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Diffusion Models in Analysing Emerging Technology-Based Services

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Abstract: In this article we discuss the problems of utilizing innovation diffusion (or, adoption) models in developing scenarios for mobile commerce services in three European countries: Finland, Germany, and Greece. We are not to test the various diffusion models as such, but rather to utilise the fundamental ideas of the models in determining the prerequisites for, the status of, and the pace of diffusion of mobile services in these different market areas. The estimates would serve as a starting point and as a validity check for scenario development. The early experience at the research design phase show that the 'mainstream' diffusion approach is vulnerable to three factors specific to the adoption of services that are subject to technical change and development: *'layered' adoption process in its social context, supply side, and continuous technical development.*

1. THE DIFFUSION OF MOBILE SERVICES

In this article we discuss the problems of utilizing innovation diffusion (or, adoption) models in developing scenarios for mobile commerce services in three European countries: Finland, Germany, and Greece. From the scenario point of view, we are not to test the various diffusion models as such, but rather to utilise the fundamental ideas of the models in determining the prerequisites for, the status of, and the pace of diffusion of mobile services in these different countries. The estimates would serve as a starting point and as a validity check for scenario development.

We are especially interested in distinguishing the adopter categories as an indication of the progress of diffusion, In the scenarios it would be most useful to be able to depict the situation on each of the three market areas by dividing the respondents in adopter categories according to the well known models of diffusion.

Unfortunately, there is little public information available on the state-of-the-diffusion of mobile services, especially such information tied to the diffusion process[64].

The early experience at the research design phase show that the diffusion approach is vulnerable to three factors specific to the adoption of services that are subject to technical change and development: *'layered' adoption process in its social context, supply side,* and *continuous technical development.*

To cast light on these issues we first analyse and categorise a set of diffusion models in their basic features: in the context of new services we are especially interested in the basic differences between various diffusion adoption models. We first describe the models, categorize them according to the interrelatedness of the adopters' behaviour, uncertainty, and the information handling. In the end we discuss the experiences of utilizing the ideas in finding out the state-of-the diffusion.

2. DIFFUSION MODELS

The basic diffusion models can be categorized in many ways, but they all share the sigmoidal cumulative function of growth, or spreading of innovation among the adopter population. Examples of such curves are logistic growth, cumulative normal, Gompertz, and log-normal. Technically, these curves illustrate cumulative density functions of a bell-shaped frequency distribution over a population.

2.1 Rogers

The most commonly referred diffusion model is introduced by Rogers in 1983. Rogers sums up the results from more than 3,000 diffusion publications. This impressive summary forms the base of the widely applied model of diffusion, although it is actually a hybrid of a number of models. Despite the fact we call it the mainstream model. According to Rogers, the adopters can be classified by their individual *information processing styles* and by *their use of communication channels.* These are fairly constant characteristics, and determine the innovativeness of the adopters. The innovativeness is argued to be normally distributed among potential adopters, and therefore the cumulative density function of the adopter population is a sigmoid shaped diffusion curve (Heikkilä, 1995).

This statement is quite a strong assumption in favour of unlimited communication within the social system. The adopters are acting independently of each other, but they are *'contaminated'* by increasing unlimited information flow. The normally distributed adopters are divided into five categories according to their

[64] With the notable exception of study of Nokia (1999).

'resistance' to the information. The distribution of adopters over time is presented in Figure 1.

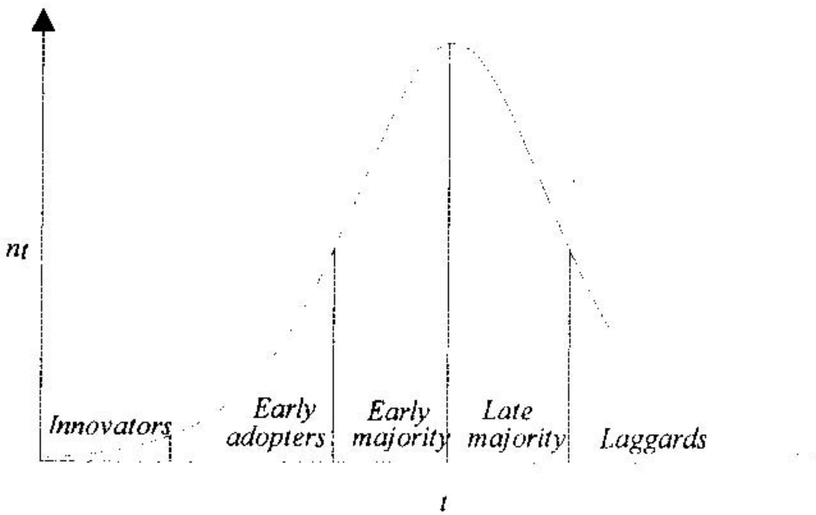

Figure 1. Adopter Categories of the Mainstream Innovation Diffusion Model

According to Rogers (1983), there are some change agents and opinion leaders who are important for the success of the innovation. An opinion leader is a pioneer, whose behaviour has an effect on others' attitudes towards an innovation. A change agent tries to persuade a potential adopter to accept and adopt an innovation.

Note that the mainstream diffusion model assumes rational decision-making capabilities only implicitly, as the users are rather contaminated (i.e. obtaining knowledge about the potential) and persuaded to adopt by the increasing exposure to information (Bailey, 1957; c.f. Heikkilä, 1995).

In a later revision of the model, Moore (1998) makes a strong argument for the existence of a *chasm* between early adopters and early majority, especially when the pace of technical development is fast. When the diffusion process moves from the initial stages to early majority, there is a change of logic of diffusion: in the beginning the importance of services is high, later the services as a means of competition are replaced with the capabilities of commercialise, produce and deliver the products efficiently for the masses. The masses rely more on their peers than on the opinion leaders, marketing, etc., It is here, at the chasm located between early adopters and early majority where the markets are won or lost.

The mainstream model consists of following sets of variables, which explain the success of an innovation on the market:

1. The attributes of an innovation. Rogers (1983) argues that the following five characteristics of an innovation are the most important when making the adoption decision: 1. Relative advantage, i.e., "the degree to which an innovation is perceived as being better than the idea it supersedes." (Rogers, 1983, p. 213). These can be perceived in terms of economic profitability, status, etc. 2. Compatibility, i.e., "he degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 1983, p. 223). 3. Complexity, i.e., "the degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers, 1983, pp. 230-231). 4. Trialability, i.e., "the degree to which an innovation may be experimented with on a limited basis" (Rogers, 1983, p. 231). 5. Observability, i.e., "the degree to which the results of an innovation are visible to others" (Rogers, 1983, p. 232).
2. The type of innovation decision, i.e., the four generic types of innovation decisions depending on the decision-maker characteristics (Rogers, 1983, Ch. 10): 1. *Choice* - the decision is based solely on the characteristics of the innovation by the individual adopter solely. 2. *Collective* - the decision is based on a commitment of the members to a solution. 3. *Autocratic* - the decision is dependent on authoritative persons. 4. *Conditional* - the decision to adopt is dependent on the preceding innovation adoption decision (contingent innovation decision in Rogers' terminology (1983).
3. The social system characteristics
4. Promotion efforts, and
5. The communication channels. The communication channels have been extensively studied in the earlier research (see e.g. for theoretical work in Lekvall & Wahlbin, 1973; a good example of empirical IS research in Brancheau & Wetherbe, 1990).

The sets of variables appeal to common sense and give a good understanding of the factors affecting the pace of diffusion. However, there are some other considerations not explicitly handled by Rogers.

2.2 Decision making models

Although the mainstream model of Rogers (1983) has been successfully applied to various forecasting and descriptive purposes, it has some problems, which must be taken into account. In Rogers's synthesis, an innovation is defined as whatever an adopter finds new in his use situation. Newness itself is not sufficient reason for adoption but it rather implies that the expected net benefits of the innovation must be positive before the adoption takes place. However, the outcomes are uncertain, as the innovation is, by definition, new to the adopter in his social context, and it will take some time before favourable effects on the work become apparent. However, Rogers' model *does not precisely state the relationship between information and* *uncertainty*. Furthermore, *it assumes an independent individual adopter,* only remarking on the importance of interdependencies between adopters, i.e. his model excludes network effects (also called as externalities Fichman, 1992; c.f. Heikkilä 1995).

2.2.1 Uncertain versus Certain Information on the Attributes of Innovation

According to Lippman & McCardle (1991, p. 1475), the probability of adoption depends on the uncertain profitability estimate on the value of the innovation. The uncertainty can be reduced by suspending the adoption and continuing to gather more information on the innovation. If information gathering reveals that the expected discounted value of the innovation exceeds the investment threshold, the search stops, and adoption takes place. If the expected value is insufficient, the innovation is rejected. The probability of adoption is likely to increase when more positive information is gathered, and vice versa. But, the information gathering is costly, reducing the net value of the innovation. To summarise, according to this model, the users select how much they are gathering information against the expected value of the innovation, instead of just becoming contaminated (as in Rogers, 1983).

Additionally, or alternatively, to contagious information as an affecting factor of the diffusion's shape is the uncertainty inhibited by the innovation. For example, Valente (1996) argues that the timing of adoption is affected by social exposure, by which he divides adopters into categories. According to his theory, the different adoption timing of adopters is caused by different risk behaviour. Thus, adopters require a different amount of exposure to the innovation before they adopt it. Also this approach yields a sigmoid diffusion curve assuming that the adopters risk behaviour, and thus their need of exposure, is based on the normal (or a similar) distribution. This is inline with the ideas of Moore (1999).

2.2.2 Network effects and strategic behaviour

The externality effect in economic theory means that (some) activities have consequences that affect the well-being of other, external actors. In presence of network externalities wise actors take each other's actions into account, in the network of associated actors, leading to strategic behaviour. The logic is, consequently, somewhat in contrast to the logic of adoption in the pioneering phase, where the adoption was seen as a one-man effort to gain information about the innovation.

To be more specific, when adopting new technical innovations, the novices may learn and be given advice from others, they may benefit from improved architecture, etc. On the other hand, the pioneers benefit from e.g. compatible working practices and increased information exchange (Farrell & Saloner, 1985; Katz & Shapiro, 1986). To relate this to diffusion theory let us look at Figure 2. The Figure illustrates how the net benefits are expected to appear in the future. The 0 level is the adoption threshold, i.e. the net benefits from the innovation are expected to be positive - it is time to adopt. The lower curve shows that the user is to adopt at N1t. But, if a user can rely on help from others and on other similar positive network externality effects, it increases the expected benefits, and thus may hasten the willingness to adopt (dotted curve) to Nt*. The increase in interpersonal relationships in seeking and providing help in computer-related issues was also detected by Brancheau & Wetherbe (1990). According to Rogers' categorisation, this is a kind of 'conditional' decision situation, where the successive adoptions depend on the preceding adoption decisions.

But, many real situations are not so straightforward, e.g., the usefulness of innovation is uncertain, or it may be difficult to shift from the old technology to the new one, because of time constraints, skills, funds, etc. In many cases it is the commitment schemes respond exactly to these problems. They are used to decrease the uncertainty by committing potential adopters to a solution, to allocate resources to the transition, and to tackle the required transformation problems in advance. They are very motivational because of the intertwined benefits of the members of the social system.

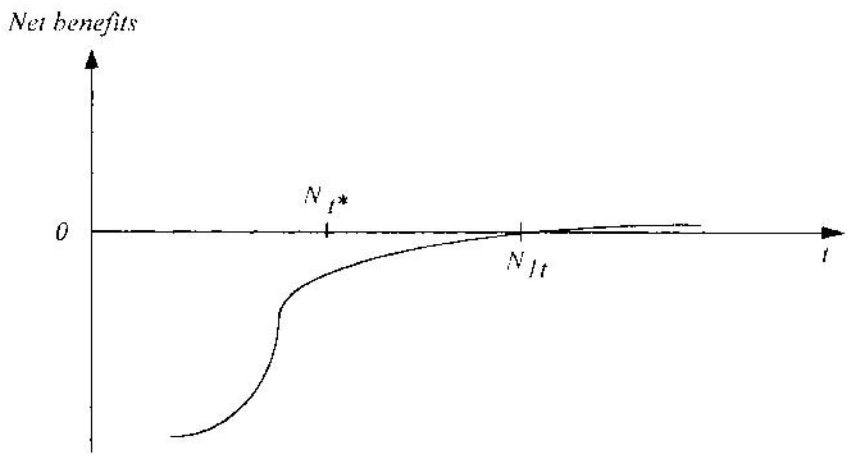

Figure 2. Benefits With and Without Positive Network Externalities

2.2.3 Observing the behaviour of other adopters

Another type of adoption behaviour in the presence of network effects is that the decision is based rather on opinions, experiences, and *observations of others' behaviour, than on gathering information about the innovation itself.* Clear examples of this are the models of herd behaviour (Scharfstein & Stein, 1990; Banerjee, 1992). It suggests that a decision-maker believes (rationally) that other colleagues, who have already made their decisions, may have some other information, which is important for his own decision-making. So, instead of gathering his own information, and relying on that, he looks at the behaviour of the other colleagues. Unfortunately, this kind of herding is almost always inefficient, although common, especially in the context of adopting technology that must be applied differently in a specific context.

2.2.4 Social cohesion

Burt (1987) studies the diffusion of a new drug by observing the doctors prescriptions. He hypotheses two alternative processes: 1) social cohesion: the doctors have got their information from another doctor; 2) structural equivalence: the doctors have acquired information of the drug by acting in a way a doctor acts in his position by, for example, reading medical journals. The first approach yields an analogous result with the basic contagious information (or epidemic) model: a sigmoid curve on the aggregate level. The reasoning behind the structural cohesion model is that information drains from a social group to another. Thus, there is no contagion and the diffusion on aggregate level gains a different form. The results indicate that beside social cohesion also other factors have influenced the diffusion of the drug.

2.2.5 Summary of the models

To summarize the differences between different models, we have drawn up the following Table 1, which clearly shows that there are notable differences between the models. The latter models also show crucial factors in the adoption processes not covered properly in Rogers's synthesis.

Table 1. Differences between the models

	Interrelatedness of decision-makers (externalities)	**Uncertainty of the object of adoption**	**Object of inquiry in obtaining information about an innovation**
Mainstream model (e.g., Rogers, 1983)	Independent non-related individuals	Not explicit	Exposure to information through information channels
Decision theoretic models (e.g., Lippman & McCardle, 1991)	An independent individual	Technology is uncertain	Uncertainty reduction by gathering more information
Active information gathering (Valente, 1999)	Independent individuals	Technology is uncertain	Exposure to information, but different reaction depending on the risk attitude
Models with network externalities (e.g., Farrell & Saloner, 1985)	Individuals with interrelated benefits	Technology is certain	Characteristics of the innovation are known and the behaviour of others is observed
Models of herd behaviour (e.g., Banerjee, 1992)	Individuals with interrelated benefits	Technology is uncertain	Only the behaviour of others is observed
Social cohesion (e.g., Burt, 1997)	Individuals with interrelated benefits	Technology is uncertain	Others' behaviour is observed and the technology is tried. Others can mean peers or different social classes (two variants).

We utilized the table to create a set of questions to analyze the adoption and consequent processes of diffusion for developing the scenarios. Note that we have been concentrating mainly on the population of rational adopters. However, if we are to depict the diffusion process in its real context (e.g., in the very different countries mentioned in the beginning), we should take into account also some of the supply side and temporal issues more explicitly.

3. AMENDMENTS TO THE DIFFUSION PROCESS FOR SCENARIOS

The technical development during the diffusion process makes a difference, because it at the same time affects the adopters understanding and maximum potential (new features). Where the mainstream (and most of the other models) assumes a constant maximum potential for one technology generation, it maybe actually growing[65] . One could argue that it is just a matter of defining the technology generations, but we argue that when talking about new services based on changing technology, it is not the case. This is because from the users point of view it is the content of services that matters, not the technology generations. We would like to illustrate these problems with the concepts of *layered adoption process,* and *continuous technical development.*

3.1 Layered adoption process

The layered adoption process means that the services can be utilized only after the 'technology stack' is high enough. For example, in order to use mobile services, the user has to acquire a phone (1st level adoption), subscribe the generic services (e.g., switch on voice-mail, text messaging, install and configure WAP; 2nd level adoption), and finally subscribe the value-added services (3rd level adoption; see also Figure 3.). There are few adoption models that take this type of adoption process into account explicitly. Thus it is most important to take this into consideration explicitly when studying diffusion to be utilized in more long-term analysis, such as scenarios in our case.

3.2 Continuous technical development

In Rogers's model the maximum potential is defined as a constant, whereas in many cases the technical development increases the maximum potential, i.e., there will be new, first-time adopters. During the process, there will be also earlier adopters choosing to stay with the old technology, choosing to have both the new and old, or switching to the new one. An example of such a process of the 1st level adoption of cellular terminals is depicted in Figure 3 below.

[65] Diffusion in dynamic population is studied, e.g., already by Mahajan & Peterson (1978).

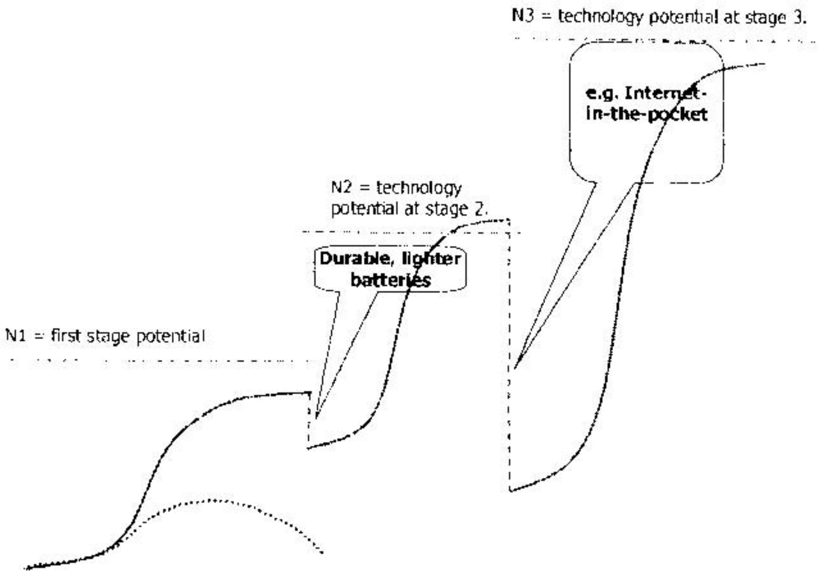

Figure 3. Stepwise increase in potential due to technical development

Another, yet different example is the spatial roll-out of new technology, which increases following a concave function instead of a constant, or stepwise maximum potential. For example the maximum potential of GSM-services was determined by the roll-out starting at city centers, densely populated areas and along main roads (lot of traffic). This way a relatively small number of devices could cover most of the potential needs, and it took a longer time to cover the whole area (thus the concave function along time).

4. COMBINING DIFFUSION MODELS AND SUPPLY SIDE FOR SCENARIOS

Finally, we would suggest to use the following approach in determining the diffusion for the creating long-term scenarios for services under circumstances of quick technical development. The Mobicom project is to launch studies on consumer behaviour and mobile users demographics, demand-side quantitative analysis of e- & m-commerce and to recognize state-of-the art technology and key players for m-commerce services (see Figure 4), which are to feed in to scenario development. The diffusion/adoption models are depicted on the dotted area.

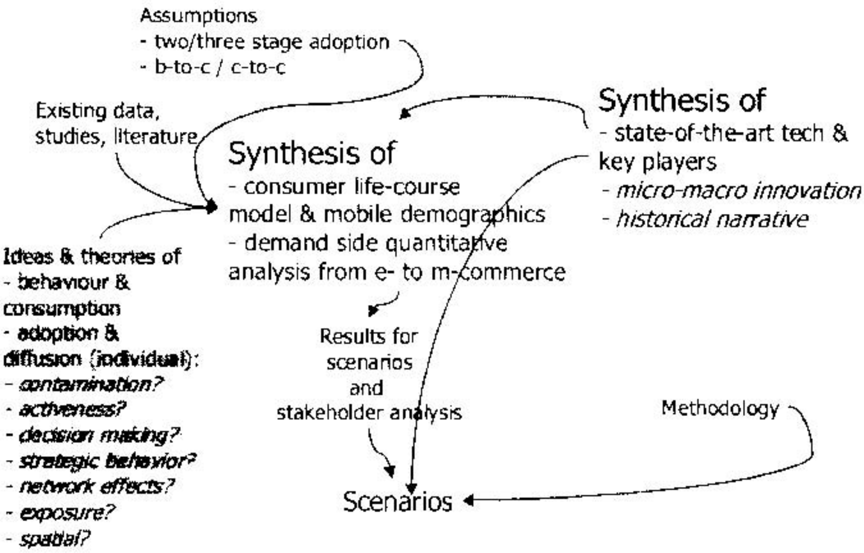

Figure 4. The framework for creating scenarios for services in changing technical environment

The scenarios will be built upon the survey results from individual adoption in each of the market areas, where the adoption and diffusion ideas and assumptions are taken into account. As a consequence the survey should supplement the existing literature by casting light on the *adoption and diffusion* in multiple layers. It is also to take into account the *technical development, as it may have* a notable difference on the maximum potential, as argued above. Finally, the research framework should explicitly take into account whether we are talking about b-to-c or c-to-c services. It has been shown in many studies that the innovations change the everyday life, and especially the communication technology adopted in peers is highly social phenomenon (Kopomaa, 2000).

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