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UMTS Growth Model,
A System Dynamics Model for Simulating the Take-up of UMTS

Jeroen de Ridder,
Ilse Paarlberg,
Els van Daalen,
Jolien Ubacht,
Policy Analysis Group,
School of Systems Engineering, Policy Analysis and Management,
Delft University of Technology,
P.O. Box 5015, 2600 GA Delft, The Netherlands,
Phone: +31 15 2781143, Fax: +31 15 2783422
E-mail: G.J.deRidder@tbm.tudelft.nl,
I.M.Paarlberg@tbm.tudelft.nl,
C.vanDaalen@tbm.tudelft.nl,
J.Ubacht@tbm.tudelft.nl

Abstract

Within a few years, the Universal Mobile Telecommunication System (UMTS) is expected to be commercially available. This system is the European implementation of third generation mobile telecommunication and is expected to be the successor of second generation systems like GSM (Global System for Mobile communication). A key uncertainty is how and at what speed the customer take-up of UMTS is likely to proceed, especially in relation to the current use of second generation systems. This question is of importance to telecom operators because it could significantly influence their strategic decision making.
Since this problem involves strategic, long term considerations and it does not have the level of detailed specification required for more exact forecasting techniques, a System Dynamics approach was used to build a Powersim model. The model takes into account the key factors in the take-up and migration process and allows the user to simulate different scenarios of UMTS take-up in the United Kingdom in order to develop a general insight into the market dynamics.
Three different groups of UMTS users are taken into account: (1) new users (users that have not used second generation systems), (2) second generation users migrating to UMTS and (3) users who migrate to UMTS but keep on using second generation systems (dual users). The market is divided into two segments: business and residential users. Important factors relating to the take-up of UMTS that are taken into account are: quality of service, hardware quality, cost, technological developments and customer attitude.

1. Introduction

The nature of telecommunications is changing rapidly. There are at least three important trends causing this development (Riseley, 1999). Firstly, demands are growing: people want to communicate on the move, they want to be able to use their telecommunications services whenever they want and they also want to receive important messages instantly. Secondly, communication is becoming more personal. Cell phones, for example, do not belong to households any longer, but to individuals. Finally, keeping track of messages is becoming harder, because each recipient has multiple mailboxes (voicemail, answer phone, work/home email, cell phone, etc.) and the sender has no guarantee if and when messages will be retrieved from these mailboxes.

These developments cause a shift in communication patterns towards *'any one, any time, any place'* communication. Current systems for mobile communications, like GSM[1], a so called second generation system, will probably not be able to handle this changing way of communication adequately. These systems, despite their evolution, are still constrained in terms of the data rates, and thus the kind of services they can offer and in their flexibility to facilitate complex, yet user friendly multimedia services.
Third generation mobile systems are systems that do meet the requirements of the *'any one, any time, any place'* environment. The European implementation of these third generation mobile and wireless systems is the Universal Mobile Telecommunication System (UMTS). It has a high capacity (up to 2 Mbit/s, in comparison: at the moment it is expected that GSM will extend its capacity up to 384 kb/s). It is expected to be able to serve a highly personalised mass market and to provide new, innovative, interactive multimedia services. Multi-mode terminals for access to second and third generation services will enable the use of wireless services in the remotest places (UMTS Forum, 1998).
It is obvious that the introduction of UMTS will pose an important challenge (and perhaps a serious threat) to European telecommunication providers. They will have to react adequately to the introduction at an early stage, or else they risk jeopardising their future market position, revenues, competitive edge, etc. To determine their strategy, telecom providers therefore need to gain an early insight into the market dynamics of this new telecommunication system. This paper describes a System Dynamics model that was developed to simulate different scenarios of customer take-up of UMTS in order to gain some understanding of the market dynamics that will accompany the introduction of UMTS in the UK.
This paper is organised as follows. Section 2 gives a brief overview of UMTS. Section 3 describes the basic structure and main ideas of the model. Sections 4 and 5 focus on two main features of the model: the way in which customer behaviour was modelled and the graphical user interface that was added to it. Section 6 concludes this paper and provides recommendations for further research.

2. The Universal Mobile Telecommunication System

The first generation of mobile telecommunication systems, introduced in the 50's and phased out in most West European countries by now, were so called analogue systems. Terminals were used mainly in cars, because of their size and weight. With the introduction of digital transmission techniques in mobile telecommunication, the second generation of mobile telephony was born. These second generation telecommunication systems have evolved into the well known and widely used cellular phones. In Europe, the GSM standard has become the default. Worldwide, a lot of effort is put into the development of third generation systems, that will provide improved features over second generation systems. UMTS is the European version of these third generation systems. It is being standardised by the European Telecommunications Standards Institute (ETSI) in cooperation with other national and regional standardisation bodies. Introduction of UMTS services is expected in 2002.
The major differences with second generation systems will be the improved flexibility and greater available bandwidth (UMTS Forum, 1998). Because of this, new and customisable services will be possible. Examples of these services will be discussed later. UMTS will provide fast access and (high) transmission rates on demand. Data rates of up to 2 Mbps and

[1] Global System for Mobile Communication, originally Groupe Spécial Mobile, after the French design group of the GSM standard. GSM is the most widely used standard for mobile cellular telecommunication in Europe. For an overview see Scourias (1995). A comprehensive treatment is given in Mouly & Pautet (1992).

even higher will be possible, depending on the user's location and actual traffic load. Asymmetric use of bandwidth will be possible (i.e. a user's incoming and outgoing data rate can differ from each other). This allows for (interactive) multimedia applications. UMTS technology provides virtual connectivity to the network at all times, which implies that users can receive instant notification of events and continuous updates of information.
Users have their own Virtual Home Environment (VHE), a consistent set of interfaces, applications etc., which can be tailored according to the user's specific demands. This VHE can be easily transferred from terminal to terminal, for example by means of an identification card, that can be plugged into terminals.
UMTS services will be based on standardised service capabilities, that form the building blocks for more advanced, user specific, services. Examples of UMTS services can be divided into three categories: fixed or mobile multimedia services, mobile only services and mobile multimedia services (European Commission, 1997). The first category includes services like video and audio-on-demand, interactive education and games, home shopping, banking, videoconferencing, videotelephony, remote collaborative working, etc. The second category includes some of the already known mobile services like plain mobile telephony, voicemail, Short Message Service, e-mail delivery, broadcast and public information messaging, Internet and intranet access, fax, etc. The third and last category represents services such as: application sharing, lottery and betting services, sophisticated broadcast and public information messaging, online shopping, fast Internet access, videoconferencing, telepresence, etc.
Initial (limited) UMTS services will be introduced in selected areas in the UK in January 2002. The roll-out of the network will then continue until full service is available around January 2005. In the long term, UMTS should reach global coverage through its flexible layered radio cell architecture. This is depicted in figure 1.

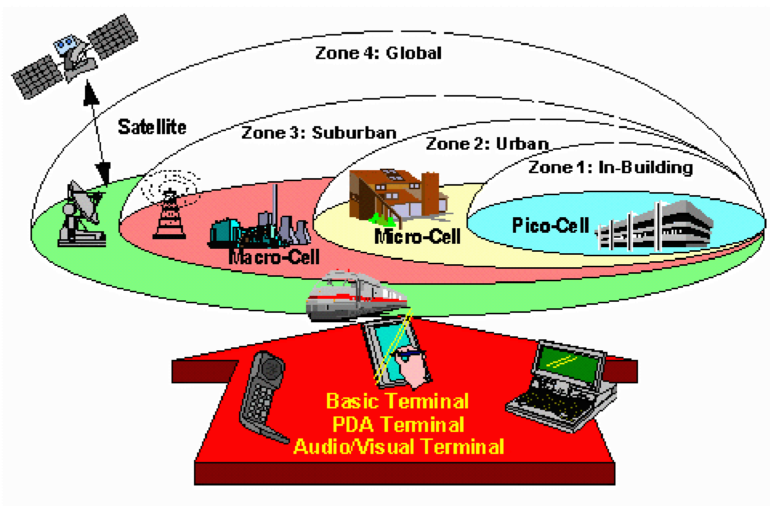

Figure 1: UMTS layered radio cell architecture (UMTS Forum, 1998)

3. The UMTS take-up simulation model

This section outlines the basis structure of the UMTS Growth Model and describes the main ideas behind it. The model provides a tool to explore different scenarios for UMTS take-up and customer migration from second generation systems to UMTS in the UK. The System Dynamics UMTS Growth Model has been implemented in Powersim. The model offers a range of flexibility regarding UMTS and second generation developments, technological development in general and customer attitude towards advanced mobile systems, so that a variety of future developments can be explored.

The model divides the UK market into two main segments: the business market and the residential market. ‘Profiles’ of these two segments can be determined by setting their preferences for different aspects of second generation systems and UMTS. The model simulates the take-up of UMTS and customer migration for both market segments.

Figure 2 shows an aggregated diagram of the main variables and their mutual relations in the model. The most important variable is the *total number of UMTS users*. This number is made up of three groups of UMTS users:

1. *UMTS new users:* This group consists of UMTS customers who have never used second generation systems;
2. *UMTS migrated customers:* The second group are prior second generation customers, that have exchanged their subscription to second generation systems for UMTS;
3. *Dual users:* The third group consists of the people that do adopt UMTS, but do not instantly dispose of their subscription to second generation systems. For a period of time, they use both systems simultaneously in ways that depend on their specific needs.

The group of *second generation users* is composed of the customers of all different types of second generation systems (e.g. GSM 900, GSM 1800).

The *attractiveness* of both UMTS and second generation systems is determined by three main components: Quality of Service (QoS), hardware quality and cost (see Oodan et al. (1997), Bouch & Sasse (1999)). In reality, these three components are also composed of a number of factors, such as compatibility, coverage, user-friendliness, utility, terminal manageability, cost of network access, tariffs, etc. The attractiveness is also affected by the users’ preferences. The business and residential market segments are likely to appreciate the three components differently. Therefore, the attractiveness of both systems will not only depend on the product features, but also on users’ specific preferences.

The *technological development* reflects the development of technology in general. This variable expresses the progress in different technological areas that influence (mobile) telecommunication systems, such as data compression, middleware, battery, interface and billing technology, etc. This variable influences the QoS, hardware quality and cost of both second generation systems and UMTS.

The *customer attitude* represents the general societal attitude towards advanced mobile telecommunication systems. It is an index for the ‘trust’ in and acceptance of these systems. Factors that influence this attitude include desire for individuality and personalised services, culture of working flexibly, environmental concerns, etc.

The flows of customer take-up and migration were described by equations, based on the work of Bass (1969) and the adjustments that were suggested by Easingwood (1988). Research by Parker (1994) suggests that these models are an adequate description of customer take-up processes. The way in which user behaviour was modelled to determine attractiveness, will be described in more detail in the next section.

Three scenarios were added to the model, for high, medium and slow UMTS growth. They show three possible future courses of development for UMTS, second generation systems, technological development and customer attitude. These scenarios can be used to obtain a first impression of how the model behaves.

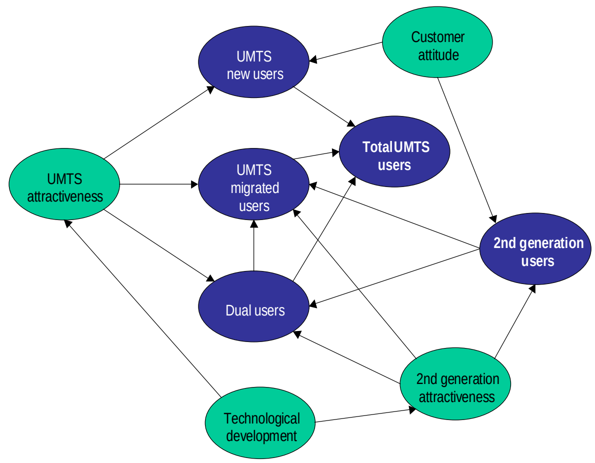

Figure 2: Key variables and relations in the model

4. Modelling user behaviour

While user modelling (i.e. customer modelling) is one of the most important determinants for the adequacy of the model, it is also an impossible task. The complex patterns and mechanisms that determine (aspects of) human behaviour, will probably never be caught in computer models. Therefore, some simplifications had to be made. It is assumed that users act strictly rationally (an assumption that is not uncommon in general decision theory (see Beroggi, 1998)), which in this case implies that when the attractiveness of one product is greater than that of another, users will start buying that product and once they have acquired it, they will never buy the other product (again).

The total user market is divided into two general segments: business and residential. Within these segments, users are homogeneous. The way in which these two segments differ, is their appreciation of the system features. Generally speaking, business users attach greater value to QoS, whereas cost will be less of a concern to them.

This brings us to the main idea underlying user modelling in the UMTS Growth Model. On the one hand, the 'objective' system features like hardware quality, QoS and cost play an important role in the user's decision, but on the other hand, his or her 'subjective' appreciation of these features is important (see e.g. Oodan et al., 1997). A system with excellent hardware quality and extremely high costs, will not be attractive for users that are insensitive to beautiful terminals but do care about their expenditures.

To allow both of these components to influence user behaviour, a user specific attractiveness index is introduced, which incorporates both the objective and the subjective factors. The 'objective' factors are expressed in terms of an index $r_{i,s}$ ($i = 1, 2, 3$ for the system features and $s = 1, 2$ for system type, either UMTS or second generation), ranging from zero (*0*) to two (*2*) (symmetric around one (*1*))[2]. Each system has its own values for these indices. The user's appreciation of these factors is expressed as a 'weight factor' $w_{i,u}$ ($i = 1, 2, 3$ and $u = 1, 2$ for user type, either business or residential). Both user types have their own set of weight factors for both systems' hardware quality, QoS and cost. The overall attractiveness $a_{s,u}$ of system s and user type u is then computed as follows:

$$a_{s,u} = \sum_i r_{i,s}^{\;w_{i,u}} \quad (1)$$

[2] Note that cost is directed in the opposite way compared to hardware quality and QoS. High cost will be negatively appreciated, whereas high QoS will be positively appreciated.

The weight factors thus act on the indices in an exponential manner. This approach allows for greater flexibility than a simple multiplicative relation. In this way, the ‘subjective’ weight factors have a much greater impact on the total attractiveness, representing the large impact of user appreciation and perception on their decision making process.
This attractiveness index is the basis for users’ decisions. Once the attractiveness of UMTS becomes greater than that of second generation systems, users will start adopting UMTS, either instead of their second generation systems (migrated users) or in addition to them (dual users). Here, the assumption of strict rationality is important. Once users have adopted UMTS, they will not go back to second generation systems. Dual users will, after a while, become UMTS-only users.
Our attractiveness index seems to play the same role as the ‘probability of purchase’ that is used in Maier (1998). Like the attractiveness index, this probability also acts upon the basic coefficients of the adoption equations, so as to influence the rate of adoption. The probability is determined by structural elements of innovation diffusion such as market structure, pricing, quality, repeated purchases, etc. Our approach differs from that of Maier (1998), in that it tries to incorporate the ‘subjective’ elements of customer behaviour in innovation adoption.

5. The graphical user interface (GUI)

The main purpose of the model is to allow exploration of different scenarios of UMTS take-up. The model was developed to be used by marketing specialists of telecom providers. It was thus of great importance that the model could be used by non-business-modelling-experts. Therefore, the model is equipped with a customised graphical user interface. The improved graphical possibilities of Powersim 2.5 were used to build this interface.
The central part of the interface is the ‘guide through the model’ screen. This screen contains buttons to all relevant parts of the model, including a short (textual) introduction to the model, in which the main goal and functions of the model are described, and a graphical representation of the influence diagram (causal diagram) that formed the basis for the model. This screen is shown in figure 3. Each button takes the user of the model to a following screen, where s/he is given additional on-screen information and can adjust parameter values, view the Powersim diagram itself, or view model output graphs. These screens also have navigation buttons to take the user to the *previous* and *next* screen (based on the guide) or back to the guide. An example is shown in figure 4.
Another feature of the interface is the control buttons screen, which can also be seen in figure 3 on the left hand side. These buttons always remain visible and give the model user control over key functions, such as *run*, *pause*, *output* (figure 5), *guide*, *stop* and *quit*. In this way, the model user does not have to use any of the normal Powersim buttons. S/he can just focus on the model itself without having to know anything about Powersim.
A further important aspect of the model is the possibility to either explore one of the three built-in scenarios or to fully customise the model. The guide screen (figure 3) helps the user of the model to make this choice. S/he can choose one of two paths through the guide. Inexperienced model users will probably prefer to get acquainted with the model by exploring one of the three scenarios. These scenarios are ready to use, the model user just has to choose one (with a tick box) and push the *run* button. The experienced model user may prefer to adjust all of the parameters according to his or her specific wishes for that simulation. S/he can do this by just navigating through the screens and setting the parameter values (figure 4). All of the parameters can be adjusted by slider bars, tick boxes and radio buttons. Here too, s/he does not need to have any knowledge of the normal Powersim interface. All the Powersim details are completely hidden.

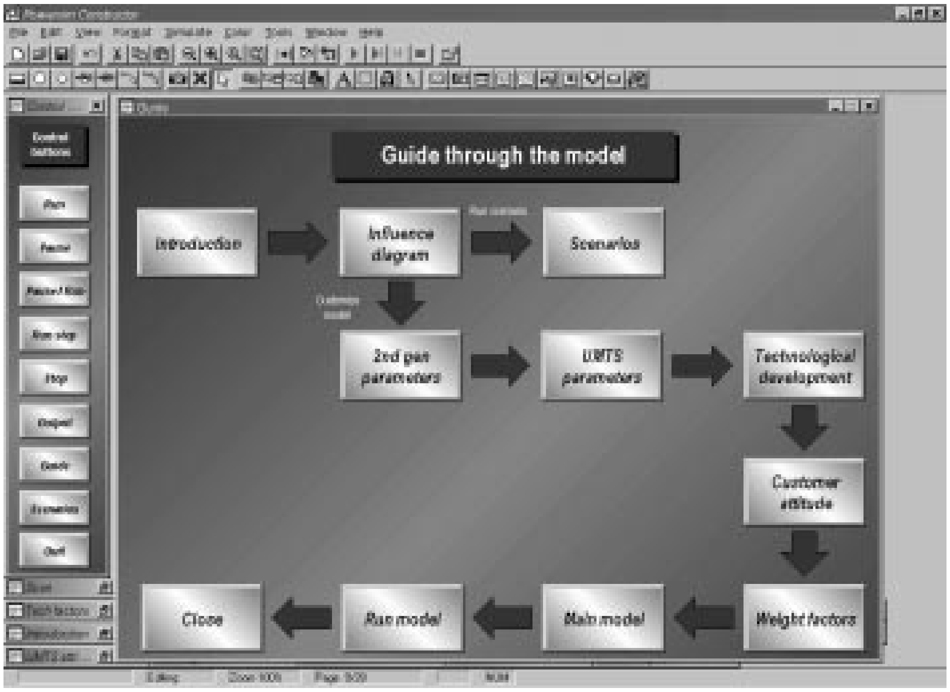

Figure 3: 'Guide through the model' screen

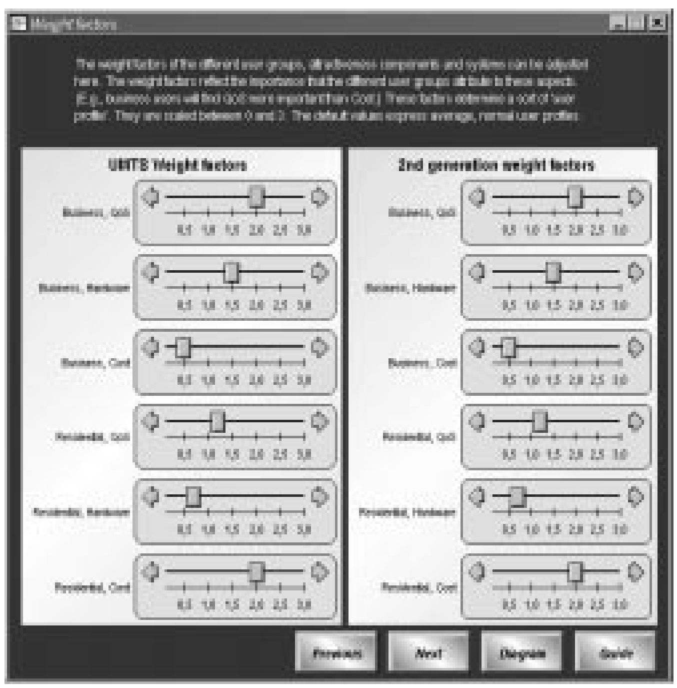

Figure 4: Example of a screen with navigation buttons and slider bars to adjust parameters

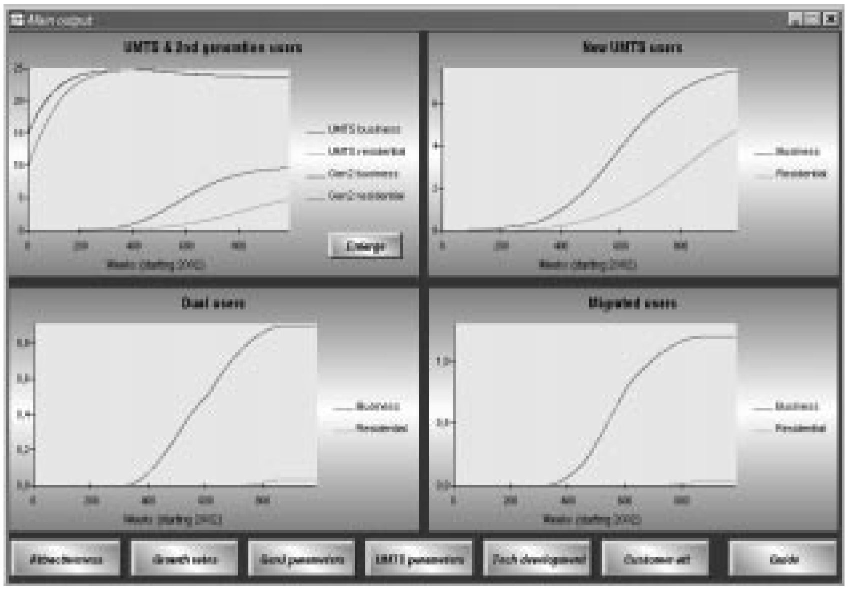

Figure 5: Main output screen

6. Conclusion and recommendations

UMTS, being the successor of the widely used second generations mobile systems, is likely to have a significant impact on the telecommunications market. Telecom providers therefore have an interest[3] in investigating the customer take-up and in understanding the market dynamics which will accompany the introduction of UMTS. In this paper, a System Dynamics model was presented that can be used to simulate a wide range of scenarios and allow the user to explore the effect of various relevant parameters. User behaviour was modelled by introducing a subjective attractiveness index per customer type, which includes objective system features as well as subjective customer appreciation of these features. A complete GUI was added to the model to allow people that are not familiar with Powersim to use the model.

A number of conclusions can be drawn from this project. Forecasting future market developments is a virtually impossible task, especially when hardly any or no quantitative data is available. Since UMTS has not been introduced in the market place yet, the only option was to use figures from the take-up of mobile telephones and the use of mobile data services.

Modelling customer behaviour will probably always remain one of the greatest challenges for business modelling. The highly complex processes that constitute human decisions can never be described by simple formulas. This model presents a simple scheme to combine objective product features, such as quality and cost, with subjective customer appreciation of such features into one attractiveness index. This scheme appears to have useful features, but the validity should be more thoroughly examined by comparing it with ‘real’ customers’ decision processes. In general, research should be carried out into how human decision processes can be described. The relation between objective system features and subjective perception requires further examination.

[3] Just before submission of this paper, the authors were informed that UMTS licenses have been sold in the UK on 27 April 2000 for the astronomical total amount of 35.4 billion US dollars. This stresses the importance of understanding future market developments of UMTS.

A GUI can strongly enhance the usability of business models, since the people who would like to use them generally do not have the knowledge and expertise to work with a computer simulation tool like Powersim. The interface can serve as a ‘shell’ which hides the technical modelling details and still allows the (inexperienced) user to fully benefit from the merits of computer simulation models. However, there is a risk in this way of using the model. The inexperienced user of the model is largely unaware of the assumptions which underlie the model and thus of its limitations. S/he might start to perceive the model as a highly reliable black box, that can be used to predict the future with great precision. The more sophisticated and ‘glamorous’ the interface looks, the stronger this effect may be.
The interface was tested with a small number of inexperienced model users and they found it quite easy to work with. Further testing and modification of the interface is desirable to find out whether model users are really comfortable with it. Perhaps the ‘guide through the model’ screen should be adjusted, or more explanation is required, etc.
The model itself can also be improved upon. The present market segmentation that is used in the model is very coarse. A further segmentation would be desirable to allow for fine tuning of the model. The spatial effects of UMTS adoption should be added to it to investigate how the take-up will proceed in different geographical areas. An interesting approach is presented in Nijkamp & Reggiani (1996). They argue that space does not only act as a geographical dimension upon which techno-economic changes are projected, but it also serves as a medium of opportunities and barriers through which such techno-economic changes are filtered. They also suggest methods to model this spatial diffusion. Another important extension would be to include competition in the model. The present version only models the market as a whole, and does not model the supply side, market shares, etc. Elaboration of the model to include this, would be a very valuable feature. The suggestions given in Maier (1998) seem to be relevant here.

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