Decisions in the Construction Planning Process: Development of a Dynamic Model about Individual's Energy Efficiency Intention over Time

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I. Abstract

The residential building environment accounts to a large extent for the emission of greenhouse gases. In Switzerland, 27% of the carbon dioxide emissions are generated for heating houses, providing warm water and electricity. The employment of state of the art energy efficient technologies can reduce these emissions significantly. Why are the technologies not applied on a regular basis? In this paper, we focus on the decision process and the decisions taken which the individual building owner has to make at the end of the planning process for a house. The paper's contribution is multifold: systematization of important decisions during the planning process, development of static hypotheses of decision making based on psychological action research, enrichment of the static hypotheses by empirical research, and development of dynamic hypotheses to explain intention and behavior of individuals regarding energy efficiency. From a content point of view, the paper sheds light on the development of interlinked variables during the building planning process. From a methodological perspective, the paper adds to more traceability during the model conceptualization phase.

Keywords

Theory building, adoption behavior, social-psychological research, methodology, decision making, structural equation model, energy efficiency, conceptualization phase[1],[2]

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1. Introduction

Global warming is the observed increase in the average temperature of the Earth's near-surface air and oceans in recent decades and its projected continuation. The Intergovernmental Panel on Climate Change (IPCC) concludes in its latest study that "most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations [e.g., carbon dioxide, the author]," (IPCC 2007). One of the main culprits for global warming is carbon dioxide which is set free through the deforestation and burning of fossil fuels, e.g., for the heating of buildings, leading to higher carbon dioxide concentrations in the atmosphere.

In **Switzerland**, the building environment for habitation, economy and public authorities consumes approx. 45% of the total Swiss energy demand (BFS 2005) and defines thereby to a crucially large extent both the energy consumption pattern of the country and its CO_2-emissions. The fraction of the residential building environment accounts for 27% of the total energy consumption. Given that to achieve the objective of sustainability requires a significant reduction of this consumption and CO_2-emissions in industrialized countries, the **residential building environment** is a high leverage point to reduce the total energy consumption in a sustainable manner (Koschenz and Pfeiffer 2005). This evaluation is backed up by similar developments in the European Union. It has passed a directive about energy efficiency of buildings stating that “increased energy efficiency constitutes an important part of the package of policies and measures needed to comply with the Kyoto Protocol and should appear in any policy package to meet further commitments (Art. 3)“ (Commission 2003). Both the total energy consumption of the Swiss building environment and the importance of the building environment to reduce the energy consumption show the importance of a **sustainable building stock** in order to achieve the long-term objectives of the energy politics.

A major instrument to accomplish the vision in Switzerland is the Minergie label, a family of standards about **energy efficient** design and construction of buildings and a quality label for new and refurbished energy efficient buildings (Minergie 2005). The registered trademark is mutually supported by the Swiss confederation, the Swiss cantons along with the industry. Minergie-P, is the Swiss equivalent to the German Passivhaus-Standard by which the ‘Factor 4-Vision’ (von Weizäcker, Lovins et al. 1997), can be realized, which is similar to the Swiss ‘2000 Watt per capita society’(Jochem, Favrat et al. 2004).

The energy efficiency of a building in this paper means the ratio of annual total energy consumption, calculated according to the SIA 380/1 standard (SIA 2001), divided by the energy reference area, calculated according to SIA 180/4 (SIA 1982).

1.1 Problem

Highly sophisticated technologies exist to build in energy efficient manner are available on the market and are economically affordable. However, these technologies are **not applied** on a regular base; but only in

[1] Financial support provided by the Swiss National Science Foundation (Project No. 405440-107211/1). This contribution is part of the DeeB-Research Project. DeeB is the abbreviation for “Diffusion of Energy-Efficient Buildings”. For further information about the DeeB-project contact the corresponding author or visit the website www.deeb.ch.
[2] Throughout the paper, we use the abbreviations ‘ee’ for ‘*energy efficiency*’ or ‘*energy efficient*’, and ‘ef’ for ‘*environmentally friendly*’.

approximately twelve percent of the new residential building constructions (Minergie 2004). There is a large **discrepancy** between the technologically achievable energy efficiency, on the one hand, and the actually implemented energy efficiency, on the other. The question raises therefore, who can improve this situation and how it can be done. As has been shown by Müller et al. (2007) and Muschwitz (2005) several actors interplay in the residential building environment. In this paper, we focus on private building owners.

1.2 Literature Background: Individual Action Theories

In the following, three psychological action theories and an attempt to synthesize them are reviewed that have the potential to contribute to the explanation of the decisions during the planning process of a building.

Schwartz's norm activation theory of altruism (Schwartz and Howard 1980; Schwartz and Howard 1981) has been applied to pro-environmental behavior with some success (e.g., Hunecke, Blobaum et al. 2001). The theory holds that pro-environmental actions occur in response to personal moral norms about such actions and that these are activated in individuals who believe that environmental conditions pose threats to other people or other species (awareness of consequences) and that their initiated actions could avert those consequences (ascription of responsibility to self). In other words, the norm activation theory implies, first, that the individual has a pro-environmental norm of certain strength, second, that it is activated under certain conditions, and third, that the individual – once the personal norm is activated – judges its amount of control of the situation.

Another relevant theory is the **theory of planned behavior** (Ajzen and Madden 1986; Ajzen 1991). It is a theory about the link between attitudes and behavior. The main message from the theory is that human action is guided by three kinds of considerations: First, beliefs about the likely outcomes of the behavior and the evaluations of these outcomes (behavioral believes), second, beliefs about the normative expectations of others and motivation to comply with these expectations (normative believes), and third, beliefs about the presence of factors that may facilitate or impede performance of the behavior and the perceived power of these factors (control believes). In their respective aggregates, behavioral beliefs produce a favorable or unfavorable attitude toward the behavior; normative beliefs result in perceived social pressure or subjective norm; and control beliefs give rise to perceived behavioral control. In combination, attitude toward the behavior, subjective norm, and perception of behavioral control lead to the formation of a behavioral intention. As a general rule, the more favorable the attitude and subjective norm, and the greater the perceived control, the stronger should be the person's intention to perform the behavior in question. Finally, given a sufficient degree of actual control over the behavior, people are expected to carry out their intentions when the opportunity arises. Intention is thus assumed to be the immediate antecedent of behavior. However, because many behaviors pose difficulties of execution that may limit volitional control, perceived behavioral control is thought to have an additional direct effect on behavior. In broad terms, the theory is well supported by empirical evidence and is widely used in environmental psychology but nevertheless also faces limits of predictive power (e.g., Bamberg and Möser 2007). In principle the theory is open to the inclusion of further variables that improve its predictive power for specific situations (Ajzen 1991).

A third approach to explain individual behavior, is the **needs-opportunity-abilities model** (Gatersleben and Vlek 1998). According to the Webster Dictionary (2003) a *need* is a lack of something requisite, desirable, or useful. It can also be a physiological or psychological requirement for the well-being of an organism. Needs are, in other words, objectives of individuals they pursue in order to maintain or improve their well-being or quality of life[3]. *Opportunities* can be seen as a set of external facilitating conditions, such as the objective availability of goods, materials and services, their accessibility, the relevant information that is available and prices" (Gatersleben and Vlek 1998, p. 148). *Abilities*, as last concept, are described as the set of internal capacities of an individual or household to procure goods and services. These abilities include the financial, temporal, spatial, cognitive, and physical means and skills. These three concept variables are influenced by macro level factors, such as developments in technology, economy, demography, formal and informal institutions as well as culture. The macro level factors have strong influences on consumer behavior due to their change effects on abilities, opportunities, and needs. For the residential building system specific macro level factors do exist but will not be further explained here.

The aforementioned three theories have been selected due to the criteria: theoretical robustness, degree of theory maturation, and suitability for the residential building environment and the decisions in this context, respectively. The caveat resulting from the named characteristics of the theories is that they are highly general and wide reaching; put differently, they are not specific to the context of the research object. The extensive literature review conveyed only one empirical study modeling (with a static empirical model) the decision behavior in the residential building environment, hereby integrating the above mentioned Norm-Activation-Model and the Theory of Planned Behavior and the distinction between cognitive and emotional responsibility-oriented constructs (see also Montada and Kals (1994) that create the readiness to behave in an environmental-friendly manner: It is **Sauerborn's model of responsible actors** (Sauerborn 2005). Both structural and social context conditions are assumed to influence actual behavior, independent from the readiness to act but were not operationalized to be statistically challenged.

1.3 Research Gap

In the previous chapters, both the problem situation has been described and several action theories have been considered that could provide means to understand the problem situation. However, a gap exists regarding the following topics:

1. The planning process of an energy efficient building includes several interrelated decisions and not only one individual decision as in the planning process of traditional buildings. It is necessary to find out what decisions take place during the building planning process.
2. The review puts forward, that the social context and the structural context conditions process have not been empirically taken into account.
3. Decisions in the planning phase of a house are more complex then the current available models appreciate. Literature does not account for the process before the decision is made. In addition, current psychological theories and research do not include feedback mechanisms, such as learning effects that are active in that decision making process. Generally stated, psychological action theo-

[3] More details about the definition and operationalization of the needs concept is provided by Gatersleben et al. (1998, p. 148).

ries are rather static than dynamic. Hence, we can state that the **current literature does not provide an explanatory and predicting theory of individual's intention and behavior** in the planning process of buildings.

1.4 Research Questions

For the paper, we depart from two main research questions, from which we derive several subsequent, more detailed and operational research questions.

Main Research Questions

I	How can the discrepancy between the available high standard, energy efficient technologies, on the one hand, and the low adoption, diffusion and implementation of those by private building owners, be explained, on the other hand?
II	Given different configurations of individual's characteristics, how is the development of intention and, finally, behavior of the individual regarding energy efficient technologies over time?

Subsequent Research Questions

1. What are important decisions for the private building owner in the construction process that determine the energy efficiency of the building?
2. What are the antecedent factors of the important decisions?
3. What feedback mechanisms are active during the planning process?

1.5 Contribution of the Paper

The existing psychological action theories are either to general or lack important explanatory constructs and, therefore, they are not sufficient to expound the considered behaviors. Consequently, we intend to develop a more suitable model with increased explanatory power that is, first, based on the existing literature and, second, that will be enriched by explorative empirical research. Our model wants to explain intention and behavior of a private building owner over time during the building planning process. Thereby, static decision research in psychological action research is enriched by a dynamic simulation approach that considers feedback mechanisms, nonlinearities dependencies between variables and time delays.

The paper contributes to both system knowledge and methodology. Regarding system knowledge about the residential building environment, the paper **systematizes** important **decisions** that occur in the construction process of a residential building. Second, we develop, based on existing psychological action research, **static hypotheses** about decision making during the construction process. Thereby, we concentrate on the most important **antecedents** that explain the decisions of the private building owners to a significant degree. Third, the literature based static decision model is conceptionally **enriched by empirical research** conducted in the built environment. Fourth, based on the static model, a **dynamic model** is cre-

ated. The **simulation model** helps to shed some light on the various social and individual psychological feedback mechanisms that are active in the decision process. Given a better comprehension of the complex decision process, ways and means to arrive at a more energy efficient construction can be derived., This will be done in a future version of the paper. This paper goes beyond the existing action theory literature by, first, trying to assess the relative importance of these variables in predicting household adoption of conservation behaviors by means of a feedback model. Second, it includes social and structural context conditions, concepts that have not been operationalized in this context.

In methodological respect, the paper contributes to improve the traceability of **the model conceptualization** phase. Up to now, this step in the model creation or theory development is considered more an art than a science. By the research process 'literature review – static, literature based model development – on empiricism based model enrichment – deduction of a dynamic model' the model formulation becomes more traceable, comprehensible and criticizable – all properties of a falsifiable, and therefore 'good theory' in the Popperian sense of critical rationalism (Popper 1968).

In the following chapters, static hypotheses about the considered decision will be developed which are mainly based on psychological action research and as well as empirical findings (Chapter 3). Thereafter, dynamic hypotheses will be developed that build on the static hypotheses. Especially, feedback mechanisms and time delays are incorporated (Chapter 4). These dynamic hypotheses are implemented as a simulation model (Chapter 5). The discussion in Chapter 6 focuses on first insights of the model and on methodological challenges. Chapter 7 concludes the paper.

2. Development of Static Hypotheses

2.1 Literature-Based Development of Static Hypotheses

The first step to synthesize the models we refer to in the literature background. Figure 1 shows a graphical 'construct-link-construct' representation of the proposed theory which will be explained in the following. The thickness of the links indicates the assumed influence the cause construct has on the effect construct – the thicker the link, the stronger the supposed influence.

In order to understand the meaning of the different constructs, definitions and/or examples will be provided for each in Table 3 in the appendix. The definitions and explanations are strongly based on the original literature (Schwartz and Howard 1981; Ajzen 1991; Gatersleben and Vlek 1998; Sauerborn 2005).

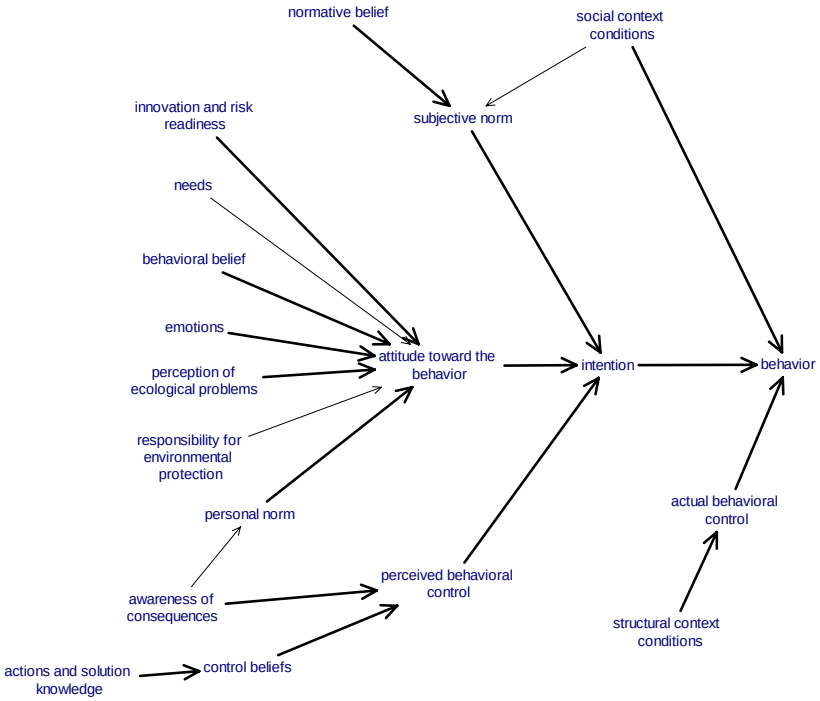

Figure 1: The proposed static hypotheses, depicts the antecedents of individual's behavior. The construct-link-construct diagram shows the causal network influencing individual's behavior.

The static hypotheses can be understood as a **four-layered network of causal influences** or causalities, in which the behavior variable is the outcome variable (cf. Figure 1, most-right and Figure 2). The executed behavior is a function of the intention influenced by the social context conditions as well as the actual behavior control. Intention, a variable on the first layer, is influenced by the concepts of subjective norm, attitude towards the behavior and perceived behavioral control, as Ajzen's theory of planned behavior suggests. Out of these three, attitude toward the behavior is the most complex construct of the second layer, which, in turn, is determined by several variables with wide ranging characteristics and on different levels of aggregation (the third layer of causality).

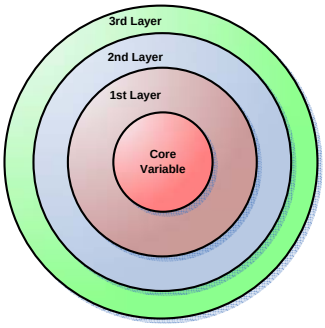

Figure 2: Layers of causality. The core variable is explained by several layers of dependent variables. The outer layer (3rd layer) is the level with the exogenous variables.

Given the causal structure in Figure 1 and Figure 2, the question could be raised: why to stop at the third layer level of causal explanation? We stop the investigation here since the causes underlying the third layer variables, e.g., the causes of behavioral believes, would lay outside the model boundary for the dynamic theory that will be developed later. In other words, the model boundary of the dynamic model defines the kind of variables that are considered in the static hypotheses.

2.2 Qualitative Interviews and Analysis for Theory Development

In the following, the static hypotheses will be enriched by insights from empirical research. We will introduce briefly the design that has been selected for the exploratory research phase. We will explain the research process, the interview situation, characterize the interviewees and the results obtained. The objective of the qualitative interviews is to obtain information about possible context specific operationalizations of the general action theories.

Interview Method

Explorative interviews have been conducted to obtain empirical knowledge about the building environment. The method used is the interview technique '**cognitive mapping**' (Bryson, Ackermann et al. 2004). The qualitative approach is chosen because, first, in standardized interviews no information beyond the standardized questions is obtained. Obviously, this procedure is not useful when exploring research question one, i.e., what are the important decisions in the view of the buy owner, because significant knowledge about the research object must exist in order to construct a insightful standardized questionnaire (Diekmann 2005). Second, cognitive mapping is a focused interview technique that combines soft interview, e.g., agree and motivate the interviewee, and hard interview conduction, e.g., criticize and point to inconsistencies. Third, cognitive mapping is beneficial if the richness of a person's cognition about an issue is important. By its structuring approach, cognitive mapping enables both to elicit and capture this richness with simple **concept-arrow diagrams** (Ackermann and Eden 2004; Bryson, Ackermann et al. 2004).

One drawback of the cognitive mapping method is that it is quite resource demanding. Both the guideline for the interviews (cf. Ulli-Beer, Bruppacher et al. 2006) as well as the procedure for data evaluation was developed in the research team. Several test interviews have been conducted which ensured a high quality of the interview process.

The **theoretical sampling** of the interview partners is guided by the fact that results of qualitative research are not representative, but should ensure their generalizability (Merkens 2000). Therefore, the maximal variation of the dimensions 'actor position in the residential building environment' and 'type of constructed houses' is intended (Patton 1990). The criteria for the selection of the interview partners were:

- They must be attached to reference buildings,
- They must have knowledge and expertise/experience, which the researchers need,
- They are willing to freely participate in the interviews, and
- They are willing to participate in the whole research project.

One problem of the chosen research design can be that of retrospective questions (Diekmann 2005). It is, therefore, intended to motivate and obtain building owners who constructed their building in approximately the same time period in order to create same contexts for all interviewees and this time period should not reach too far back in history.

Interview Situation

In total, eight interviews with an average duration of approximately 70 minutes have been conducted. The interviews have been conducted in the German speaking part of Switzerland. The interview took place at the location of the interview partner. This ensured the highest possible convenience for the interviewees. The interview date has been arranged via telephone. In addition, the content and the situation of the future interview have been described to the interviewee. In order to increase the quality of the interview, two interviewers conducted the interview: one was responsible for the interview process and the content of the interview; the other interviewer was responsible for the instant creation of the cognitive map with the computer software Decision Explorer® and enhanced the quality of the created cognitive map. A projector was used to constantly visualize the work in progress. The interviewee has been involved in interactively developing the cognitive map. For this, the interviewee has been familiarized with the method at the beginning of the interview. The individual have been interviewed about their decisions and behaviors during the house building process (for the interview guidelines, cf. Ulli-Beer, Bruppacher et al. 2006). Their answers have been captured as cognitive maps.

Results of the Cognitive Mapping of Private Building Owners

The goal of the initial, field-opening empirical research is to obtain a first glance of the **important decisions** as well as to get an idea about possible antecedent variables. In other words, the objective was to elicit the interview partner's expert knowledge about the construction process and decisions relevant to energy efficiency. Table 1 summarizes the main decisions mentioned in the interviews and groups them in more general categories.

Label	Category	Decision
0	basic decision for a house	decision to build a house instead of renting one
		decision to build a house instead of not building a house
A	comprehensive, holistic decision for energy efficient **(planned energy efficiency)**	decision about energy efficient house
		decision about energy efficient standard (Minergie)
B	energy efficiency as by-product **(emergent energy efficiency)**	decision about energy and building technology
		decision about the kind of building envelope
		decision about the thickness of the envelope
		decision about heating technology
		decision about windows
C	energy efficiency as conflicting property **(conflicting objectives)**	decision for aesthetics

Table 1: Summary of the decisions of the empirical research

It can be seen that the decisions can be differentiated in **three categories**. The first is the category of **planned energy efficiency**. The decisions in this group indicate that some awareness of the topic of en-

ergy efficiency existed already before the planning process and that a certain plan existed. The second category comprises decisions that indicate that the issue of **energy efficiency emerged** during the planning process. The last category indicated that the issue of energy efficiency was contrary to some of other objectives (**conflicting objectives**). The category labeled with '0' is not of further interest for the research, since we consider only private building owners that have already decided to build an own house instead of renting or not building one. The decisions are, on the one hand, results from the interviews that help to answer the first research question (cf. Chapter 1.4). On the other hand, they serve as points of departures for further questions during the interview process which help to elaborate to explain the actions of the interview partner during the planning process.

Label	Category	Empirical Concept
OP	operationalize theoretical concepts	propose own's ideas
		decision for natural material
		accept additional effort for energy efficiency
		reference objects
		adequacy of budget
		prospering economic conditions
		degree of provider and comptetence locally available
		access to adeqaute information
		personal independence
		identification with solution
		realization of own ideas
CA	influence theoretical concepts	realization of an environmentally friendly philosophy of life
		ability to gather required information
		ability to find solutions with minimal efforts
		propose own's creativity
		ability to enforce own ideas
		ability to convince others
		decisiveness
		interest and learning motivation

Table 2: Empirical concepts that either operationalize existing or influence theoretical concepts.

Table 2 summarizes empirical concepts that have been obtained by the interviews and which have the potential to contribute to the explanation of the planning process. **Two kinds of empirical concepts** have been collected: the first category comprises of concepts that **operationalize theoretical concepts.** For instance, the concept 'degree of provider and competence locally available' represents the specific context of the residential built environment and hence operationalize existing theoretical concepts. The second category contains causes that **influence existing theoretical concepts** to a certain degree. For example, influences the 'ability to gather required information' the 'action and solution knowledge'. The collected empirical concepts (cf. Table 2) will be integrated in the hypotheses which are, up to now, based on literature.

Expansion of the Static Theory by Empirical Concepts

In the following, the static hypotheses about the antecedents of energy efficient behaviors will be enriched by the empirical research. The concepts shown in Table 2 will be used to enrich and complement the initial hypotheses. The different **concepts styles** indicate the origin of the concept: concepts in bold blue are

theoretical constructs; grey underlined **concepts** are derived **empirically.** The links with arrowhead indicate causal relationships between the cause and the effect. In case the links has no arrowhead, the connection provides connotative information.

There are three main insights that have been obtained by connection of the theoretical work with the empirical: First, important **behaviors** that are connected to the outcome variable of the static hypotheses have been **discovered**, second, necessary **operationalizations** of several highly aggregated and theoretical variables have been established (e.g., control beliefs), and third, several connections of the **between constructs of the theoretical hypotheses have been confirmed** by the explorative interviews. Fourth, new constructs have been explored that seem to be important to explain the behavior in the planning phase.

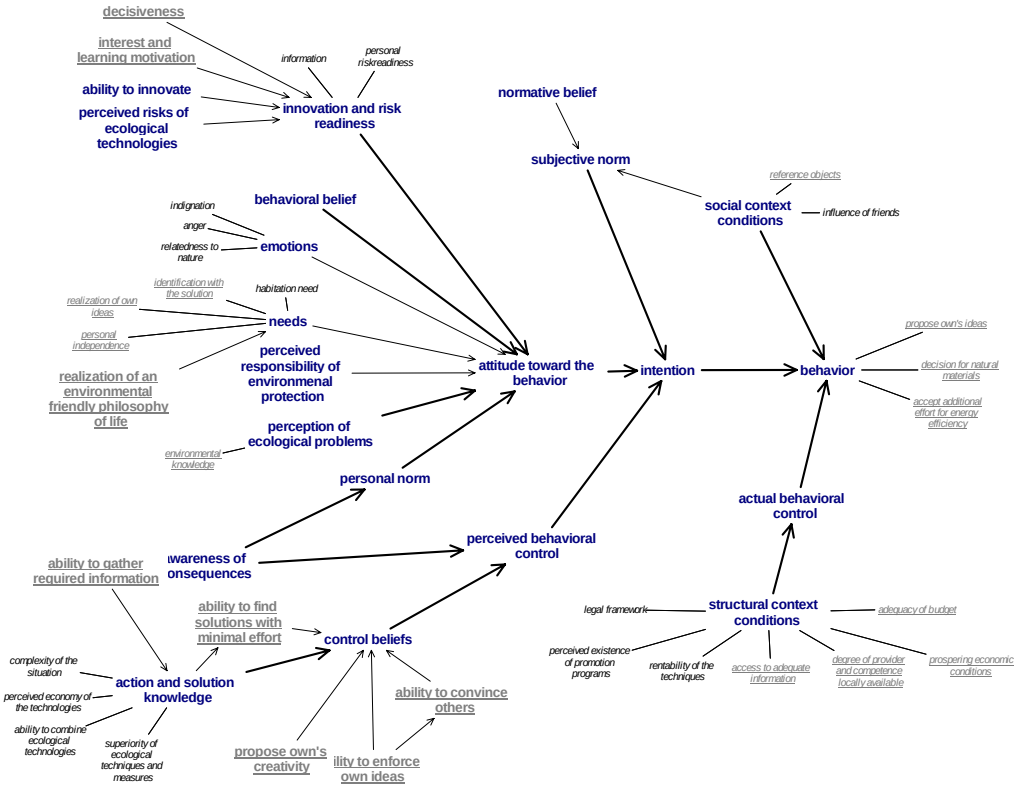

Figure 3: Enriched static theory. The construct-link-construct diagram combines the insights of the literature analysis and the empirical research. The different concept styles denominate the different sources of the variable. Concepts in bold blue are theoretical constructs; grey underlined concepts are derived empirically. The links with arrowhead indicate causal relationships between the cause and the effect. In case the links has no arrowhead, the connection provides connotative information. However, as can be seen, the diagram does not show any feedback mechanisms.

2.3 Structural Equation Model about Behavior

Compared to the ordinary regression analysis, which allows modeling and predicting one dependent variable, the structural equation modeling approach allows modeling complex and simultaneous interrelations between latent variables. “Structural equation modeling uses various types of models to depict relationships among observed variables, with the same basic goal of providing a quantitative test” (Schumacker

and Lomax 2004). Figure 4 shows the causal structure of the model that has been created based on the static hypotheses and which will be statistically tested in the near future. We will not discuss the structural equation model in detail here but use it to inform the development of the qualitative dynamic hypotheses in the next chapter.

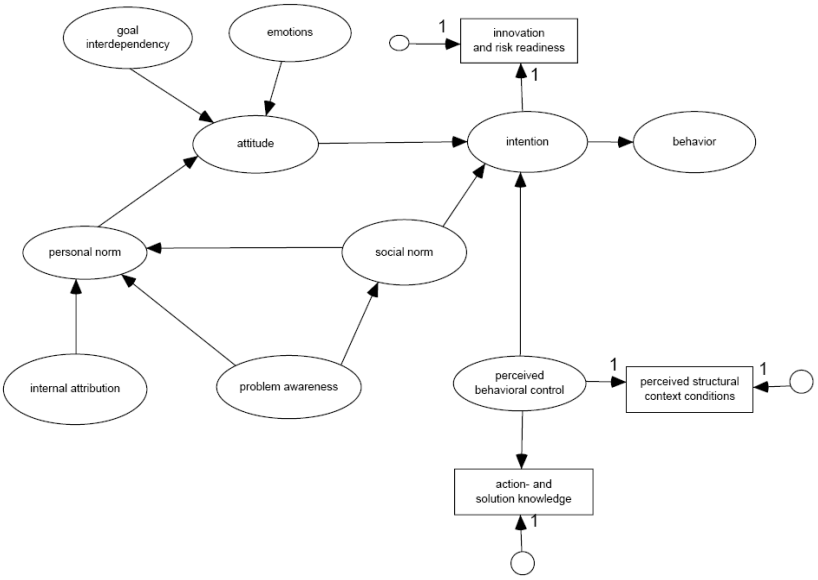

Figure 4: Causal structure of a structural equation model that shows the antecedents of energy efficient behavior of private building owners[4]

Having these empirically enriched static hypotheses about the intention and behavior in the residential building environment, the question raises: Is there really no feedback in the system as Figure 4 suggests? Is a static explanation of the intention and behavior sufficient to understand the discrepancy between the available high standard, energy efficient technologies, on the one hand, and the low adoption, diffusion and implementation of those, on the other hand? Taking into that the individual actors perceive the environment of the building process as exogenous and not influenceable, that their decisions and actions are guided by the structure of the environment, that the actor's expectations about the perceived current societal structures and expected future developments guide present actions, and that the individual actions can change the societal structure on the aggregated level over time, we suppose that the creation of a dynamic theory of individual's behavior is worth the effort in order to understand how the intention, and subsequently behavior, changes over time. Several feedback mechanisms will be incorporated in the next step. By this we expect to further improve the explanation of individual behavior. Especially we want to transcendent the boundary from a static to a dynamic explanation of the intention during the planning phase.

[4] The figure shows a preliminary version of the structural equation model.

3. Qualitative Dynamic Hypotheses

The definition of reference modes guides the formation of dynamic hypotheses about the variables of interest. Figure 5 shows several possible reference modes of the **level of intention** of an individual during the planning process of a building. The reference modes are conceptual in its nature and are not supported by empirical data simply because up to now no data about development of intention during the decision process has been recorded. High values stand for a strong intention to utilize energy efficient technologies; low values indicate the opposite. The planning phase is a rather mid to long-term process that takes place within a time frame of six to 24 months with **18 months being the approximated average**. The different runs show different configurations of individual characteristics regarding antecedents variables of the environmentally friendly behavior.

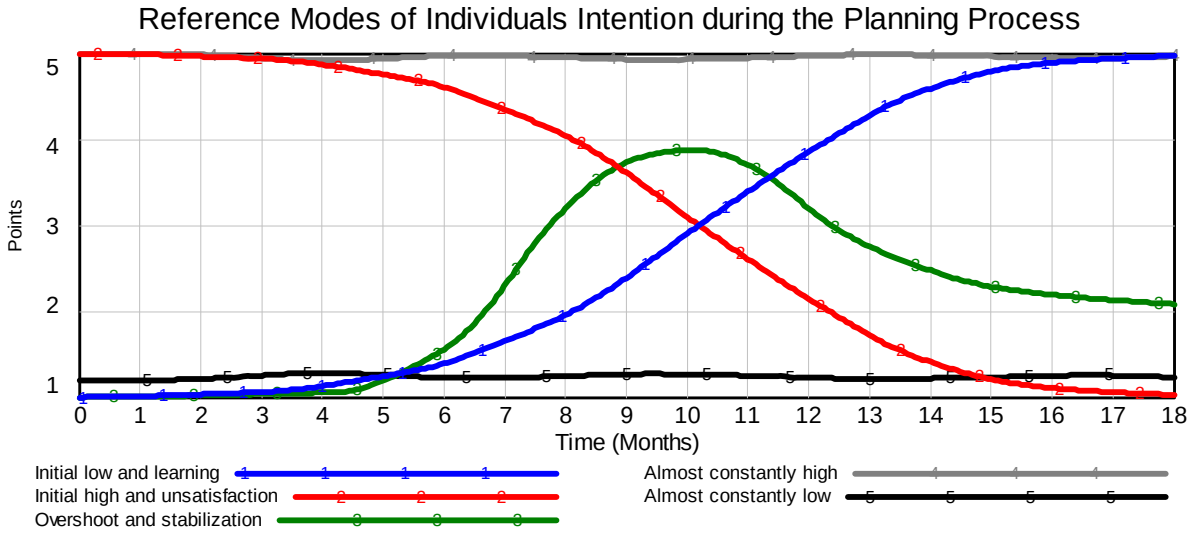

Figure 5: Reference mode of individual's intention during the planning process. The diagram shows several possible reference modes for individual's intention.

Departing from the reference modes, a model boundary chart will be described. It is a mean which helps to utilize the static hypotheses about the individual's behavior and its antecedents variables, transform them into dynamic hypotheses and focus on the variable of interest, at the same time. With the model boundary chart, the following questions can be answered: What variables create the dynamics of the explanandum? What variables have to be endogenously explained in the system dynamics model? What variables lie outside the model boundary? The description and definition of the variables is provided in Table 3 (Appendix). Both the reference modes and the model boundary chart try to reduce the complexity and focus the formation of the dynamic simulation model.

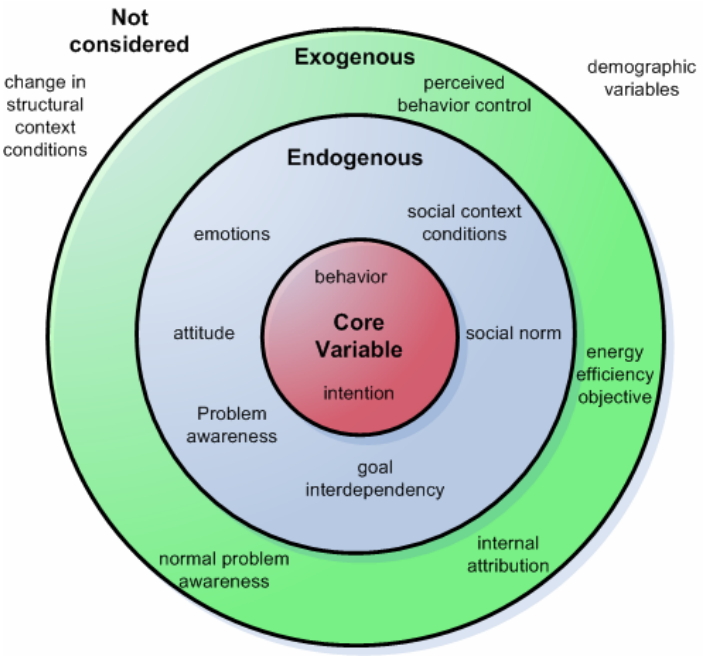

Figure 6: Model boundary chart - intention and environmentally friendly behavior are the core variables that have to be explained. The chart comprises endogenous created variables as well as exogenous parameters.

First Iteration: Base Structure of the Dynamic Model

The first version of the model comprises the System Dynamics representation of the main static hypotheses of Figure 3. In this step, the most important stocks in the causal structure have been denoted (e.g., the stock variable 'intention'). Furthermore, significant delays in the base structure have been introduced. Up to now, however, **not a single feedback loop exists** in the hypotheses. This is because, at the moment, only the static hypotheses have been translated into the iconography of System Dynamics. In other words, until now we have a pure 'open loop model'.

Second Iteration: Balancing Feedback Structures

Figure 7 shows the hypothesized balancing feedback loops B1 and B2. As can be seen, and this is valid for all causal loop diagram in this model, the variable that is part of every feedback loop is 'intention' and not 'behavior'. Behavior represents the executed behavior at the end of the decision process. In other words, the decision guides an action which is the corresponding behavior. For the dynamic model, the **decision making process** as such is of **interest** and how it can be influenced. Hence, intention is the most influential antecedents of behavior and our proxy for the behavior that changes during the decision making process. The behavior will not be considered explicitly for the purpose of this elaboration.

Balancing loop B1 controls the intention towards an energy efficient behavior with regards to a **personal objective about energy efficiency**. The own level of intention creates an expectation about the level of achievement of the personal energy efficient objectives, if this intention would be implemented. The possible consequences of the decision are anticipated and compared with the current objective about the

amount and type of energy efficiency that the person thrives for. Obviously, higher intentions lead to more closely fulfilled objectives because the anticipated achievement about energy efficiency is also larger. The inability to meet the own goals to protect the environment leads to emotional reactions of the individual which causes, after a certain time, the attitude level to increase. The intention is positively affected by the attitude to build an environmental friendly house. The **emotion driven intention effect** which is captured in B1 does not react immediately. A certain delay time exists until changes occur.

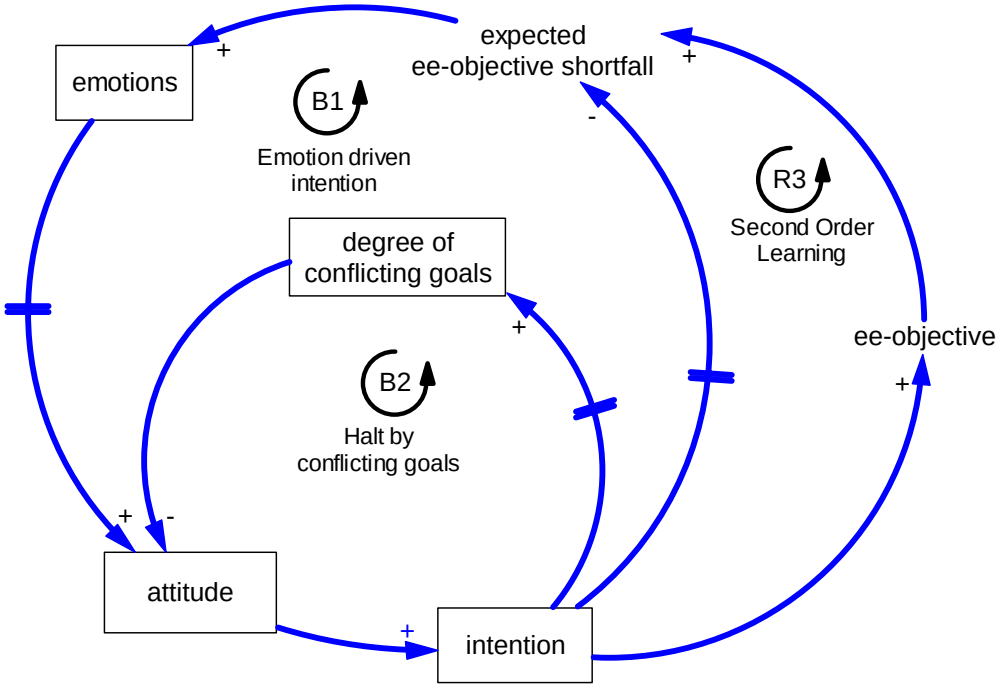

Figure 7: Balancing feedback loops B1, B2, and R3

B2, also a balancing loop, is quick in its reaction compared to B1. Larger levels of intention lead to stronger **conflicts between individual's goals**, e.g., to decide for an energy efficient layout of a building or for an architectural superior building style and therefore to more complications that lower the attitude to decide for energy efficient solutions. The conflicting goals prevents the level of intention to exceed a certain limit since the individual experiences that a high amount of effort has to be put into the planning activity in order to increase several dimension of goals simultaneously. Hence, the **intentioned is brought to a stop by means of a change in attitude** toward the behavior.

Third Iteration: Reinforcing Feedback Structures

The **reinforcing feedback structure** contains, like the balancing loops, **intention as the core variable**. The intention to decide for energy efficient technologies improve the social context conditions since the individual, for instance, actively seeks information about architects who are known for their energy efficient constructions, or that the individual uses the help of an energy counselor to improve the energy effi-

ciency of his construction plans. The new social context conditions foster the development of the social norm regarding energy efficiency what positively levers the intention. The reinforcing loop R2 depicts a social magnetism effect that increases the intention once it is activated.

The second **reinforcing mechanism (R1)** is also based on the intention toward an environmentally friendly behavior. It captures the relation that the persons with a higher intention for such a behavior have a higher awareness about environmental problems, i.e., they are more sensitive and receptive for information and rumors about environmental topics. The person's perception system, now, receives and assimilates information that has been sorted out previously. This process influences the social norm, i.e., the self-expectations for behavior. This script leads to a larger intention when the level of social norm increases as well; we have termed this mechanism '**problem awareness feeds itself'**.

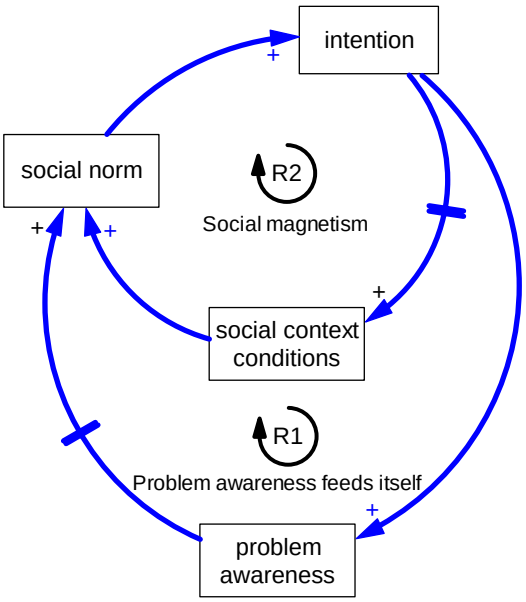

Figure 8: Third stage causal loop diagram: effects on the attitude are included.

Reinforcing loop R3 (Figure 10) captures the **second order learning** effect that occurs with changing intention. The intention influences over time the definition of the objective (Argyris 1977), in our case the intended degree of energy efficiency.

To sum up, the **causal loop diagram**, which has been develop in three iterations, **captures several processes that influence environmentally friendly intention**. The reinforcing feedback loops are: (R1) problem awareness feeds intention; (R2) higher intentions about energy efficiency attract better social context conditions. **This effect has been termed 'social magnetism'**. And finally, the reinforcing loop R3 that captures a second order learning effect. These positive processes are balanced by two loops which function as goal seeking mechanisms. In B1, the expected level of achieved energy efficiency influences the attention and the intention to halt when the objective level of energy efficiency is reached. Similar in B2, the goal concurrence between energy efficiency and architectural design goals causes the levels of attitude to saturate when the intention is large enough.

In the following, we will develop a **quantitative simulation model** that serves as a conceptual model. A survey study about the dynamic hypotheses will help to determine which parts of the model have to be reformulated, expanded, or reduced.

4. Elaboration of a Quantitative Simulation Model

The simulation model is based on the qualitative dynamic hypotheses. It was developed in a stepwise approach starting with a simple version and amending **explanatory structure and feedback**. The final version of the model is being used for the simulation analysis. The validation took place during the phase of model development (Barlas 1996). Currently, a telephone survey is conducted in order to test the hypotheses and assess the influence strengths between the different parameters. The **time horizon** for the simulation model is 18 months. This is the approximated average duration of the planning phase for a residential building of private building owners[5]. The values of the variables that will be considered in the following figures show values in the range from one to five. These values are approximative measures for intangible properties of an individual: one is the lowest value possible, five is the highest. In the figures that show the intention variable, two graphs are displayed: the first (#1) is the current simulation output; the second graph (#2) shows the supposed reference behavior taken from Figure 3. For each reference mode, the models' parameter configuration is changed in order to represent the different types of decision makers with their different attitudes, personal and social norms, problem awareness, etc. In the following, we will describe important outputs of the simulation model.

4.1 Trivial Behaviors of Private Building Owners

In the following, the rather trivial reference modes that are also displayed in Figure 3 are reproduced by the simulation model. By means of this test, the validity of the model can be increased.

Constantly Low Reference Mode

The reference mode 'constantly low intention' is unspectacular. The private building owner has, from the very beginning, a very low intention value (Figure 9) that is created by low values of the antecedents variables to intention (cf. Figure 10; attitude, social norm and perceived behavior control). Intention is caused by its antecedents variables and, therefore, directly depends on their corresponding values which are weighted by the assumed strengths of their effects. These strengths and their implementation in simulation studies will be elaborated in further versions of the model. Figure 10 shows the antecedents variables of intention. It can be seen that they have low to medium values and are constant over the entire time horizon.

[5] Based on the interviews conducted for the research project by the first author.

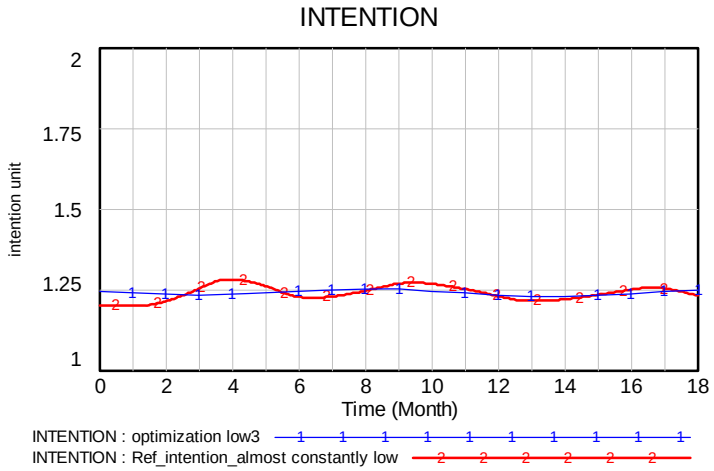

Figure 9: Intention for the reference mode ‘constantly low’

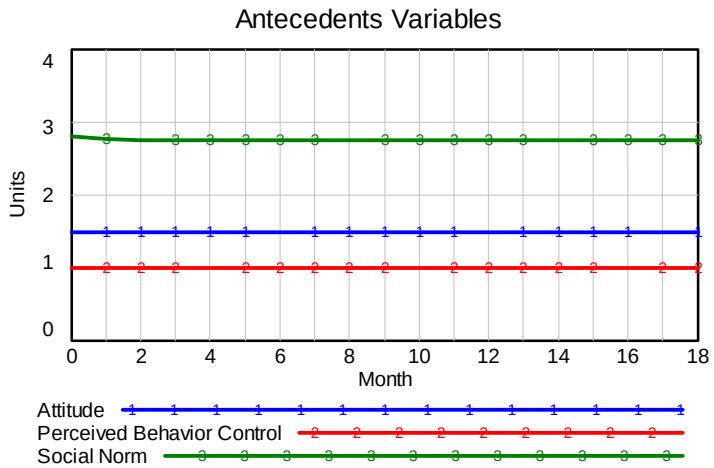

Figure 10: Antecedents variables to intention for the reference mode ‘constantly low’

Constantly High Reference Mode

The reference mode ‘constantly high intention’ is also unspectacular. From the very beginning of the planning phase, the intention has a **high value** (Figure 11), i.e., the private building owner wants to build an energy efficient house which utilizes the best available energy standard, for instance, the Swiss Minergie-P label. The antecedents variables show also highest values at the very beginning. Starting in t=1, the value **of attitude decreases slightly** (Figure 12). This is the effect which strong conflicting goals have on the attitude: very high energy efficient houses come at costs which have to be paid in terms of the degree of achievement of different objectives. Simply put, the mechanism that is represented by balancing loop B2 is active in this instance and reduces the attitude accordingly. The behavior of the antecedents variables does make sense in itself and also if it is compared to the first reference mode ‘constantly low’.

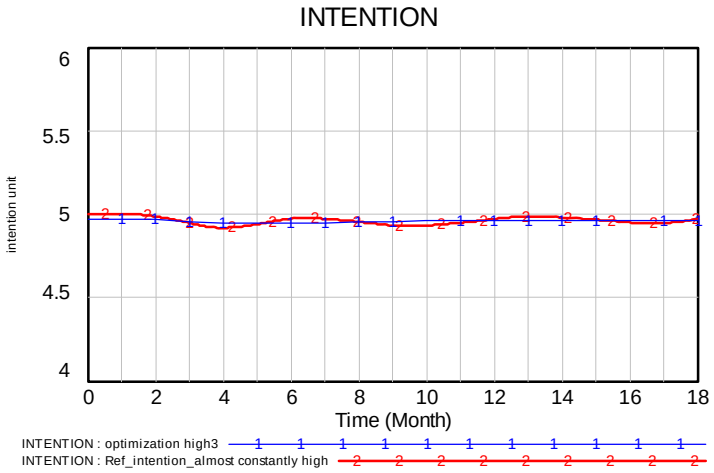

Figure 11: Intention for the reference mode ‘constantly high’

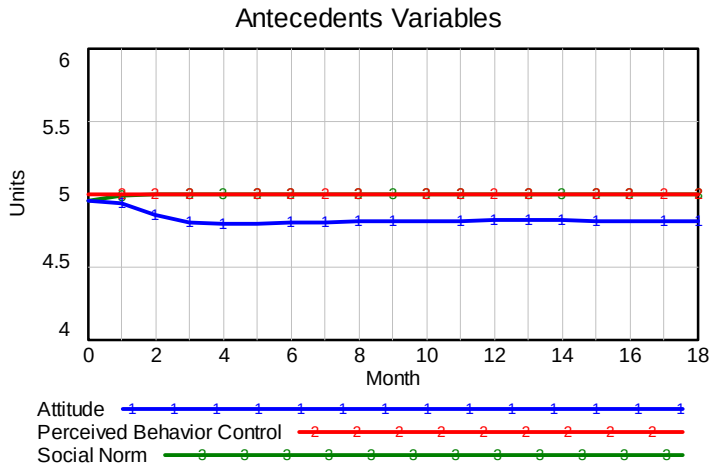

Figure 12: Antecedents variables to intention for the reference mode ‘constantly high’

The also reasonable configuration ‘**medium value of intention throughout**’ was not tested since it would be only another recombination of the initial values in order to derive the reference mode.

4.2 Advanced Behavior of Private Building Owners: Scenarios

In the following, more complex behavior modes will be assumed as references; some which are assumed to exist in reality. **Two possible situations could be possible**: first, by circumstances that are intentionally created by the private building owner or that occur by chance, **learning about energy efficiency** could take place. This learning effect could be triggered by an abrupt increase in the social context conditions of the private building owner. We have named this situation **counselor policy (P1)**. This policy resembles the reality in a way that private building owners may contact an energy counselor with a certain probability when they are in their planning phase of their house. The second policy (P2) describes the possibility that the private building owners are **dissatisfied by either energy efficiency products** or **by complica-**

tions and complexities during the planning process, e.g., the communication process with an energy counselor or an architect – to name just two possibilities.

Initially Low, Then Learning Takes Place (P1)

For this policy run, the change of the social context conditions (P1) is assumed to occur. With initially low intentions to build energy efficient, the external influence of a counselor is active at t=6 [months]. This is indicated by the increasing variable 'social norm' in Figure 14. Perceived behavior control is not part of the dynamic processes since it is not included in the feedback mechanisms.[6] The intention starts with a low value and logistically increases to approximately the maximum value (Figure 13). This indicates the ideal process that a private building owner learns about energy efficiency, first, and that no interfering actions take place that could reduce or hinder the learning, second. Figure 14 shows in addition that the attitude increases due to the goal seeking effect after the counseling action has started. It reaches a maximum at t=13 and decreases again because of the effect of conflicting goals.

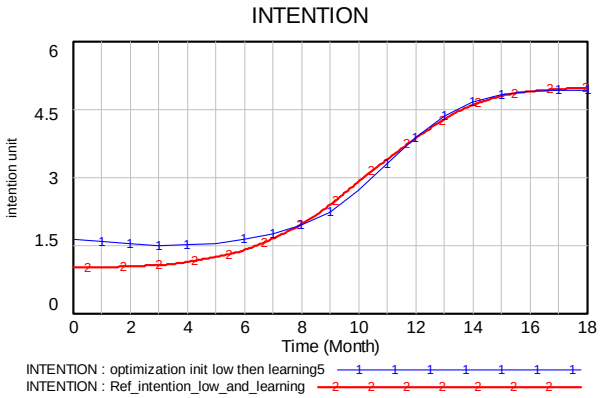

Figure 13: Intention for the reference mode 'initially low, then learning effect'

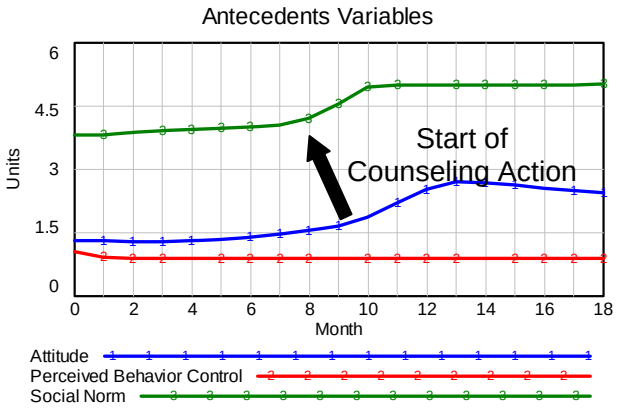

Figure 14: Antecedents variables to intention for the reference mode 'initially low, then learning effect'

[6] In a future version of the model, the **perceived behavioral control** and **internal attribution** will depend on variables that already exist in the model, e.g., problem awareness and internal attribution.

Initially High, then Dissatisfaction (P2)

In this case, the initial **intention** to build according to energy efficiency standards is **high**. However, even such a strong opinion **cannot immunize** against negative experiences. It is assumed that complications with relevant project partners (architect, energy consultant, building department of the city, etc.) overcompensate the possible future benefits of the energy efficient installation and let the **intention** to build according to an energy efficient standard **decline** (Figure 15). In terms of action theory, this occurrence can be subsumed under personal behavior control; the feeling or assessment of the person that he is not longer able to fully influence or decide about the installed energy efficiency independently, e.g., when architects heavily influence the decision making process.

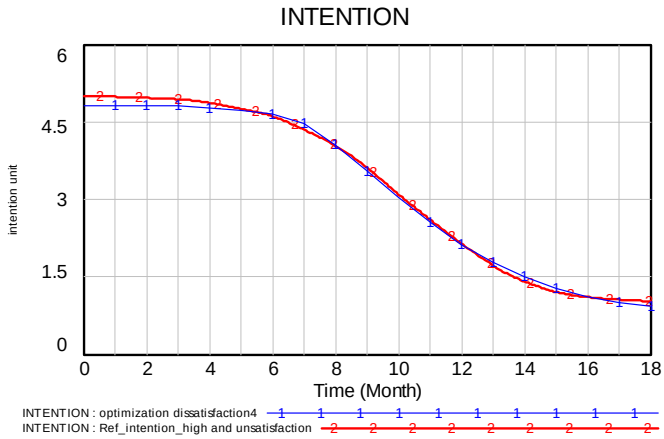

Figure 15: Intention for the reference mode ‘initially high, then dissatisfaction’

In Figure 16, the change in perceived behavior control is due to the experience with project partners which results in a lower perceived ability to control or influence the outcome of the planning phase. This processes starts at t=6.The lower intention causes a lower objective shortfall which eases the emotions the individual experiences when unrealistically high objectives are lowered. In sequence, the attitude level (Figure 16) declines slightly.

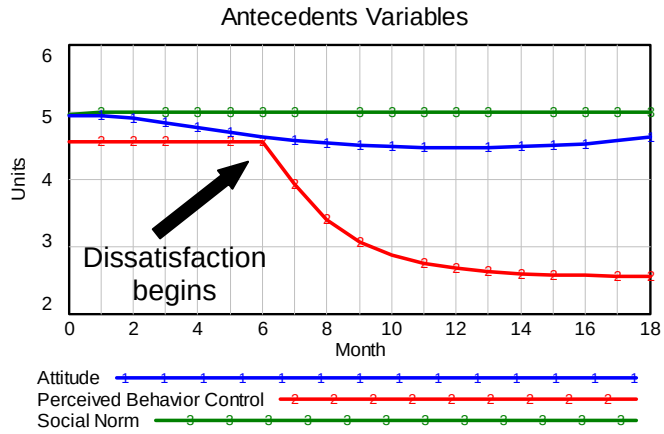

Figure 16: Antecedents variables to intention for the reference mode ‘initially high, then dissatisfaction’

Overshoot and Stabilization: Intention Roller Coaster (P1 & P2)

In the last scenario, both policies, the learning effect (P1) and the dissatisfaction effect (P2) are considered in the decision making phase. Initially, the **intention level is low**, representing a person with no intention to implement energy efficient technologies. The individual learns about energy efficiency by interactions with project partners and **builds up his intention** to design an energy efficient construction (Figure 17). Thereafter, the individual realizes that an implementation of highly energy efficient technologies does not only depend on his own willingness to do so. It also depends on the external environment, i.e., the building environment. In other words, the material offered by suppliers, budgetary restrictions, and knowledge of architects about energy efficiency. Hence, the level of **intention declines** to an average value. This is assumed to take place in many, perhaps most, of the cases of house planning and construction, and thus, is assumed to represent a typical situation that occurs during the house planning phase. Figure 18 shows the development of the according antecedents. In t=6 the counseling activity begins whereas in t=9 the dissatisfaction occurs due to negative experiences.

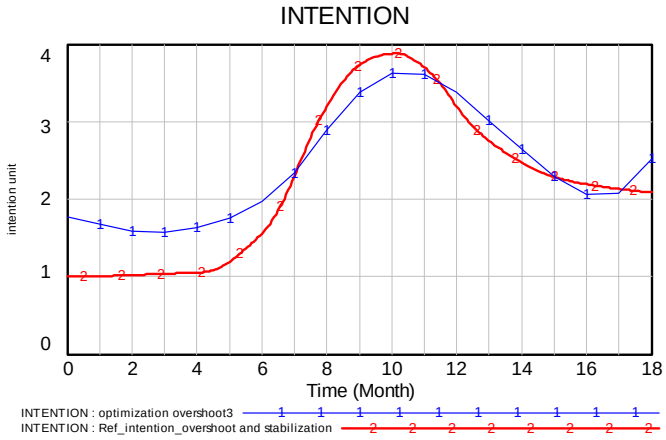

Figure 17: Intention for the reference mode ‘overshoot and stabilization’

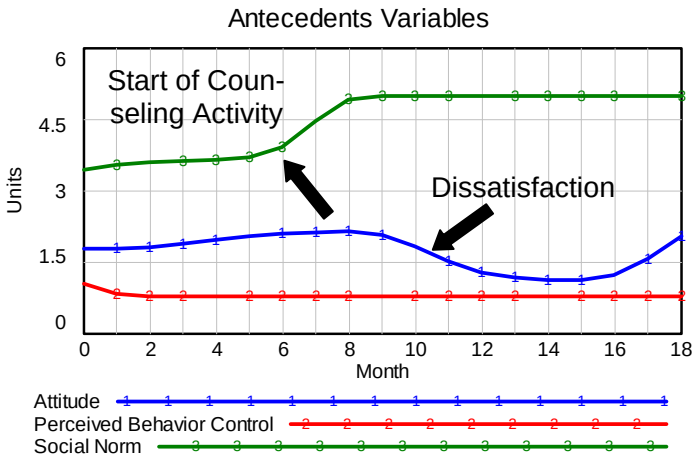

Figure 18: Antecedents variables to intention for the reference mode ‘overshoot and stabilization’

5. Discussion and Reflection

In the following, we will discuss insights as well as challenges which occurred during the modeling process and the analysis of the simulation model. We proceeded in a step-by-step approach. The goal was to build a simulation model that is grounded both in psychological action theories about individual's behavior and in empirical research. With the latest version of the model, we created one that accounts for five feedbacks mechanisms. The simulation model will be expanded and empirically challenged in further versions. Nevertheless, it can already be used to trigger the discussion of several issues.

(1) Most of the qualitative and quantitative theories of psychology are static theories. They do not account for the dynamic behavior over time. Psychological literature does mostly not consider non-linear relationships, time delays, and feedback between the variables. Consequently, when building a dynamic model, additional variables that reach out of the existing theories must be added in order to capture the feedback that exists in reality. Hence, the transition from a static theory, e.g., supported by survey and statistical research, cannot be assumed to hold in the dynamic, over time, context. It is likely that the static and dynamic **approaches are not commensurable**.

(2) Another challenge is the **micro – macro dichotomy**: Psychological action theories describe the behavior of individuals in a certain situation. They consider the macro existence only as externalities. System dynamics, on the other hand, is not used to model on both the level of the individual and the macro level at the same time. The level of aggregation ought to be consistent. This issue could create challenges when bridging the gap between the disciplines.

(3) The model helps to **integrate and dynamically simulate** the interplay of major feedbacks which, up to now, has not be done by research in the psychology literature. Levine et al. are kind exceptions and first attempts (Levine and Doyle 2002; Levine 2003).

(4) The model helps to make apparent that the integration of results from statistical survey research leads to a **linearization** of the simulation model. Normally, System Dynamics models account for the nonlinearities of reality. However, the processes utilized in survey research, for example, hypotheses testing and confirmatory statistics, do not allow including **nonlinearities** that account for most of the counterintuitive dynamics in reality. Let us turn to the results of the simulation model: when we consider the behaviors of intention of the different simulation outputs in Chapter 4.1, it becomes obvious that there are differences in the level of intention. Where do these differences stem from? - They are not cause by exceptional dynamics, meaning nonlinearities, in the model. They are mainly the result of the different linear strengths a causing variable has on an effected variable (e.g., effect of attitude on intention). However, even though the model appears to be fully static and linear, it is not; it is in a dynamic equilibrium stage. This can be seen that both graphs (Figure 12 & 14) exhibit small oscillations around the initially low or high values of intention. In other words, even though the constant weights for the different effects have been used, they do not fully linearize the model's behavior. In order to assess the differences of the linearization of nonlinear structures, we could substitute the linear weights with nonlinear relationships and observed the effects on the outcome variable. When the result is that **the patterns do not change in principle**, this would not liberate us from using nonlinear relationships. It would rather indicate that the effects are likely to be not significant in the used parameter range. This issue has to be considered in further research.

(5) Another observation that requires attention is that **reinforcing feedback loops can act as balancing loops** and do not reinforce the system behavior under special circumstances. Even though, the loop polarity is reinforcing, it contributes to the stabilization of the system rather then to its escalation. Why does this happen? Reason for this is a **total gain of the individual**, **isolated loop** that is smaller or equal to one. The equation for the calculation of the loop gain is provided in the following:

$$\prod_{n=0}^{t} = x_1 * x_2 * ... * x_t \leq 1 \qquad \text{; with x = effect strengths in a closed feedback loop}$$

By definition, in a positive loop, values for the loops gains are non-negative (>=0). In case the standardized regression coefficients from the statistical analysis are in the positive interval [0,1], the loop gain will be in the very same interval. With a **loop gain of 1 or less, no growth momentum can be generated. When the loop gain is smaller than one, even a positive feedback loop contributes to balance the system to the desired** level in a goal seeking behavior mode. This indication is important for further research, when information and values for effect weights from statistical regression analysis are incorporated. The regression coefficient can only provide information about the strength of the influence relative to other influences; the actual values cannot be used directly.

(6) In structural equation modeling the most interesting result besides the model fit is the amount of **explained variance** of the outcome variable – intention, in our case. Each antecendents variable, and also their own antecedents variables, account for the explanation of the variance according to the value of their **path coefficients**. This represents a static kind of interest; every change in the antecedents variables account for the same amount of explained variance at each point of time. However, in dynamic modeling we have to consider an **acclimatization effect** that is well researched in psychology. People react to each situation, but in a relatively short amount of time the influence of the initiating event will lose its strength (for an example, cf. Brickman, Coates et al. 1978). The simulation model accounts this effect. **Only changes in the state variables can cause changes in the subsequent state variables. In other words, static contributions of the pure static level are not possible.** The strength of these changes is largest at the beginning and decays within a short period of time. The time within which the change of antecedents variables has an effect on the outcome variable depends on the characteristic of the change generating variable. For instance, a positive change in social context conditions lasts longer then a change in individual's problem awareness.

(7) As has been shown, the feedback loops have been distinguished in reinforcing and balancing. Interestingly, the balancing feedback loops are created **internally** whereas the reinforcing feedback is generated by the individual's environment. In other words, the individual acts **within the boundaries of the internalized objectives,** whereas the **external environment** can influence the individual to change these **internalized objectives**.

(8) In this version of the paper, we **do not consider information ambiguity** (Abrahamson and Rosenkopf 1997); we rather employ the **full information assumption** that is well known in classical rational choice theory. Due to our empirical research, it is obvious that this simplifying assumption is not valid in the case of the residential built environment. Future versions of the model will take care of that situation.

(9) By definition of the authors, the **range of values for each state variable is limited**. It can vary only from one (lowest) to five (highest). Does this represent the intended concepts? In the physical world, it would definitely not. However, in the world of soft and intangible variables, in which the research is conducted, the introduced **scale of measurement** corresponds to long established **research practice in the social sciences** (for the technicalities, cf. Bortz 2005). The authors chose the scaling approach in order to ease the transition of empirical findings from survey research. The question of construct validity has to be addressed when the measures for the constructs in the model are selected. In case valid measures can be found, the accuracy of the measurement of intangible construct can be increased.[7] In addition, whenever possible an external validation for the measurement of the intangible constructs is intended.

(10) Structural equation modeling and system dynamics modeling have different understandings of the term validity. Since the structural equation modeling approach is by its methodology a static approach, its concept of **validity is also static**. The goodness of fit indicator is a measurement that indicates the parameter validity of the proposed structure given the empirical base (Schumacker and Lomax 2004). System Dynamics modeling is dynamic in its nature. Hence, its **validity is also of a dynamic type**. Parameter validity is a part of the dynamic understanding of validity (Barlas 1996). Considering the created simulation model, different degrees of validity can be distinguished. First, the survey-based parameters have a higher validity due to its strong empirical basis.[8] Second, the information feedback connections, third, the used nonlinear relationships, and fourth, the introduced time delays have a lower parameter validity since they are not grounded on such a strong empirical base like the aforementioned parameter values. However, the inclusion of information feedbacks, nonlinearities, and time delays increases the content validity of the study. In other words, the **relevance of the study is increased by sacrificing its parameter accuracy**.

(11) The model functions as a **communication device** in an interdisciplinary research project, in which this modeling endeavor is a crucial part. The members of the team have such different educations as psychology, management, economics, and simulation modeling. The model creation enabled fruitful discussions between the members of the discipline and helped to bridge gaps between the disciplines. Noteworthy is that the interdisciplinary attempt requires extra time and commitment of the team members.

[7] Even though this issue is important, it will not be elaborated here. The development of valid measures will be provided in future publications.
[8] When the survey research is completed, we expect that the structural equation model support the validation of several parameters in the simulation model.

6. Conclusion and Further Research

Conclusion

Decisions during the construction process in the residential built environment are poorly covered by scientific research. This is most interesting since the decisions in the building creation process determine to a large extent the energy efficiency of the building for a long period of time. This becomes especially important when someone considers the increased significance of the global warming and climate change movement (IPCC 2007). The authors want to contribute to shed light on the dark areas of decision making during the construction planning process. In this paper, we concentrate on the individual building owner and, first, systematize important decisions that occur in the construction process of a residential building. Based on existing psychological action theories, we develop **static hypotheses** of decision making during the planning process. In parallel, the created static, action hypothesis is conceptionally enriched as well as validated by empirical research. Consecutively, the static hypotheses are transformed into dynamic hypotheses. Thereafter, a **simulation model** is created that incorporates five feedback mechanisms: (1) emotion driven intention, (2) halt by conflicting goals, (3) social magnetism, (4) second order learning and (5) problem awareness feeds itself, which can **explain five** possible **reference behaviors** of private building owners. The parameter configuration is changed for each reference behavior. This represents different types of decision makers with different kinds of attitudes, personal and social norms, problem awareness, etc. The created simulation model helps to point out **important modeling issues** that have been addressed in the discussion section and which will guide efforts of the future research.

Further Research

The developed result is, up to now, hypothetical and is yet to be supported by empirical research. This implies two actions for the author team: first, the dynamic hypotheses have to be developed further in order to better explain the behavior of building owner's decision during the construction planning process. And second, the static hypotheses which built a network of hypotheses will be tested statistically in a survey study. Insights gained through these further steps will further improve and validate the development of the simulation model.

A further contribution would be a policy analysis of the model in order to answer questions about where and when to intervene in the decision phase in order to influence the behavior to achieve a higher energy efficient behavior.

From a methodological point of view, the paper has shown a possible path for how to transform and extent a static empirical model into a system dynamics simulation model. Allowedly, the degree of traceability could be improved in further research. The authors consider this an important avenue to proceed and motivate scholar to support us and to undertake similar attempts to bring scientific rigor to the art of simulation modeling. And finally, several challenges for the field of system dynamics have been pointed out in the discussion chapter to be tackled in future research.

Acknowledgements

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III. Appendix

Table 3: Definition and explanation of important concepts of the static hypotheses

Construct	Explanation, Definition, Example
Behavior	Behavior is the manifest, observable response in a given situation with respect to a given target. Single behavioral observations can be aggregated across contexts and times to produce a more broadly representative measure of behavior. Behavior is a function of compatible intentions and perceptions of behavioral control as well as depending on social and structural context conditions. Conceptually, perceived behavioral control is expected to moderate the effect of intention on behavior, such that a favorable intention produces the behavior only when perceived behavioral control is strong.
Intention	Intention is an indication of a person's readiness to perform a given behavior, and it is considered to be the immediate antecedent of behavior. The intention is based on attitude toward the behavior, subjective norm, and perceived behavioral control, with each predictor weighted for its importance in relation to the behavior and population of interest.
Actual behavioral control	Actual behavioral control refers to the extent to which a person has the skills, resources, and other prerequisites needed to perform a given behavior.
Structural context conditions	Structural context conditions are defined by the characteristics of the technologies, the legal framework, perceived relevance of promotional programs and their availability. It is assumed that the structural context conditions significantly influences the actual behavior control.
Social context conditions	Social context conditions account for the influence of friends and acquaintances have on the own intention and behavior. It considers informal relationships, which can have an effect on subjective norms and which can influence the actual behavior.
Subjective norm	Subjective norm is the perceived social pressure to engage or not to engage in a behavior. It is assumed that subjective norm is determined by the total set of accessible normative beliefs concerning the expectations of important referents.
Normative belief	Normative beliefs refer to the perceived behavioral expectations of such important referent individuals or groups as the person's spouse, family, and friends. It is assumed that these normative beliefs determine the prevailing subjective norm.
Perceived behavioral	Perceived behavioral control refers to people's perceptions of their ability to perform a given behavior. It is assumed that perceived behavioral control is determined by the total set of accessible control beliefs, i.e., beliefs about the presence of factors

control	that may facilitate or impede performance of the behavior. To the extent that it is an accurate reflection of actual behavioral control, perceived behavioral control can, together with intention, be used to predict behavior.
Control Belief	Control beliefs have to do with the perceived presence of factors that may facilitate or impede performance of a behavior. It is assumed that these control beliefs determine the prevailing perceived behavioral control.
Action- and solution knowledge	Action- and solution knowledge is the state of knowledge about technologies and measures of energy efficient building planning and their situational applicability.
Awareness of consequences	Awareness of consequences describes the causal relation between behavior and environmental consequences.
Attitude toward the behavior	Attitude toward a behavior is the degree to which performance of the behavior is positively or negatively valued. Attitude toward a behavior is determined by the total set of accessible behavioral beliefs linking the behavior to various outcomes and other attributes.
Emotions	Emotions are conscious mental reactions, such as anger, indignation, and relatedness to the environment, subjectively experienced as strong feeling usually directed toward a specific object.
Innovation and risk readiness	Innovation and risk readiness is an individual characteristic that influences the attitude toward the behavior. Innovation readiness comprises insistency, frustration tolerance and creativity. Risk readiness captures the attitude towards risk, ranging on a spectrum from total rejection to willing acceptance of risk.
Behavioral belief	Behavioral beliefs link the behavior of interest to expected outcomes. A behavioral belief is the subjective probability that the behavior will produce a given outcome. It is assumed that these accessible beliefs determine the prevailing attitude toward the behavior.
Personal norm	Personal norms refer to self-expectations for behavior backed by the anticipation of self-enhancement or -deprecation. Personal norms are built from the person’s general value system and are experienced as feelings of obligation to act in a particular manner in specific situations. Before personal norms can have any effect, they must be activated. Activation is stimulated by the perception of another's need and of one's own responsibility to act. It results in the person's formulating specific self-expectations for behavior, expectations which are experienced as feelings of moral obligation.