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van der Vlies, R.D.; van Bronswijk, J.E.M.H.

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HOME AUTOMATION AS AN EXAMPLE OF CONSTRUCTION INNOVATION

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Remy D. van der Vlies MSc PDEng¹ and Johanna E.M.H. van Bronswijk PhD²

¹ r.d.v.d.vlies@tue.nl, Technische Universiteit Eindhoven Den Dolech 2, Eindhoven, the Netherlands, TNO Bouwinnovatie Van Mourik Broekmanweg 6, Delft
² j.e.m.h.v.bronswijk@tue.nl, Technische Universiteit Eindhoven Den Dolech 2, Eindhoven, the Netherlands

Home automation can contribute to the health of (older) adults. Home automation covers a broad field of ‘intelligent’ electronic or mechanical devices in the home (domestic) environment. Realizing home automation is technically possible, though still not common. In this paper main influential factors for home-automation diffusion are identified by applying innovation management theory to this specific domain. An innovation is defined as an idea, practice, or object that is perceived as new by an individual or other ‘unit of adoption’. For home automation, three units of adoption are involved: the user, the health professional and the building specifier. 

User adoption of home automation is influenced by its (i) relative advantage, (ii) compatibility, and (iii) complexity. Known influential factors for home-automation diffusion are age and health of the user and home-automation’s contribution to either independence and autonomy, or safety of older users, as well as convenience and comfort of younger users. However, user and innovation characteristics often do not match. Adoption by health professionals might be influenced by the absorptive capacity and technophobia of care organisations, number of stakeholders, and financial structure within the care sector. Adoption decisions of building specifiers might benefit from learning capacity, innovativeness, and absorptive capacity of the company, and will be hampered by the building industries fragmentation and short term orientation as is known for the adoption of sustainable construction products. The influential factors mentioned for health professionals and building specifiers still lack sufficient empirical support. To have home automation adopted and diffused we need to develop tools to assess home-automation functionality for all units of adoption during its design.

Keywords: [technology acceptation, innovation diffusion, home automation, smart home, older adults].
INTRODUCTION

Realizing home automation is technically possible (Chan et al. 2008). However, home automation is successfully applied in a small percentage of the housing stock (Franchimon et al. 2005). In the late nineties and the beginning of the century this lack of diffusion was thought to be caused by a lack of user orientation (Sixsmith & Sixsmith 2000). This has been studied frequently in the last decade (Demiris et al. 2004; Demiris et al. 2008). User orientation improved (Morandell e.a. 2008; Ringbauer e.a. 2003; Veldhoven e.a. 2008) but did not result in home automation to become common. This indicates that most likely, there are other barriers for the diffusion of home automation in construction.

Innovation Management

Innovation theory gives influential factors for the diffusion of new technologies. Are those factors discussed for home automation? ‘Innovation’ is used by some to describe the creation of new (building) technology (Gann & Salter 2000). Others discuss both the creation and the diffusion of innovative products (Miozzo & Dewick 2004). An innovation is defined in this paper as an idea, practice, or object that is perceived as new by an individual or other unit of adoption. An innovation and an invention are considered to be two different things based on the definition of Roberts (2007): 

\[ \text{Innovation} = \text{Invention} + \text{Exploitation} \]

Based on Roberts and in line with Rogers’ definition of an innovation an invention is defined as a functioning idea, practice or prototype object which is the result of creating new knowledge and generating technical ideas aimed at new and enhanced products, manufacturing processes and services.

Home Automation

Home Automation can contribute to the health of (older) adults (Korporaal et al. 2002; Loera 2008; Nispen 2003) and reduce costs of care (Tang & Venables 2000; Chan et al. 2008). ‘Home automation’ covers a broad field of ‘intelligent’ electronic or mechanical devices in the home (domestic) environment. Four types of home automation are distinguished (Heusinger 2005): 1) Building Services, 2) Infotainment, 3) Household appliances, 4) Service enabling technologies. The latter can for instance enable grocery shopping; it is however more commonly used for health care. Zsuzsa & Ferene (2008) and Heusinger (2005) define an intelligent or smart home to be a house in which already automated units or subsystems are integrated into one programmable system. In this paper this is perceived as home automation.

Aim

The aim is to identify main influential factors for home-automation diffusion by applying innovation management theory. What influential factors for innovation diffusion are known from innovation theory that are not yet discussed for home automation?
INNOVATION MANAGEMENT THEORY

Within this paper, home automation literature is evaluated against innovation management theory. Both Rogers’ Innovation Diffusion Theory (IDT) and Technology Acceptance Model (TAM) (Davis, 1989) are frequently used. IDT is the more complete theory. TAM explains user acceptance based on perceived usefulness and perceived ease of use. In IDT these variables are known as relative advantage and complexity. These two factors combined account for slightly more than 40% of variance (Legris e.a. 2003). Influential factors suggested by Bouma et al. (2007) and Oppenauer (2009) to extend TAM are all present in IDT. Therefore IDT is used in this research.

Innovation-Decision Process

The diffusion of an innovation is perceived in IDT as a series of decisions to buy or use an innovative product. The more people (or other units of adoption) decide to buy or use the innovation, the larger the rate of diffusion is. Rogers’ model of the innovation decision process helps to understand what factors influence the decision to either adopt (buy or use) an innovation or to reject it.

The innovation-decision is influenced by five factors, see figure 1(Rogers 1995):

1) prior conditions include (i) previous practice, (ii) innovativeness, and (iii) felt needs providing the information, values, and sense of urgency that result in awareness of or knowledge from an innovation.

2) characteristics of the DMU (decision-making unit); level of social status, education, empathy, rationality, and interconnectedness influence the venturesomeness of the decision-maker(s).

3) characteristics of the innovation are (i) relative advantages in terms of costs and quality, (2) compatibility with habits and values of the DMU, (iii) complexity in use for the DMU, (iv) trialability or testability of the innovation before making the decision, and (v) observability or visibility of the advantages of the innovation.

4) characteristics of the communication channels are (i) presence of opinion leaders, (ii) strength of network ties, and (iii) presence of a (governmental) change agency directing the innovation decision.

5) functionality: is there indeed a ‘functioning idea, practice, or prototype’? Is it already an invention, or is it still being invented?

Rogers does not explicitly mention ‘functionality’ but appears to take it for granted. During the literature study it was found that the (mal)functioning of the innovation was a topic. Therefore this fifth influential factor is explicitly mentioned.

Prior conditions proved during research to be open to different interpretations. Previous practice (1.i) and innovativeness (1.ii) are closely related to the socioeconomic and demographic characteristics of the DMU. Many papers discuss home automation in general instead of a specific artifact. In those cases it proved difficult to distinguish ‘the felt need for home automation’ (1.iii) from ‘the relative advantage a home automation might provide’ (3.i). It is therefore suggested that in future research ‘prior conditions’ is not discussed as a separate group of influential factors but put together with the other four factors.
Emmitt & Yeomans (2001) adapted Rogers’ model to describe the innovation-decision process of a specifier (selector of building materials and components) working in an architectural office. The model surpasses the span of control of the specifying architect by including the clients’ decision to tender and also the possibility of the specification of a substitution by the contractor. Emmitt & Yeomans thus point out the possibility of multiple units of adoption.

**Literature searching method**

Literature on the diffusion of home automation is searched using Google Scholar. Combinations of key words used for identifying relevant articles are shown in table 1:

<table>
<thead>
<tr>
<th>Diffusion acceptation</th>
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<tbody>
<tr>
<td><strong>Domotics</strong></td>
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<tr>
<td>X</td>
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<tr>
<td>&quot;home automation&quot;</td>
</tr>
<tr>
<td>X</td>
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<tr>
<td>X</td>
</tr>
<tr>
<td>&quot;smart home&quot;</td>
</tr>
<tr>
<td>X</td>
</tr>
</tbody>
</table>

Domotics, a combination of domus and robotics, is used as a synonym for home automation (Chan et al. 2008). The combination of domotics and diffusion resulted in less than ten relevant papers. Other papers often discussed the diffusion of data or information within the home automation system instead of the diffusion of the domotics-technology itself.
RESULTS

The main influential factors as given by different authors are summarized below for (i) ‘prior conditions’; characteristics of the (ii) DMU’, (iii) innovation’, and (iv) communication channels; and (v) functionality. The factors are summarized in table 2.

(i) Prior conditions are discussed by three authors in the selected literature. Felt needs and felt problems, and norms of the social system are discussed for older adults. Concerning felt needs and problems Ahn (2004) found in a survey amongst 1000 respondents aged 55-80 that 56% expects problems with their house as they age; 14,6 % expects problems related to medical services, house keeping, and safety. Safety (especially related to falling) and independence were the most frequently mentioned concerns in focus groups of persons aged 65+ (Mahmood et al. 2008; Wild 2008). Interview with 24 elderly residents by Boulanger & Deroussent confirm this (2008). The second prior condition is the ‘norms of the social system’ (Zaad & Ben Allouch 2008). Their relatives’ norms toward ICT use are unknown to 45% of the elderly users interviewed by Boulanger & Deroussent (2008).

(ii) The most prominent characteristic of the home automation user appears to be his or her age and health (Ahn 2004; Loera 2008; Meyer & Schulze 2002; Sponselee et al. 2008). It was found that younger adults with better health conditions and higher education levels have a more positive perception of residential technology. The type of occupation and the level of education also influence the decision to live in a smart home (Han & Tan 2003; Petersen 2001).

Only one characteristic of the health professional and building specifier was found. The health professional is found to be technophobic (Magnusson e.a. 2004; Sponselee e.a. 2008), in contrary to the building specifier (Sponselee et al. 2008).

(iii) Home automation is commonly characterised from a user perspective. Only two authors discuss the characteristics of the innovation from the perspective of the health professional. No characteristics of the innovation as perceived by the building specifier were found.

Three characteristics of the innovation are found most frequently: relative advantages to the user, compatibility with the users’ habits and values; and complexity in use. Home automation is expected to contribute to (elder) users’ safety and independence, as is shown with focus groups with adults aged 65+ (Demiris et al. 2004; Demiris et al. 2008; Zaad & Ben Allouch 2008). Some home automation has relative disadvantages, as is found in 41 interviews with older adults by Grael & Spellerberg (2008). For example, several respondents experienced disadvantages from the switch to turn off plugs when leaving the apartment; clocks had to be reprogrammed, and freezers defrosted. Home automation can also enhance control over security and building services, as is shown in a user trial of 12 persons aged 23-33 (Rentto et al. 2003). Han & Tan (2003) found the prime relative advantages of a smart home to be convenience and costs. Intrusiveness and privacy matters are concerns in compatibility. Compatibility with privacy-values can be a barrier for (older) adults’ adoption of smart home technology (Courtney et al. 2007; Rentto et al. 2003), however, the perceived relative advantage can override the privacy concerns (Courtney et al. 2008). Complexity is the third characteristic of home automation.
(Demiris et al. 2004). Older adults are more likely to consider ease of use as important as younger adults when adopting innovative technologies (Ahn 2004).

One characteristic of the innovation as perceived by the health professional was found. Home automation can reduce costs of care by reducing time spent on care (Magnusson e.a. 2004). It was also found that health professionals experience a reduction in time spent with clients as los of quality of care and thus a relative disadvantage (Magnusson et al.2004; Sponselee et al. 2008).

(iv) Few characteristics of the way in which information concerning home automation is communicated were found. Aldrich (2003) mentions ‘technology push’ by suppliers as a negative characteristic. Also the evaluation of realized projects is poor (Aldrich 2003).

(v) Functionality related influential factors are ‘interoperability with products of other vendors’ and ‘compatibility with existing building stock’. Interoperability is recognized by engineers as a design topic (Bellazzi et al. 2001). However, diffusion will only be possible with increased interoperability and universal plug-and-play of all applications (Bronswijk et al. 2007). Also systems were found only to be applicable in newly built housing (Grauel & Spellerberg 2008).

Apart from innovation influential factors also new technological ideas, principles and prototypes (inventions) were also found. The following are a random selection of many papers and articles: Arcelus et al. 2007; Carreras et al. 2007; Dario Bonino & Garbo 2006; Giorgetti et al. 2008; Koskela & Väänänen-Vainio-Mattila 2004; Mainardi et al. 2005; Mirabella et al. 2008; Morandell et al.2008; Pellegrino et al. 2006; Ringbauer et al. 2003; (Veldhoven e.a. 2008); and, Yamamoto et al. 2004.
<table>
<thead>
<tr>
<th>Success factor for diffusion</th>
<th>Discussed by author</th>
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<tbody>
<tr>
<td><strong>Prior conditions</strong></td>
<td></td>
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<tr>
<td>Felt needs / problems</td>
<td>Ahn 2004; Boulanger &amp; Deroussent 2008; Mahmood et al. 2008; Wild et al. 2008</td>
</tr>
<tr>
<td>Norms of the social system</td>
<td>Boulanger &amp; Deroussent 2008; Zaad &amp; Ben Allouch 2008</td>
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<tr>
<td><strong>Characteristics of the decision-making unit</strong></td>
<td></td>
</tr>
<tr>
<td>User</td>
<td>Ahn 2004; Han &amp; Tan 2003; Loera 2008; Meyer &amp; Schulze 2002; (Sponselee e.a. 2008); Petersen et al. 2001</td>
</tr>
<tr>
<td>Health professional</td>
<td>Bellazzi et al. 2001; Magnusson et al. 2004; Sponselee et al. 2008</td>
</tr>
<tr>
<td>Building specifier</td>
<td>Sponselee et al. 2008</td>
</tr>
<tr>
<td><strong>Perceived characteristics of the innovation</strong></td>
<td></td>
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<tr>
<td>User perspective</td>
<td></td>
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<tr>
<td>Relative advantages</td>
<td>Ahn 2004; Aldrich 2003; Courtney et al. 2008; Demiris et al. 2004; Demiris et al. 2008; Grauel &amp; Spellerberg 2008; Han &amp; Tan 2003; Magnusson et al. 2004; Meyer &amp; Schulze 2002; Petersen et al. 2001; (Rentto e.a. 2003); Zaad &amp; Ben Allouch 2008</td>
</tr>
<tr>
<td>Compatibility</td>
<td>Ahn 2004; Courtney et al. 2007; Courtney et al. 2008; Demiris et al. 2004; Demiris et al. 2008; Hensel et al. 2006; (Rentto e.a. 2003); Sponselee et al. 2008; Venkatesh &amp; Shih 2001</td>
</tr>
<tr>
<td>Complexity</td>
<td>Ahn 2004; Bellazzi et al. 2001; Demiris et al. 2004; Magnusson et al. 2004</td>
</tr>
<tr>
<td>Testability</td>
<td>Ahn 2004</td>
</tr>
<tr>
<td>Observability</td>
<td>Ahn 2004</td>
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<tr>
<td>Health professional perspective</td>
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<tr>
<td>Relative advantage</td>
<td>Magnusson et al. 2004; Sponselee et al. 2008</td>
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<tr>
<td>Building specifier perspective</td>
<td></td>
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<tr>
<td>Relative advantage</td>
<td>-</td>
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<tr>
<td><strong>Characteristics of the communication channels</strong></td>
<td></td>
</tr>
<tr>
<td>Technology push</td>
<td>Aldrich 2003</td>
</tr>
<tr>
<td>Little usability evaluation by suppliers</td>
<td>Aldrich 2003</td>
</tr>
<tr>
<td><strong>Functionality</strong></td>
<td></td>
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<tr>
<td>Interoperability with products of other vendors</td>
<td>Ahn 2004; Aldrich 2003; Bellazzi et al. 2001; Bronswijk e.a. 2007</td>
</tr>
<tr>
<td>Compatibility with existing building stock</td>
<td>Grauel &amp; Spellerberg 2008; Venkatesh &amp; Shih 2001</td>
</tr>
</tbody>
</table>
DISCUSSION

Five influential factors and three decision making units are distinguished based on innovation diffusion theory. In home automation literature few influential factors concerning the building specifier, the health professional, communication channels, and home automation functionality are discussed, but user characteristics and innovation characteristics from the user perspective are found. What might be the relevance of the ‘unknown’ influential factors?

Prior conditions

Some user related prior conditions are found, but other non user related are not. Regulation, legislation and fiscal and financial incentives can encourage innovation and can help to promote the diffusion of technology as is shown for Active Solar Heating by Dewick & Miozzo (2002). Chan et al. (2008) concluded that further research is needed into legal (liability and reimbursement) and ethical problems related to home automation.

Characteristics of the decision making units

User characteristics are prominent. However, it is known from the diffusion of sustainable building products that characteristics of the building specifier can influence adoption as well.

Characteristics of building specifiers might prove (Blayse & Manley 2004): learning capacity of manufacturers, innovativeness of construction firm’s culture, absorptive capacity of construction firm, and the presence of innovation champions in the construction firm. Unlike many other industries, innovations in construction are not implemented within construction firms themselves but on the projects on which firms are involved (Dewick & Miozzo 2002; Harty 2005). No less than ten key actor types are involved in construction (Seaden & Manseau 2001). For this reason not only the characteristics of the building partners but also the characteristics of the construction project organisation are to be considered.

A special ‘building partner’ is the client. Characteristics of health professionals might prove (RVZ 2001; Sponselee et al.2008; Nispen 2003): absorptive capacity of care organisations, number of stakeholders, technophobia of stakeholders, financial structure within the care sector. For the Velemansdroom project (12 apartments) in Sappemeer, Netherlands, for example, no less then 12 funds were involved (Korporaal et al.2002).

Further characterisation of all building partners might be possible. In line with the distinction between invention and innovation, as made in this paper, it might also prove useful to make a distinction between invention-generating and innovation-adopting organisations (Hobday 1998).

Characteristics of the innovation

The benefits for both older and younger users are identified but the relative advantages to other stakeholders needs further research. Older adults and ‘younger adults’ perceive the technology differently. By seniors home-automation is seen as a contribution to their indecency and safety. Younger users appreciate especially the extra convenience and comfort a smart home offers. One might assume that
perceptions for all other stakeholders will vary concerning the broad range of interests from for example, health-care insurance agencies, electrical engineers, and nurses.

It might prove useful to distinguish categories of home automation based on the number or types of stakeholders involved. Harty (2005) divides innovations into two types: ‘bounded', where the implications of innovation are restricted within a single, coherent sphere of influence, and 'unbounded', where the effects of implementation spill over beyond this. He argues: “unbounded innovations require an approach to understand and facilitate the interactions both within a range of actors and between the actors and technological artefacts.”

Characteristics of the communication channels

A prime factor known to slow down the diffusion of sustainable innovation in the housing industry is the lack of information transfer between projects (Van Hal 2000). The change agent is an important factor for diffusion of sustainable construction technology. There are several change agents for home automation. Internationally active are for instance LonMark and the Konnex-assocation. Both promote their own specific standard. A neutral organisation promoting home automation is for example the Netherlands focussed ‘Smart Homes’. Their effectiveness as change agents are unknown.

Functionality

Lack of interoperability and compatibility with other technology proved to be main reasons for the dysfunctioning of installed home automation. Adopting technology based on un(satisfactorily)-tested products about which little is known results in a risk for the safety of the user and a risk for the responsibility for the builder (Dewick & Miozzo 2002). When the technology is a means for receiving care this risk will be even higher.

The need for a standardized communication platform has been long recognized: “Testing usability and users’ acceptance is a key issue for a computerized system” (Bellazzi et al. 2001). Several platforms, including LonMark and Konnex, have been introduced. None has sofar developed into the standard (Franchimon & Brink 2009). A reason for this might be company politics and fragmentation of the industry. A solution is still to be found.

CONCLUSION

Concluding we may say that the main influential factors for home-automation diffusion are age and health of the user; innovative capacity of the building specifier; financial structures in which health professionals operate; and home-automation’s contribution to either the independence and safety of older users or convenience and comfort of younger users. The influential factors mentioned for health professionals and building specifiers still lack sufficient empirical support. To have home automation adopted and diffused we need to develop tools to assess home-automation functionality for all units of adoption during its design.
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