing was rather low at that time. Concurrently there was a scarcity of construction labour, since the training and education programs had stopped during the war and the available workforce lost their skills and techniques. Moreover, other industries with innovative technologies were more attractive to young people. Before WW II there was no shortage of building materials neither was there a shortage of labour. Annual production of about 40.000 houses per year matched the annual demand for housing due to population growth. Residential building construction could easily be financed.

Technology systems for residential building

Traditional building systems such as those commonly used before World War II for residential buildings in the Netherlands was labour intensive and took in majority place on-site by using masonry systems with burnt clay bricks with timber flooring and roofing systems. Building materials that came on site as manufactured products were bricks, glass, connection materials, hinges and ironmongery. Prefabrication of building elements – especially steel based parts- has already started, but only limited and in cases of scarcity of labour and material. Examples are the 10.000 houses which were built in the UK during the 1920s with the Dorlonco prefab steel system and a prefab timber system in Sweden (135.000 houses in 1927). (Lichtenberg 2002) Although there was some experience with alternative prefab building systems before WWII in the Netherlands, they did not catch up due to stabilization of material prices and labour costs (Bouw 1948) After the war a variety of innovative prefab building systems were developed to overcome the housing backlog. Among these were Krabo, Bron, NV Systeembouw, Elementen bouw, Trabo, Bruynzeel, Duinker & Verruit, Daalbouw, Airey and Polynorm. Next to these prefab systems also monolith concrete construction systems were developed. The latter could ascertain a breakthrough at the end of the 1950s, thanks to the development of special formwork, such as tunnel forms, with which a reduction of 66% man-hours could be reached for wall and floor construction, provided that the houses are built in mass construction projects. (Blom 2004)

The Polynorm building system

The Polynorm system promised a high speed fulfillment of the extreme housing need of the Dutch lower and middle income population after World War II by means of industrialized (mass-) production and application of a modular lightweight prefab steel structure at lower cost.

Figure 2. The Polynorm Building system

The houses built with the Polynorm system provided functional spaces and integrated facilities in line with the requirements of the post war households and building regulations. The standard housing units built with the Polynorm system (comply, with the required minimal dimensions (Guidelines "Voorschriften en wenken voor het ontwerpen van woningen", 1951). The major properties of the Polynorm system are indicated in table 1.

Table 1. Major properties of the prefab Polynorm building system

Production & construction	Industrialized mechanical engineering based production, High accuracy, low tolerance, relatively high quality Integrated elements for services Decreased production costs of building system Decreased on-site Construction time

	Increased quality of building system Easy light weight on-site assembly Un-skilled on-site labour Decreased dependence from climate during on-site work
Material use	Functional and durable to reduce material and weight Cold rolled strip steel profiles (1-3mm) with rather low carbon contents, from scrap steel, in abundance available after WW2. Light weight steel frames (25% of the weight of traditional systems) Decreased dimensions of the foundation *Exterior walls* :prefab concrete façade panels fixed to columns, cavity with rockwool insulation (40mm) & interior asbestos sheets fixed with small aluminum frames to steel construction *Separation walls* prefab concrete panels R*oof* aluminum roofing sheets.
Strength & rigidity	In accordance with the building regulations
Durability	Steel system lasts at least 50 years (in reality even outlasted that period) Relative high level of corrosion resistance (by painting and muffling) Limited maintenance (specific façade construction & appropriate technical details).
Fire resistance	secured finishing with asbestos sheets
Thermal & sound insulation	In accordance with regulations in 1950. (cavity wall construction with 50mm rockwool insulation) Impact noise abatement by means of soft board strips on top of the steel joists.
Humidity resistance	Weak does not meet the building regulations Humidity percolation and roof leakages after some time
Functionality	Spaces, dimensions and facilities according to building regulations
Aesthetic quality	Not directly in line with the conventional expectations. Primarily a consequence of functional and technical requirements. Alleviation of the housing shortage more important than aesthetic quality. System allows adaptation of building appearance to ideas of local architects and households by means of different finishings
Costs	Decreased total building costs possible thanks to construction time reduction

The fact that rockwool *insulation* was not common by that time (1950 certainly no obligation) can be considered as an extra quality of the Polynorm system compared to the traditional ones. A weak aspect appeared to be the *Rainwater and Humidity resistance* of the system.

Provisions for services were included in the production process of the steel frames. The production of the steel elements had to take place with a high precision. The basic concept of industrialized prefabrication of the building components has been taken over from mechanical engineering based mass production processes. A prerequisite was a seamless connection between the different elements, which did not allow any tolerance. Production had to be adapted in communication with the on-site construction which took place by the Polynorm construction company with un-skilled labour force on-site. The traditional contractor with his craftsmen disappeared from the Polynorm building site.

Actor network involved in Polynorm housing projects

Figure 2 illustrates the profile of the actor network such as it performed in housing projects with involvement of Polynorm. The thickness of the lines indicates the strength of the relationships amongst the actors. The actors indicated in italics were the actual decision makers for a project in the period 1945-1952. After 1952 the major decision making tasks were decentralized to the municipal authorities.

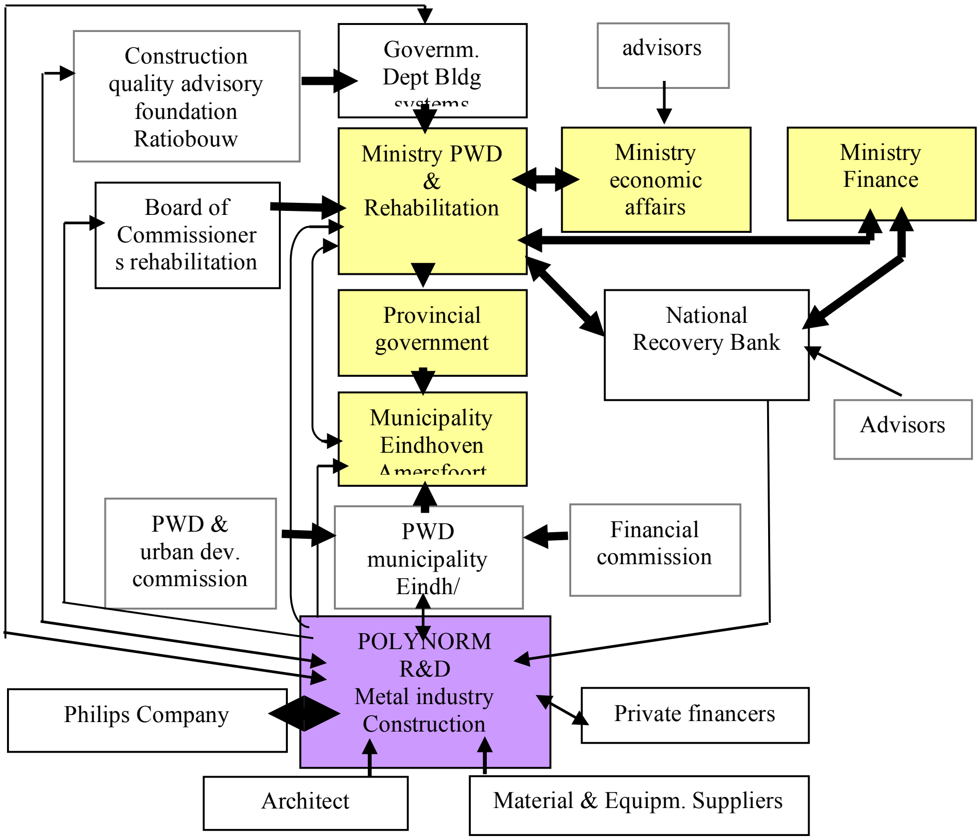

Figure 3. Actor Network

Technological Regime (TR) amongst the actors

The TR of the Dutch government during the post war years can be traced back in their policies, strategies and professional practices. The policy was focused at a fast post-war rehabilitation and industrialization towards socio-economic growth. For that purpose financial means were put at disposal for innovative building systems with which residential building projects could be carried out at a higher speed. The building systems should meet certain conditions that were safeguarded by advisory groups such as Ratio-bouw (construction quality advisory foundation). The latter had a positive opinion about the Polynorm system and strongly recommended to put the system into practice with support of government financing of the R&D costs, the costs of a pilot project, the set-up of production plants and the execution of housing projects. In general, can be stated that at national level, government authorities were positive regarding the Polynorm system. However, the decision making procedures were rather complicated and time-consuming.

The local authorities at municipal level had in the first instance a less positive opinion of the Polynorm system at least in the case of the Eindhoven municipality. Their opinion was based on the negative perception of the aesthetic quality of the houses. Moreover, the idea was that steel is ‘temporary’ and ‘perishable’, since steel is subject to oxidation. On top of that they considered the costs of at least the pilot project too high.

The perceptions and opinions amongst municipalities differed as appears from the fact that the Amersfoort municipality agreed on the execution of the pilot project in their city. Besides the establishment of a new industry in the neighborhood, that helps to alleviate un-employment problems in the region, could have given an additional motivation to approve the plans for the pilot project.

The driving actors behind the Polynorm system were the inventors themselves, who were convinced of the quality and benefits of their product with which they could conquer the national and international market. They founded their vision on their perception that industrialization of the construction process could give a solution to the problem of fragmentation due to which construction failures in terms of cost en time overruns occur. To their opinion through industrialized construction production, construction and assembly could be carried out by one party, which completely finishes the building. By doing so it is possible to bring about (1) building at faster pace; (2) meeting the functional needs for housing of the population (3) achieving a higher quality through prefab assembly; (4) being in-dependent of skilled workforce; (5) being independent of outdoor weather circumstances. They don’t mean that all buildings should look alike; rather building elements should be produced that are applicable to any type of building. Moreover, the produced elements should be compatible with the elements applied in traditional building systems. Failures of other attempts to industrialize the construction industry should have been based on a focus at single elements or components that are incompatible to their opinion.

They founded the realization of their objectives on their perception that thin-walled cold rolled steel is an excellent material to meet their ideas, which enhances the rate of accuracy in construction and reduces the dead load of the building; is beneficial for material utilization in the foundation as well as facilitates handling of the elements during on-site assembly. The practices of Polynorm can be illustrated by the division of tasks within the Polynorm group of enterprises in such manner that these correspond to the capacities of the management and their workforce to be able to manage and control the processes efficiently and effectively. This implied that the organizational structure was based on the primary processes (R&D, Production, Publicity, External relations and Construction/ Assembly) and the corresponding responsibilities were allocated to the divisions in question. In practice this organizational structure lead to a negative effect on collaboration between the divisions. The cold rolling of steel technology (knowledge, skills and machines) were transferred from the USA, without any guidelines on how to use and maintain the machines properly. This implied a learning-by-doing process for the workforce that had to be trained for the job, which has been rather time-consuming at the start. Besides the production process was subject to great pressure particularly during the housing project at Eindhoven. Production and construction were not geared to each other, which resulted in delivery of in-sufficient, wrong or no material at all on site. Using un-skilled workforce on-site appeared to be impossible since – especially at the start of the housing project at Eindhoven- many adaptations had to be made to the basic elements to fit them together. Internal communication failed, much has to be organized informally, due to which the processes could hardly be controlled. External relations were limited to the national governmental institutions, some municipalities and existing ones such as with the Philips Company. Competition failures included project costs and delivery time as well as a lack of acquisition capacity. The latter became clear in Polynorm's dependence on one party (the government) and their failure to anticipate on changes in the decision-making structure of the government.

It must be admitted that there have been made construction mistakes or design errors in the past that have endorsed the opinion that steel is not an appropriate housing material. Historic tragedies with noise pollution, condensation and overheating still pursue steel. This leads understandably to suspicion, distrust and persistent prejudices. This is not only the case with consumers, but also in with contractors and construction companies.

Table 2. Innovation trajectory of the Polynorm system

1943	Idea
1945-1947	1945 R&D prototypes 1946 Establishment Polynorm Foundation Start networking Negotiations for financing factory + for financing Pilot project at Eindhoven & Amersfoort 1947 Start pilot project 4 houses Amersfoort financed by private funds and National Recovery Bank
1948-1949	• 1948 successful delivery 4 pilot houses 1948 Establishment of Polynorm R&D company; (b) Dutch metal industry; (c) construction & assembly company 1948-1949 Construction of production plant at Bunschoten 1948 Philips & Eindhoven willing to investment in 212 houses at Eindhoven 1949 Negotiations on housing project Eindhoven • 1949 Construction of 54 houses for employees near factory financed by Municipality & Polynorm
1950	Building plans 212 houses at Eindhoven & specification approved Building permit issued Projected delivery date 31 dec 1950 Start mass production steel frames

	Start construction with unskilled labour by Polynorm Assembly company System needs several on-site adaptations • Delay delivery raw materials to factory
1951-1954	Oct. 1951 delivery 20 houses Adaptations needed technical details due to water percolation in facades. Febr 1952 delivery 98 houses • June 1952 total delivery 212 houses

1943 The idea for the Polynorm system came from Horowitz (mechanical engineer) employed as researcher by the Philips company (N.V. Philips 'Gloeilampenfabriek) at Eindhoven He was experienced in mass production of consumer goods and elaborated his idea in close collaboration with van Hulst Sr. (director Automatic Screw Works at Nijmegen), his son (director PWD at a municipality) and van Waveren (Philips mechanical engineer).

1945 Direct after the war they started realizing their plans, established together the Polynorm foundation and investigated options at the cities Eindhoven and Amersfoort to carry out a pilot project of four houses (1946). At that time the Dutch government had a program to stimulate post-war rehabilitation and industrialization for which financial means could be obtained under certain conditions. For project proposals that support rehabilitation this meant that they had to obtain the approval of the Construction Advisory Foundation (RatioBouw) as well as of the municipality in which the project is to be realized. RatioBouw gave a positive advise, which was taken over by the Ministry of PWD and rehabilitation. At Eindhoven however the municipality rejected the application based on their concerns about the aesthetic quality of the houses and the costs of the project that included R&D costs.

1947 The Amersfoort municipality approved the project thanks to the additional recommendations by RatioBouw to carry on with the project. The 4 houses were successfully built (1947-1948) in majority with private finance (by v Hulst) and partly with finance of the Dutch government. The pilot project delivered quite some valuable information, which was useful for further development of the Polynorm system. (Polynorm 40 jaar, 1988).

1948 After the pilot project the Polynorm inventors invited their relations – amongst whom the Philips directors, government officials and municipality employees- to show the success of the project and promote the Polynorm system. This stimulated the Eindhoven municipality and the Philips company to engage an architect to develop a project for 300 Polynorm houses at Eindhoven.

In 1948 the Foundation Polynorm was transformed into the Polynorm organization that was composed of three individual enterprises: The Polynorm Development Company headed by Horowitz, The Dutch Metal Industry and the Construction Company Polynorm, headed by v Hulst (organization and acquisition) and vWaveren (production and construction).

Two factory buildings (100 x30m) for Polynorm were built in the period 1948-1950 at Bunschoten a location in the Netherlands with a relatively high un-employment rate under a workforce, which easily could be trained. Both factory buildings were built with a steel construction system; only the second hall was built with the Polynorm system. Polynorm houses (54) were also built in 1949 for employees near the factory; 38 financed by the municipality and 16 houses by Polynorm.

The realization of the housing project at Eindhoven was not easy for Polynorm. They still had to convince the various stakeholders on the quality of the system. It has been Frits Philips who has opened the gateway to finally obtain a building permit for 212 houses to start the project in 1950. The construction process took about 2 years to finish the building of all 212 houses, which meant a time overrun of 1,5 year and a rather high boete.

In 1952 the Dutch Government decided to decentralize the distribution of financial means for rehabilitation and housing projects and the authorized municipalities. Discussions and negotiations which were already in a far stage with the national government authorities to build5000 houses in various cities could not be continued. This occasion implied the final killing of the Polynorm organization, which was not well organized for large scale acquisition tasks.

CONCLUSIONS

Although a number of external factors were due to this (e.g. problems in raw materials delivery) it is also possible to discover a learning curve in the trajectory of this project. Innovative production processes in the beginning often include necessary adaptations of various components of the process, such as adaptations of materials, equipment and tools, labour, information and documentation or organization of the work. Moreover, an innovative process also includes a process of learning by doing amongst all involved stakeholders.

The Innovation Theories and the Strategic Niche Management approach as applied in the case study have resulted in valuable data. The innovative construction technologies that were investigated can be considered as a technological niche. The case studies indicated the promoting and constraining factors in the technological regime of the construction sector for the diffusion and implementation of innovative technologies. By means of SNM niche managers can stand up to intervene in the hampered process of diffusion and implementation of the innovative technology in the residential construction sector to fully benefit from its technical and social advantages.

However, this is just a first step on a longer way to achieve a full recognition of an innovative technology among the major actors in an innovation system. Once the possible intervention mechanisms have been determined, then the feasibility of these including the dynamics between the different mechanisms should be thoroughly assessed.

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