Studying Innovation Trajectories and Networks: **The Case of Benecol Margarine**

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During the 1980's and 1990's, the concept of network has gained importance in the comprehension of innovation processes. It has been acknowledged that the locus of the innovation has shifted from a single firm to a network of firms or other actors collaborating in different ways during the innovation process. This network postulate is apparent in technology policy documents (OECD, 1992; 1998), as well as in research literature (Powell, 1990; Powell *et al.*, 1996). The utilization of the network concept in empirical innovation studies is, as yet, on a developmental phase. In this article, I shall elaborate two theoretical approaches that may help advance the empirical employment of the network concept in innovation studies.

The first theoretical approach I shall deal with is Actor-network theory (ANT). ANT is a member of a group of theories called 'the social shaping of technology' (SST). SST was formed during the last quarter of the 20th century, when researchers from different disciplinary backgrounds were brought together by a critique of traditional, deterministic conceptions of technology. These researchers insisted that the content of technology, not just its adoption or adjustment, had to be exposed and analyzed empirically. This was pivotal in showing that there were 'choices' or negotiations inherent in technological design processes. The social shaping of technology has meant studying this negotiability of technology (the possibility of different outcomes), and, in addition to that, the irreversibility of technology (the stabilization of innovation and foreclosing other choices). (Williams & Edge, 1996: 865-867.)

ANT has shared these tenets of SST, whilst it has developed an original actor-network approach of studying technology and innovation processes. Currently, the concept of actor-network is gradually expanding in innovation studies and other disciplines.[1] Nevertheless, the cri-

tique on ANT is strengthening at the same time (e.g. Bloor, 1999). The current situation appears imbalanced since the critique is concentrating on the theoretical weaknesses of the theory, whereas the actor-network theorists are emphasizing the methodological nature of the approach. In this article, I shall study the methodology of ANT and use especially one prominent case study of ANT, the TSR 2 military aircraft project (Law & Callon, 1988), as a point of reference.

The second theory I shall approach is Activity theory (AT). The background of AT goes back to the beginning of the 20th century. It was developed in the 1920's by Russian psychologists as a solution to the crisis of psychology of that time period (Vygotsky, 1979). As the character of the AT is meta-theoretical, it has been applied in many disciplines since its establishing. In the 1990's, new applications of AT in innovation research have appeared (Miettinen, 1998 & 1999; Miettinen & Hasu, 1999; Hasu & Engeström, 2000; Engeström & Escalante, 1995). AT has been introduced as an approach that has much in common with ANT and can, possibly, correct the main weaknesses of ANT. I shall introduce and compare the methodological framework of AT to ANT, and use a case study of ethanol production from wood (Miettinen, 1998 & 1999) as a point of reference.

I shall also apply both ANT and AT to the innovation process of Benecol Margarine in order to intensify the comparison. Benecol margarine is a functional food product that has a specific positive effect on health, namely, on the cholesterol level of human serum. It was developed in Finland in the 1980's and 1990's and it is nowadays sold in many European countries and in the USA. I have carried out research on the innovation process of Benecol Margarine in 1997-2000, which provides an adequate basis for applying and comparing ANT and AT on the basis of my empirical data. In the conclusion, I shall summarize the findings of the comparison, in particular, and present some implications for the innovation research, in general.

The Methodological Principles of ANT in Innovation Studies

In 1999, a volume entitled *Actor Network Theory and after* (Law & Hassard, 1999) was published. In the book, many theoretical problems and promises of ANT take a crystallized and self-reflected form. In his article, Bruno Latour (1999) argues that an important contribution of ANT was to pay attention to the actors' world building activities, 'circulations', which exceed the traditional levels of sociological analysis. This way, ANT was actually a method, not a theory, to learn from the actors about their own concepts and categories of world building activities. ANT has been a method to access research sites without essentialistic sociological presumptions. The problem has been that the vocabulary designed for this task has not been neutral or 'poor' enough to give space for the actors' own categories.

In his article, John Law (1999) defines ANT as an application of semiotics; ANT shares a semiotic world-view in which divisions and distinctions are understood as effects of activities and not a given order of things. This principle is called relational materiality. According to Law, ANT has been successful as long as its own basic assumptions of network elements have not been called into ques-

tion. However, Law states that there are 'topological' presumptions in the network vocabulary of ANT that may prevent us from comprehending complexities, such as the difference between privileged and non-privileged positions of people, and the difference between strategic and non-strategic orderings.

Latour and Law both agree that ANT is not a fixed theory but a method: ANT has been, with its limitations, a semiotic method to avoid the traditional sociological a priorities and categories. As a consequence, the critique of ANT has been mismatched if it has regarded ANT as a theory and not as a method. If ANT is, as according to Latour and Law, a method, then the evaluation of the approach is justified by studying closely empirical case studies made by ANT.

The innovation studies of ANT have addressed a military air-craft project called the TSR 2 (Law & Callon, 1988), the genesis of an electric vehicle called the VEL (Callon, 1986), and a public transportation system called Aramis (Latour, 1996) among others. All the research objects have proven to be complex technological processes with close contact to the political decision-making. The selection of this kind of research sites has not been made in a random manner. The actor-network theorists have a theoretical commitment to manifest that all technological processes inherently include social and political elements (Law & Callon, 1988: 284-285).

The main theoretical and methodological principles applied in the case studies of ANT are as follows:

1. The cases have been analyzed by a neutral network vocabulary that does not distinguish on a priori grounds what is social and what is technical in the innovation processes. Technical and social elements are not explanatory factors as such, but they are jointly created by a single process. (Law & Callon, 1988: 296.)

2. During the innovation process, processes called "translations" take place. In translation, actors define and distribute roles, and mobilize or invent others, including humans and non-humans, to play these roles (Law & Callon, 1988). The actor-network, which is the focus of analysis, is an arrangement of heterogeneous elements that has been translated (Callon, 1986). In principle, translation is political action and the description of translation is a political analysis (Callon *et al*., 1986:5; Callon & Latour, 1981:279).

3. In the analysis, the innovation network is divided into the global and local network. From the standpoint of the innovation process, the interaction with the outside actors, such as funding agencies, is called 'a global network'. This global network is analyzed as a series of transactions, such as economic, technical, and political transactions. (Law & Callon, 1992:24.) 'A local network', which is isolated from the direct influence of outside actors, generates a so-called autonomous 'negotiation space', a period of time and resources, in which the innovation may occur (Law & Callon, 1992:21). The elements in local and global networks are juxtaposed and may interact with each other. The position in which an actor can control over the interaction between the local and global networks is called 'an obligatory point of passage' (Law & Callon, 1992:42.). In turn, by the similar and concurrent analysis of the both local and global networks, the division between content and context is transcended (Law & Callon, 1992:22).

The principles brought up above are not intended to cover the essential content of the theoretical discussion related to ANT (for the general theoretical discussion of ANT, see, e.g., Pickering, 1992). The principles are merely the main principles used, explained, and evaluated in the innovation case studies of ANT.

In the following, I shall briefly study, how the methodological principles of ANT, including the neutral vocabulary, translation process, and network concepts, have been applied in the case study of a British military aircraft project, the TSR 2. John Law and Michel Callon have extensively studied how the development of the TSR 2 started, what kind of events supported or hindered the progression of the process, and why the innovation failed (Law, 1988; 1992b; 2000; 2001; Law & Callon, 1988; 1992). At first, according to Law and Callon, the innovation project had to assure and persuade the outside actors to support the project. This is called the construction of a *global network* (Law & Callon, 1988: 289).

The negotiation and persuasion included different kinds of interactions, such as political, economical, and technical. By negotiation, the interests of the outside actors were reformed, or *translated*, to support the project. The end product of this process was a global network that offered resources, political support, and financing that allowed starting the designing of a product development project consisting of several enterprises. The project itself is called as a *local network*. (Law & Callon, 1992:22-26.)

The analysis of the genesis of the global network is based on the *simplification* of the actors. By simplification, complex organizations are reduced to a single function, such as provision of funds. (Law & Callon, 1992: 24.) The research interest lies primarily in the *intermediaries*, which circulate between actors, such as money or political support. With the help of simplification, there is only one level in the analysis of the global network. The explanatory factor of the birth of the global network is the *negotiation process* carried out by the managers of the project. The negotiation process is manifested, for instance, in planning documents in which the TSR 2 project is suggested as a solution to the problems of the actors concerned. (Law & Callon, 1988: 287-288.)

In the study of the local network, the division between technical content and social context is avoided by examining, in detail, product development work during the innovation process. In product development work, social arrangements, such as the division of labor, influenced substantially on the technical design work. On the other hand, technical problems, such as the destruction of the engines, called for new organizational co-operation during the innovation process. (Law, 1992b.) This way, the engineering work of the innovation process is *heterogeneous*: the social and technical elements are built alongside (Law & Callon, 1988: 285).

Law and Callon utilize the concept of an *obligatory point of passage* to analyze the relationship between the global and local networks. Furthermore, the obligatory point of passage serves as one primary explanation of the fortune of the whole innovation process. The obligatory point of passage is a position in which an actor is able to control over the interaction between the local and global

networks. If the other actors in local and global networks interact directly with each other, the obligatory point of passage is weak. A solid, indispensable innovation project is achieved by a high degree of mobilization and attachment of actors in global and local network, and, in addition to that, by imposing one self as the only connection between the local and global networks. (Law & Callon, 1992: 46.)

Law and Callon point out various *contingencies* in the process that led to the failure of the TSR project. There is no single reason, neither technical nor political, for the cancellation of the TSR 2. However, Law and Callon suggest that the crucial, strategic pattern in the innovation process, in general, is the creation of a distinction between global and local network and an obligatory point of passage. In the case of the TSR 2, this never took place. (Law & Callon, 1992: 30.)

An Activity Theoretical Approach to Innovation Processes

The Russian psychologist L. Vygotsky founded AT in the 1920's. Vygotsky endeavored to prove an antidualistic solution to the problem confronted in the psychology at that time: was the human consciousness independent of the material environment, or was the human mind only a surface phenomenon of biological processes? Vygotsky, leaning on the work of Marx and the dialectical tradition, formulated the concept of *mediated action* as a solution to the dilemma. According to the concept, the human activity is always mediated by cultural means or artifacts, such as language and tools. (Vygotsky, 1979.)

After Vygotsky, the concept of mediation has been extended to also cover social mediation (Leont'ev, 1978). Engeström has introduced the concept of *activity system* in which activity is mediated by historically and culturally formed tools and signs, on one hand, and by social properties, such as community, division of labor, and rules, on the other hand (Engeström, 1987). Consequently, activity is always materially and socially mediated object-oriented practice. The object of activity, in activity theoretical terms, does not mean a goal imposed by individuals. Neither does it mean resistance of natural objects. The object of activity includes both aspects: in an activity system, the object is constantly being modified and the object itself modifies the rest of the activity system. The process takes place through social, material and symbolical mediation. (For the discussion about the difference between the goal and the object, see Miettinen, 1999: 173-174)

During the 1990's, AT has been applied to science and technology studies (Miettinen, 1998; 1999; Miettinen & Hasu, 1999; Hasu, 1999; Saari, 1999). Some of the ideas of ANT have influenced the applications, even if there are many differences. Both approaches have studied the simultaneous construction of an innovation and a network constructing it. They also acknowledge that during an innovation process, heterogeneous mediation or engineering, comprising handling of material and social elements, takes place. Neither ANT nor AT recognizes the difference between micro- and macro-scale phenomena.

In the following, I shall present the main theoretical and methodological principles applied in the case studies of AT. These tenets also comprehend the

original characteristics of AT that differ from ANT.

1. In an innovation network, the resources and know-how of participants are complementary in regard to the innovation being developed together. Hence, the innovation is called, in activity theoretical terms, a shared object of an innovation network. The synergy and uniqueness of the competencies of the participants is important to the success of an innovation process. The emphasis is given to analyzing the trajectory of the innovation and to recognize the contributions of the participants in different phases.

2. The participants themselves are analyzed as historically and culturally formed activity systems. Activity systems are typically institutionalized working communities, such as divisions of firms or research groups. The reason for joining in an innovation network is derived from their history: they solve problems of their activity, endeavor to expand their activity and try to use their resources and know-how in novel ways. (Miettinen, 1999: 183.)

3. From the activity theoretical viewpoint, the innovation process is always multivoiced: the participants have different perspectives on the innovation process. For instance, a research partner considers an innovation primarily as a research object, whereas an industrial partner sees it as a possible commercialized product. The different perspectives are, in principle, equal in analysis. (Miettinen, 1993: 24-27; 1999: 191.)

4. The relationship between the researcher and the objects of study, the participants of the innovation network, is dialogical. The researcher tests his or her hypothesis with the research objects in a dialog. She may even arrange interventions, such as seminars, in order to reflect some present dilemma to the participants of the innovation network. For instance, these seminars may deal with the problems confronted by the users of the artifact. (Hasu, 1999; Miettinen & Hasu, 1999; Hasu & Engeström, 2000; Engeström & Escalante, 1995.)

In the following, I shall show how these premises are applied in a case study of ethanol production from wood. I shall also discuss to what extent these premises produce similar and different outcomes in comparison to ANT.

Miettinen has studied an innovation process that aimed at the production of ethanol from wood or other cellulosic material (Miettinen, 1998 & 1999). The innovation process took place in Finland between 1975 and 1981. Miettinen primarily analyzes how the participants contributed to the innovation, on what basis the participants took part in the innovation network, and what were the means used in the collaboration.

The industrial process of ethanol production required various kinds of *contributions*, such as technical components, computer programs, living organisms, organic materials, and specific knowledge related to all of them. According to Miettinen, the development work of the industrial process was a co-evolution of cognitive (hypothesis and visions), material (substrates, organisms, and laboratory equipment), and social (division of labor and project management) elements. The industrial process itself was the *shared object* and organizing principle of this development work. The relationship between the shared object and the innovation network was dynamic. Some elements of the object,

such as the raw material, did not act as hoped and forced the innovation network to develop new solutions. Ultimately, the resistance of material elements led to the conclusion that ethanol production was too expensive for commercialization. (Miettinen, 1999: 183-188.)

After analyzing the innovation trajectory and the contributions of the innovation network, Miettinen concentrates on the *history* of each participant. From the point of view of AT, each participant is attending to the innovation network in order to solve problems of their activity, expand their activity, or use their resources and know-how in new ways. The industrial partners, for instance, attained the innovation network for specific reasons, such as getting new raw material for ethanol products or utilizing abundant waste material. According to Miettinen, the interests of the participants can be characterized as a transformation or expansion of their present object of activity and corresponding means and know-how. (Miettinen, 1999: 187.)

The third aspect of innovation process in Miettinen's analysis is the *means of collaboration*. For instance, Miettinen studies a model of ethanol production that synthesized and generalized the results of the project and oriented the future action: which parts of the production process were accomplished and which parts required further research and testing. According to Miettinen, these models are crucial vehicles for planning new networks and mobilizing other actors. (Miettinen, 1999: 190-191.)

ANT and AT have many similarities on a basic level in studying the innovation processes. For instance, both approaches study the trajectory of the innovation and the composition of the collaboration network in different phases. This process is understood dynamically in both approaches, as the innovation transforms in different phases, which causes changes in the network developing it, and vice versa. Nevertheless, the case studies of ANT and AT have a distinct divergence. For ANT, the innovation process is essentially "a set of strategies for control" (Law, 1992b: 410). Consequently, the attention is paid to the power relationships of the innovation process: how the barriers between the inside and the outside of the innovation network are constructed, sustained, or broken down. In the case of the TSR 2, there was neither an obligatory point of passage nor a gatekeeper between the inside and outside of the project. Law and Callon suggest that this was the strategic reason why the TSR 2 project failed, even if many contingencies had occurred during the project (Law & Callon, 1992: 50-51).

For AT, the emphasis is on analyzing the culturally and historically formed specific resources and know-how of the participants, on one hand, and how these resources and know-how are applied in the construction of the innovation developed together, on the other hand. The power relationships of the innovation network are not in focus. Instead, the historical axes of each participant have an importance in the analysis. (Cf. Miettinen, 1999:186-187.)

The different focuses of the theories derive from the divergent historical backgrounds. ANT's innovation analysis is loaded with epistemological criticism that is aimed against deterministic conceptions of technology. Like the rest of the social shaping of technology movement,

the actor-network theorists desire to point out that technological processes are inherently about constructing technical and social elements alongside. The originality of ANT lies in adding to SST a power analysis that is close to the Foucauldian analysis of power (cf. Latour, 1987: 265; Law 1992a). The activity theoretical innovation analysis, instead, is initially oriented to developmental research. Technological processes have been studied in order to develop societal applications that develop and advance collaboration and learning within and between participating activities.(cf. Miettinen, 1999:192; Engeström & Escalante, 1995:365.)

A Methodological Benchmark Test: ANT and AT in the Case of Benecol Margarine

In the following, I shall apply the approaches of ANT and AT in the analysis of the case of Benecol Margarine. The data presented in the analysis is based on the interviews with the developers of Benecol Margarine; historical documents given by the developers; official documents, such as patent documents; medical articles; stock exchange and news agency bulletins. The results of this analysis have been presented to the developers of Benecol Margarine, and they have commented on the findings. First, I shall present, in general outline, the course of events of the innovation process. After this, I shall suggest how the approaches can be applied in the analysis and what kind of outcomes these approaches produce in the analysis of the same case.

Benecol Margarine is a functional food product developed in Finland at the turn of the 1990's. The active ingredient of Benecol Margarine is plant sitostanol-ester. Sitostanol-ester is a modified form of sitosterol, a common substance in plants. The most important argument in the marketing of Benecol Margarine is its lowering effect on the cholesterol level of human serum. A high cholesterol level is seen generally as one main risk factor for heart and coronary diseases which are a fundamental public health problem in Western countries. It is argued that Benecol Margarine reduces the total cholesterol level of human serum by over 10% and the detrimental LDL-cholesterol level by approximately 14%. This medical argument, which is supported by over 30 clinical studies, makes Benecol Margarine a functional food product. Functional food is a category name for food products that have a positive effect on health. Benecol Margarine has been available in Finland since 1995. Since the beginning of 1999, it has been available also in several European countries and in the United States.

The innovation process of Benecol Margarine was based on an alliance of medical scientists and industrial partners since the beginning. The series of events leading to the development of the innovation commenced, when a Finnish chemical factory, Kaukas Inc., started looking for applications for their refined sitosterol in the mid 1980's. Kaukas, a member of a large Finnish pulp and paper concern, refined sitosterol from the waste material produced in pulp production. When a large amount of wood is processed in pulp production, it is possible to refine industrially sitosterol from the waste material. Kaukas had implemented an industrial plant for this task in its pulp factory. The company had

also made a delivery agreement of sitosterol with a Finnish medical company. Sitosterol was planned to use as raw material for a steroid-based pharmaceutical product. At the start of the production of sitosterol, however, Kaukas encountered a critical problem: the order was canceled and there was no other buyer for the product at that moment. For this reason, Kaukas was forced to search for possible applications for sitosterol.

Kaukas found that sitosterol and its impact on the cholesterol level of human serum had been studied in medical science since the 1950's. In the mid-1980's, the company contacted a few Finnish medical scientists with a view to start producing cholesterol-lowering medical applications of sitosterol. In medical science, the internally taken sitosterol was known to have reduced the serum cholesterol significantly. The exact medical mechanism behind this phenomenon is yet unknown. Pharmaceutical products of sitosterol had been commercially available for decades. These products had a general problem, however: sitosterol did not produce any significant effect on the cholesterol absorption in human lipid metabolism, as it was in a crystallized form, and, therefore, poorly soluble with lipids. Consequently, the effect of the sitosterol products has been marginal in comparison with some other medical substances.

One of the medical scientists contacted was professor Tatu Miettinen, who worked in Helsinki University Central Hospital (HUCH). Professor Miettinen had studied human lipid metabolism for decades and was well acquainted with the medical properties of sitosterol. At first, he was not interested in studying the sitosterol provided by Kaukas. He was aware that the medical effect of sitosterol-based pharmaceutical products have usually been marginal. However, during the following years, two significant incidents took place that made Miettinen change his mind. First, there was a publication of a new research result (Heinemann *et al.*, 1986) showing that sitostanol, which is a saturated form of sitosterol, had a greater effect than anticipated on the cholesterol level of human serum and did not become absorbed to the blood-vascular system as sitosterol did in some extent. Professor Miettinen grew interested in testing sitostanol medically. At the same time, Kaukas tested producing sitostanol on a pilot scale.

The other incident was related to Miettinen's industrial relationships. In 1988, he was dismissed from the chairmanship of the scientific advisory board of a large Finnish dairy company. After this occurrence, he contacted Raisio Margarine Ltd., which was a large Finnish vegetable fat producer, and proposed the use of sitosterol and its modified form sitostanol in vegetable fat products. The idea of using sitosterol in food products had already been presented in the research literature (Pollak, 1985).

In the late 1980's, the research laboratory of Raisio Margarine, in cooperation with several research institutes, was studying the health effects of canola oil. The research results indicated that canola oil reduced significantly the cholesterol content of human serum. This result was published in the main Finnish newspapers and medical journals in 1989, which quadrupled the sales of

canola oil in Finland between 1988-1990. The canola oil research projects having ended, Raisio Margarine accepted Miettinen's suggestion to test sitostanol in vegetable fat products. Kaukas provided sitostanol for the research laboratory of Raisio Margarine.

There was a problem of using sitostanol in vegetable fat products due to the chemical characteristics of sitostanol: it came in a crystallized form and was poorly soluble with fats as was the case with sitosterol. During an intensive research period in 1989, the research laboratory of Raisio Margarine was able to resolve the problem with knowledge gained from the canola oil research projects: a tiny amount of the chemical composition of canola oil is, in fact, sitosterol in fat-soluble form. In optimized conditions, the fatty acids of canola oil reacted with sitostanol producing pure sitostanol-ester in the end. Sitostanol-ester was fat-soluble and mixed easily with vegetable fats. The developers were hoping that the medical effect of sitostanol-ester on the cholesterol absorption in human lipid metabolism would prove greater than that of pure sitosterol or sitostanol.

At the beginning of the 1990's, several medical test of sitostanol-ester were carried out in Finland. Kaukas produced the raw material, the research laboratory of Raisio Margarine produced the test products containing sitostanol-ester, and professor Miettinen's research group performed the experimentation. The number of test subjects varied between 14 and 67. The research results were promising and were published in medical journals between 1992 and 1995 (e.g. Vanhanen *et al.*, 1993).

Yet, this series of research projects did not quite suffice for the executive management of Raisio Margarine. An even longer test with a larger population group was required. For this task, a new research partner was required. A Finnish government agency, the North Karelia project, joined in testing. The North Karelia Project was launched in 1972 to study and prevent heart and coronary diseases in a large population group in Finland. By the 1990's, the North Karelia Project had had a great deal of experience in the large-scale testing of different kinds of drugs and foods, such as vegetable fat products. The project has published over 400 international medical articles and cooperated closely with WHO. This way, the project had a fully functional, large-scale testing organization of international recognition.

The test was carried out in the region of North Karelia, where the North Karelia Project had available a suitable sample of test subjects. The number of the test subjects was 153, and the test took place in three phases during one year, between 1993 and 1994. The double-blind method with a control group was utilized in the test. The test group had margarine brace with sitostanol-ester, and the control group had normal vegetable fat margarine. According to the results, sitostanol-ester margarine reduced the total cholesterol level of serum by over 10 % and the detrimental LDL-cholesterol level by ca. 14 %. No side effects were reported. The research results were published in New England Journal of Medicine, in November 1995 (Miettinen *et al.*, 1995). At the same time, Benecol Margarine appeared on the Finnish market and gained large public attention.

ANT: Local and Global Networks in the Case of Benecol Margarine

In table 1 bellow, the methodological schema of ANT, which I shall apply in the case Benecol Margarine, is summarized.

The global network did not actually exist in the beginning of the innovation process of Benecol Margarine. The development work was performed extraordinarily along normal work routines. The additional funding or resources were not needed as the actors could utilize existing resources. The situation changed when sitostanol-ester and its production method was discovered, and the commercial potential became evident. A funding agency, the National Technology Agency of Finland (TEKES) was persuaded to fund costly medical experiments and industrial development work. Medical experiments were needed for convincing the authorities of food control and consumers that the sitostanol-ester was safe and effective food ingredient. Medical experiments were needed also for convincing the board of directors, and, ultimately, the stockholders of Raisio Margarine that the product is worth investing in. In the construction of the global network, the medical studies proved to be the main vehicle for attaching outside actors for supporting the project.

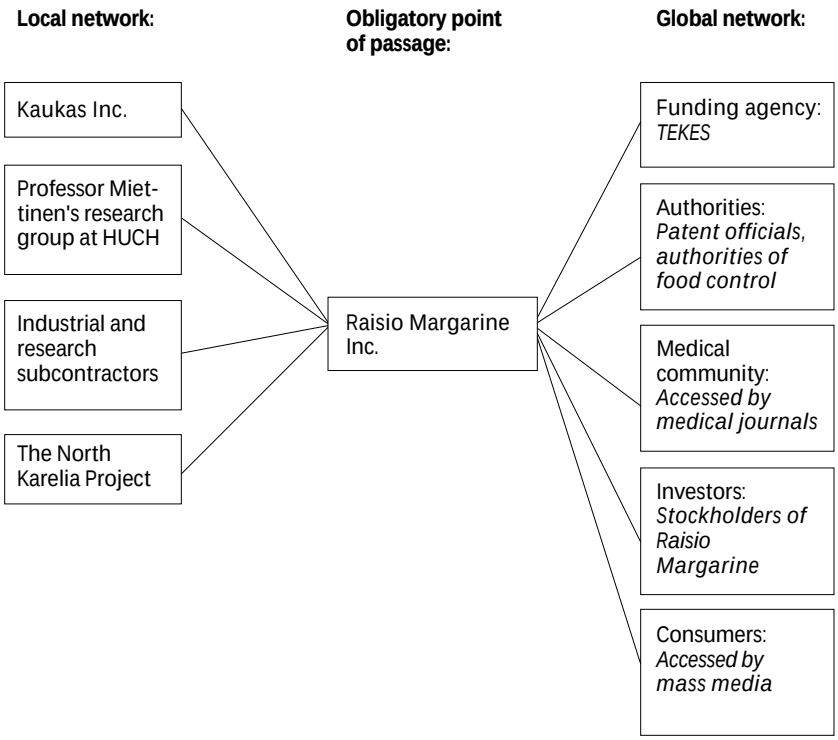
The local network was formed primarily by the Kaukas factory, Professor Miettinen's research group at HUCH, and the research laboratory of Raisio Margarine. The Kaukas factory implemented industrial sitostanol production setup with the assistance of subcontractors. Miettinen's research group carried out medical testing with the North Karelia Project. Raisio Margarine refined the sitostanol-ester and implemented the margarine production machinery. This division of labor remained until the commercialization of Benecol Margarine 1995. After commercialization, the number of industrial and medical research partners multiplied.

The position of the obligatory point of passage was gradually occupied by Raisio Margarine. It could impose itself as the main connection between the local and global network. This was partly

Table 1. The methodological schema of Actor-Network Theory.

Object of study:	**Analytic concepts:**	**Explanatory factors:**
Global network (outside actors of project)	Simplification, series of transactions, intermediaries (between outside actors)	Negotiation process
Local network (inside actors of project)	Social and technical elements (e.g. division of labor and equipment of inside actors)	Heterogeneous engineering
Obligatory point of passage (position between inside and outside actors)	Mobilization, attachment, translation of interests (of inside and outside actors)	Weak or strong obligatory point of passage

Figure 1. The innovation network of Benecol Margarine from the point of view of ANT.



done by making formal contracts with the participants. For the outside actors, such as the funding agency and investors, authorities, media, and consumers, Raisio Margarine was the main actor associated with Benecol Margarine, even though several actors had contributed to the development work. This was clearly demonstrated, when the stock value of Raisio Margarine multiplied shortly after the launching episode of Benecol Margarine. At the same time, the stock value of Kaukas Inc. which produced the raw material was not affected.

The innovation network of Benecol Margarine, from the ANT perspective, is illustrated in figure 1 above.

From the point of view of ANT, the innovation process is about constructing the borderline, the obligatory point of passage, between the project itself , the local network, and the outside actors, the global network. In the case of Benecol Margarine, this is an adequate perspective concerning the later phases of the innovation project when the cooperation was formalized by contracts and commercial potential was obvious. However, the early stages of the innovation process are difficult to analyze by using the concepts of obligatory point of passage, local, and global networks. In the case of Benecol Margarine, the relationships between the actors were open and non-formal in character in the beginning. They were usually established by using older connections that were based on earlier collaboration. The object of collaboration was hypothetical and the commercial potential was lim-

ited. Participants' interest of contributing to the project remained vague during the first years.

To sum up, the distinction between the local and global network is not possible to make, as the network structure between the actors was fragile at the early stages. Similarly, the actors' interests were ambivalent in the beginning, and they did not attempt to occupy the position of an obligatory point of passage. Immediately after the discovery of sitostanol-ester, the boundaries between the project and outside actors started to emerge in the form of contracts.

AT: The Historical Axes in the Case of Benecol Margarine

In table 2, the methodological schema of AT is presented. From the viewpoint of AT, actors or activity systems are trying to solve problems within their activity or expand their activity. In the case of Benecol Margarine, Kaukas tried to solve the problem of producing raw material, sitosterol, without applications and buyers. This led to the medical inquiry and contacts with medical scientists. From the point of view of AT, Kaukas had encountered a critical problem, or a contradiction, within its activity: Kaukas had the means, the production machinery and raw material, but no object to which apply it.

Following the point of view of AT, the engagement of the participants in the innovation process is comprehensible by analyzing the historical axes of their activities. This is an adequate approach in the case of Kaukas, as I demonstrated above. Professor Miettinen's research group was interested in sitosterol on a historical basis, too. The research group had studied sterols and their effect on lipid metabolism since the 1960's. Raisio Margarine had carried out a successful canola oil research project when Professor Miettinen contacted them, and testing sitosterol in vegetable fat products was a continuation for their research agenda. The analysis of the historical axes of the participants is especially justified at the early stages of the innovation process, when neither money nor

Table 2. The methodological schema of AT.

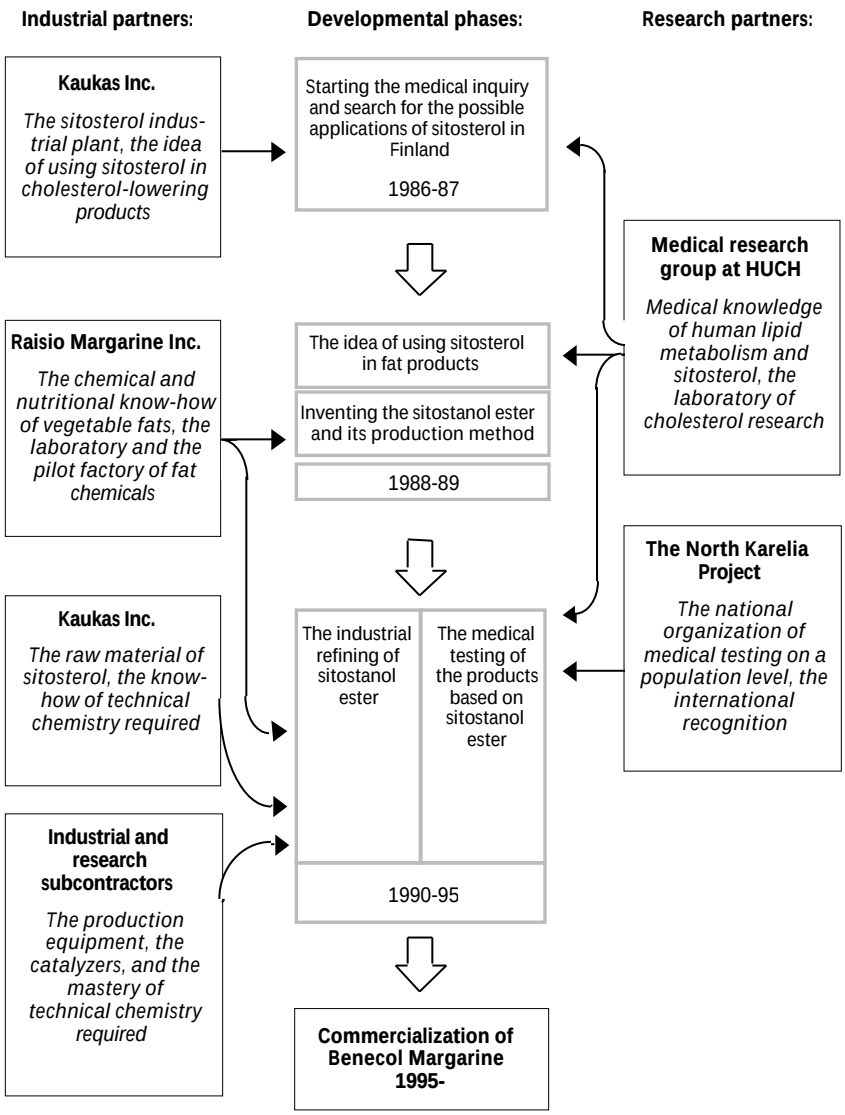
Object of study:	**Analytic concepts:**	**Explanatory factors:**
Starting phase	Initiator's activity system and its components	A critical problem (contradiction) within activity system
Collaboration phase	Network of collaborating activity systems, their contributions, shared object	Synergy of the complementary resources and know-how
Commercialization, implementation phase	User's activity system and it's components.	Solution to the user's problem

formal contracts explain the involvement of the participants to the project.

In the collaboration phase, the innovation network consisted of a network of activities with a shared object. The activities contributed to the construction of the innovation by using their historically and culturally formed resources and know-how. This network concept of AT is presented in figure 2 bellow.

In the network picture, the analytical interest is to highlight what the different phases of the innovation were; to what phases the participants contributed; and what kind of resources and know-how made the contributions possible. The

Figure 2. The innovation network of Benecol Margarine from the point of view of AT. The specific know-how and resources of the participants are indicated in connection to each participant.



important explanatory factor of the successful innovation process is the synergy of the competencies of the participants. In the case of Benecol Margarine, the competencies formed a unique combination consisting of sitosterol production capability, cholesterol research, and research made on vegetable fats. These competencies had developed during a long period of time, which became evident when their historical axes were considered above. Concerning the commercialization phase, which is not dealt with in this article, the AT approach would especially study how the product helps or hinders the user to solve problems of her activity or expand her activity; e.g. how the user could practice healthy way of life by using Benecol Margarine (cf. Engeström & Escalante, 1995).

Conclusion

Both in the analysis of the TSR 2 and Benecol Margarine, the methodological strength of ANT was in analyzing the negotiation process in which the barriers between the inside and outside of the project were constructed. In addition to that, the ANT approach concentrated on analyzing how single actors negotiate and pursue to become the only link between the inside and outside actors of the project. This link is called an obligatory point of passage. When an actor occupies the obligatory point of passage, the credit for the success of the innovation is attributed to it by outside actors. This took also place in the case of Benecol Margarine, when outside actors, such as the media and stockholders, credited one actor, Raisio Margarine, with the success of the innovation.

I acknowledge that ANT 's analysis of negotiations is especially useful, when the researcher wishes to understand how power relationships between actors are formed and how the innovation is attributed to a single actor. However, the power analysis does not necessarily help in analyzing the early phases of the innovation process. In the case of Benecol Margarine, the early collaboration network was not possible to divide analytically into inside and outside actors. Neither was there to be found an actor willing to occupy the locus of an obligatory point of passage. Accordingly, I argue that the early collaboration network requires methodological framework different from the power analysis offered by ANT. In this article, I have presented and applied AT as an alternative approach of studying the early phases of the innovation process.

The AT approach is interested in studying the historical axes of participants and the genesis of their competencies. Especially concerning the early phases of the innovation process, AT makes participants' involvement and contribution to the innovation process comprehensible. Actors' motives to collaborate are based on their historical development: they endeavor to expand their product range; use their historically-formed resources and know-how in new ways, and solve critical problems of their activities. During the early phases, communication is reciprocal and participants exchange flexibly their specific know-how. The competencies are complementary in regard to the innovation being developed, and their synergy is an important explanatory factor for the success of the innovation process. Organizational scientist Walter Powell (1990; 1996) has characterized

the locus of this type of collaboration as *networks of learning* that differ substantially from market-based or hierarchical relationships. For the analysis of the early innovation process and networks of learning, I suggest that the methodology of AT is especially viable, as I showed in the analysis of the development of Benecol Margarine.

These conclusions apply to the historical analysis of innovation processes. A future challenge is to combine the historical analysis with the research on ongoing innovation processes. The analysis of ongoing innovation processes may produce data of interaction and learning that is not possible to achieve by historical analysis. Besides, the researcher can affect innovation processes, when he or she studies ongoing processes. For instance, the researcher can reflect the problems confronted by the users of the artifact to its producers (Miettinen & Hasu, 1999). It is also possible that the researcher actively presents the results achieved by historical analysis to the participants of the innovation network. This also took place during the research on the innovation process of Benecol Margarine. Dialogue with the participants increases the pragmatic validity of the research, on one hand, and may help the participants in comprehending and modifying their on-going product development activities, on the other hand.

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Notes

1 The expansion is apparent in the extensive bibliography of ANT maintained by the Centre for Science Studies and the Department of Sociology, Lancaster University at http://www.comp. lancs.ac.uk/sociology/antres.html.

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