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AGENT-BASED MODELING AND SIMULATION OF INDIVIDUAL ELDERLY CARE DECISION-MAKING

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ABSTRACT

Recent statistics predict an increasing demand for care services in elderly care as a result of demographic change. To forecast the amount, location, and type of emerging care demand, existing approaches like Microsimulation must be revised. These approaches lack consideration of the fact that every decision for a specific type of care is dependent on the individual care recipient's situation and personal preferences. To close this gap, it seems reasonable to extend existing Microsimulation approaches by means of Agent-based Social Simulation. The goal of this work is the development of an agent-based model, that enables the simulation of individual decision-making processes. The presented model is based on sociodemographic data to take systemic properties and individual situations into account. Additionally, sociological actor types are used to implement individual preferences and the characteristics of care recipients. To evaluate the proposed approach, a case study using German census data is presented.

1 INTRODUCTION

As a result of demographic change, the ratio between elderly and younger people shifted over the last decades and the share of older people increased (OECD 2018). This development will continue in the coming years and the aging of the population is poised to become one of the most significant social transformations with implications for nearly every sector of society (UN 2017). For the elderly care sector, the main challenge will be to anticipate and meet the upcoming demand for care services. For this reason, it is necessary not only to forecast the amount of future care demand, but also to predict where it arises and which kind of care services will be requested. Existing approaches for forecasting the aging of the population (e.g., Micro-/Macro-Simulation or System Dynamics) usually project the current population into the future in order to forecast and analyze emerging care demand (Onggo 2012). For this purpose, census or land register data is used to generate an artificial population whose stepwise development is then simulated using mathematical methods such as transition probabilities and differential equations (Li and O'Donoghue 2013). By this means, the aging process and related effects such as likelihood to become care dependent or to receive a certain care level can be investigated.

To meet the emerging care demand, the creation of new or the extension of existing infrastructure might be necessary. For the adequate and sustainable planning of future care infrastructure, information on quantitative changes and geographical occurrence of care demand is not sufficient. As care recipients are free to choose between different types of care services, e.g., family care, home health care, or nursing home care, the recipients' desires must be taken into account as well. However, existing Microsimulation approaches are not capable of considering individual decision-making processes. To overcome this gap, suitable approaches for the simulation of human decision behavior have been proposed in the field of

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Agent-based Social Simulation (ABSS) (Balke and Gilbert 2014). Here, intelligent software agents, that proactively pursue individual goals, are used to model individual human behavior. Thus, to allow for the comprehensive forecast of care demand, the combination of ABSS and Microsimulation seems promising (Berndt et al. 2017).

With respect to the conceptualization of ABSS, the goal of this work is the development of an agent-based model that enables the simulation of individual care decision-making processes in elderly care. Besides the context of the care decision, the presented approach also considers objective and subjective properties of the care-dependent person. This includes sociodemographic information, as available in census data, as well as individual traits, such as the personality of the decision maker. By this means, personal differences in the perception and assessment of a specific decision situation can be taken into account. Even though moving to a specialized care facility might be medically reasonable for some care recipients, factors such as social environment, family structure, or cost aspects might result in an individual decision for home care. By extending Microsimulation by ABSS, the understanding of individual care-related decision processes can be improved and enable a more comprehensive and realistic forecast of emerging care demand.

This work is structured as follows: In Section 2, background information on elderly care is provided and different available types of care are presented. Furthermore, current approaches for both forecast and analysis of emerging care demand are presented. In Section 3, the agent-based model for simulating individual care decisions in elderly care is introduced. In this regard, we present how the *context of the care decision* as well as *objective* and *subjective* properties of the care decision maker are integrated into the model. The presented model is then applied as part of a case study to demonstrate and evaluate the model's functionality and validity by means of a sensitivity analysis. Finally, in Section 5, we draw conclusions, summarize the contributions of this work, and discuss potential future work.

2 BACKGROUND

The objective of this work is to facilitate social policy-making by means of forecasting future care demand in elderly care. The focus is on creating an adaptable and adjustable method, that can be applied to different elderly care systems. Those systems usually offer different types of possible care services such as *family care* (FC), *home (health) care* (HC) or *nursing (home) care* (NC), from which the care recipient can choose. Family care is the non-professional care option, where help and support for the care recipient is provided by the family, friends, or neighbors. Home care or nursing care are options where the recipient is nursed by a fully professional service at home (*home care*) or in a care facility for elderly people (*nursing care*). These options differ in various ways, e.g., costs, effort, or social environment. Besides obvious reasons involved in decision-making like required finances or available family support, other motives are decisive as well. One crucial reason is the length of time of support the care recipient is in need of. To take this into account, it can be assumed that every care dependent person can be classified in different care levels, depending on the required time of support (Level I (least) to III (most time required), cf. Table 2). This classification can also be used to map other influencing factors depending on the time of support, such as financial support or costs. For instance, home care is less expensive than treatment in a nursing home at care level I, whereas it will be more expensive at care level III. Besides many quantifiable motivations considered in the care decision, there are others where quantification is not given naturally, e.g., social support, social pressure, or the emotions involved in moving into a nursing home. Consequently, decision-making in this context is a sophisticated process involving emotional as well as rational reasons.

To forecast the future care demand in elderly care, Agent-based Microsimulation has been proposed as the combination of ABSS and Dynamic Microsimulation (Berndt et al. 2017). Neither of the two methods as well as the combination of both are new in the context of analyzing health or elderly care or in the context of simulating care decisions. Dynamic Microsimulation is often used to describe models that simulate the behavior of micro-units such as persons or households over time (Li and O'Donoghue 2013). Dynamic Microsimulation uses statistical data and derived probabilities for the estimation of each individuals' potential future (Rutter et al. 2011). In addition, agent-based approaches focus on the simulation of individual human behavior such as decision-making (Balke and Gilbert 2014). Originally, decision-making is explored in the Operation Research domain. Yet, their methods mostly target the optimization of decisions in some ways. This kind of optimized decision is neither needed nor wanted when reconstructing human decision-making. Instead, sophisticated sociological and psychological models and theories need to be considered in order to achieve a realistic reconstruction of human decision behavior. Consequently, ABSS with its ability to consider those models and theories (e.g., Berndt et al. (2017)) seems to be more promising, than pure mathematical models.

To this day, Agent-based Simulation is mostly used for strategic decision support (e.g., Liu and Wu (2016)), planning (e.g., Taboada et al. (2013)), or process optimization (e.g., Cabrera et al. (2011)) in the field of care analysis. However, a few approaches focus on the analysis and forecast of upcoming demand (e.g., Ma et al. (2016)). In this context, hybrid approaches that combine existing methods are presented as well, e.g., Mielczarek and Zabawa (2016), who combine System Dynamics and Discrete Event Simulation or Bae et al. (2016), who combine Agent-based Modeling and Microsimulation for the study of population dynamics. However, in the field of forecasting care demand in elderly care, there is no approach that combines established methods for population forecasting such as dynamic Microsimulation with advanced approaches for simulating complex individual decision-making such as ABSS. In conclusion, Agent-based Microsimulation is a promising approach for combining existing approaches in order to take individual decision-making into account, when forecasting emerging care demand in elderly care.

3 AGENT-BASED MODELING OF INDIVIDUAL CARE DECISIONS

To address the previously referred to shortcomings in the field of forecasting elderly care demand, a comprehensive agent-based model for simulating individual care decision-making processes is presented in this section (cf. Figure 1). The aim of the model is the differentiated assessment of possible care options from an individual perspective. For this purpose, the pursued approach integrates three dimensions that influence or must be considered in individual care decisions. First, the *context* dimension of the decision is specified. This includes the provision of criteria (*rating functions*) for the quantification and assessment of different influences or circumstances as well as all types of care that are available to the recipient. In this work, family care, home care, and nursing care are services which can potentially be chosen by the care recipients. Second, the *objective situation* of each individual is considered in the decision-making process. Here, sociodemographic indicators that objectively describe each simulated person are integrated, e.g., personal data, relationships, living conditions, or (former) employment status. By this means, an initial *objective assessment* of the suitability of each possible care type is provided for every care recipient. Third, to score the preferences of each care dependent person and for each potential type of care, the objective assessment is interpreted with regard to the recipient's *individual behavior*. In a final step, the specific care decision is made based on the scores resulting from the three presented dimensions. To this end, a random process is used to choose the desired type of care based on relative probabilities given by the respective scores. In case two or more scores are similar or even equal, the probability of choosing either of the related types of care is similar or equal as well. If one type scores markedly higher than the others, the probability of choosing this type is also markedly higher. This allows for the modeling of irrational decisions where a type of care is chosen even though it does not seem well suited.

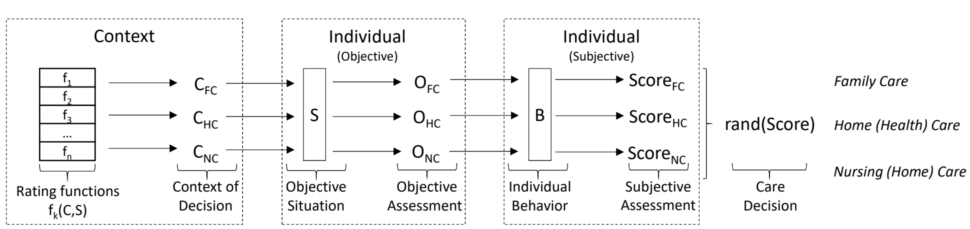

Figure 1: Agent-based model of the decision-making process in elderly care.

In the remainder of this section, the concept behind each of the three presented dimensions is introduced. In Subsection 3.1, possible rating functions are proposed and defined in terms of all possible types of care. Subsequently, in Subsection 3.2, an explanation is given of how sociodemographic data of each care recipient is used to determine individual output values of each rating function for each care decision. Finally, in Subsection 3.3, the distinct behavior of each care recipient is modeled by means of sociological actor types to take individual preferences and characteristics into account.

3.1 Context of Care Decisions

To simulate the decision behavior of care recipients, all relevant aspects that are part of the real-world decision-making process must be implemented in the model. In this regard, it is a challenge to cope with the large number of aspects that can be used to describe or assess a specific situation in addition to the quantification of these aspects. Considering emerging costs that might influence the choice of a specific care service, a distinction between different types of costs can be made, i.e., attendance allowance, nursing care insurance, household income, or retirement plans. As it is difficult to include all possible financial factors into the decision-making process, using the concept of aggregated rating functions seems reasonable. Yet, not all potential aspects can be measured for use in numeric rating functions, e.g., the influence of the social environment or the perceived social change when moving. The presented approach requires the quantification of such measures for their use in respective rating functions. Either way, rating functions must allow for individual adaptations depending on the context of care decision C, i.e., the type of care considered. In the following, five potential rating functions f_k that can be used to assess the context are introduced and specified (*saving of costs, saving of effort, social pressure, social steadiness, and adequate care*). For consistency reasons, all function output is scaled to an interval of $[0,1] \in \mathbb{R}$.

With respect to the consistent assessment of the aspects that are considered by the rating functions, the effect of the aspects must be equal in all functions. In the presented approach, low output values that are close or equal to 0 imply that the assessed aspect is not desirable while high values that are close or equal to 1 indicate that the investigated aspect is worth striving for. For this reason, rating functions must be formulated so that high values are associated with a high affinity for the rated aspect. High costs are usually not desirable in terms of elderly care decisions. Instead, a rating function that assesses the *saving of costs* seems more suitable and compliant with the affinity of most care recipients. Following this, an aversion against a specific aspect, e.g., a cosmopolitan care recipient that perceives *social steadiness* (f_4) as undesirable, must be modeled as new function f_k, that depends on existing function f_4 with $f_k = 1 - f_4$.

In order to map all the relevant aspects of ***saving of costs*** (f_1), all potential decisions and all possible levels of care need to be considered. Since there are three different decisions to choose from and three different levels of care, nine function values must be specified. These values depend strongly on the provision of financial support, e.g., by governmental institutions or care insurances. In the case of family care, recipients receive attendance allowance to compensate for inconveniences that are associated with their care services. This compensation increases with the recipient's level of care. In consequence, the saving of costs are always high and increasing proportional to the care level. For home care, the saving of costs are medium high for care level I, III and low for level II. This maps the correlation between costs and support of the example system. Because of a fixed co-payment arrangement in the care system, the nursing home care costs are constant for all care levels (cf. Table 1).

The ***saving of effort*** *function* (f_2) depends on the hours of work per week (t) that need to be provided by the care givers to the care recipient. This information and other individual data are part of each recipient's objective Situation S. In the presented system, this time is indicated by the given level of care (cf. Table 2). Consequently the saving of effort value is derived from these numbers and normalized to $[0,1]$ by the maximum effort (1.2×35 hours per week). These values are based on three assumptions: first, the system's given values map the time a professional care giver needs to provide a necessary service to a recipient. In consequence, a non-professional family member will usually take a little longer for these tasks ($1.2 \times t$). Second, even if the service is provided by a professional, some effort from the family of the recipient is needed for coordination and other smaller tasks ($0.3 \times t$). Third, in case of nursing care, a constant amount of time is required for coordination and visitation independent of the care level (approx. 4h per week).

Table 1: Output of the rating function saving of costs.

Care Level	**I**	**II**	**III**
FC	0.8	0.9	1
HC	0.4	0.2	0.4
NC	0.6	0.6	0.6

Table 2: Assistance required by care recipient.

Care Level	**hours per day**	**hours per week**
I	1.5	10.5
II	3	21
III	5	35

$$f_2(C,S) = \begin{cases} 1 - \frac{1.2t}{42}, & C = C_{FC} \\ 1 - \frac{0.3t}{42}, & C = C_{HC} \\ 1 - \frac{4}{42}, & C = C_{NC} \end{cases}$$

The ***social pressure*** *function* (f_3) is used to model the influence of and experience with former decisions made by others from the social peer group of the care recipient. This function is subject to one assumption: Every person has a set of other persons on which they rely when making decisions. It can be assumed that these persons live within a specific distance from the care recipient. Furthermore, we assume that the influence of these persons is not equal. There are some with more influence and others with less. With this thought in mind, it is possible to mathematically permute the set of influencing persons in a way that the person with the most influence lives the closest to the person in focus. With this permutation, it is possible to weight the influence of different people in one's environment according to their distance. In consequence, all persons p_i living within a distance r who have the same care level and have chosen the same care service will be considered. Following that, the output results from

$$f_3(C,S) = \frac{1}{\#Pers} \sum_{i \in I} \left(1 - \frac{distance(p_i)}{r}\right),$$

where $\#Pers$ is the cardinality of the set of considered persons I from a specific context and $distance(p_i)$ is the distance between the home of the care recipient and person p_i. Consequently, this functions allows a consideration of the mutual influence of an agent's decision behavior within the model.

The ***social steadiness*** *function* (f_4) is needed to describe the steadiness in the neighborhood and social environment of the care recipient. The output value is high when the change is minor and the steadiness is high, otherwise the output value is low if there is a major change and low steadiness. Hence, steadiness is directly dependent to change in the environment. This change can occur in two ways: first, if the care recipient decides to move away from his neighborhood to be treated in a nursing home facility. Second, if the recipient decides to be treated at home either by the family or a professional service. The change in both cases depends on how many of his contacts are already treated in a nursing home and how many are treated at home in their usual environment. If the recipient moves into a nursing facility and each of its contacts is taken care of at home, the change is high and the steadiness is low. The same applies, if the recipient decides to stay at home while most of its contacts are treated in a nursing home. Consequently, the output of the social steadiness function is only dependent on the output of the social pressure function in the nursing care context ($f_3(C_{NC},S)$). The output results from

$$f_4(C,S) = \begin{cases} 1 - f_3(C_{NC},S), & C = C_{FC} \text{ or } C_{HC} \\ 0 + f_3(C_{NC},S), & C = C_{NC}. \end{cases}$$

The ***adequate care*** *function* (f_5) represents the average decision a care recipient would make in a specific situation. The output values in this case depend on the care level and the possible care decision

Table 3: Output of the rating function adequate care.

	Care Level I	**Care Level II**	**Care Level III**
FC	0.56	0.41	0.29
HC	0.25	0.24	0.21
NC	0.19	0.35	0.50

and can be seen as a probability of choosing one option in a specific scenario. The values presented in Table 3 were derived from statistics from the use case system.

The presented rating functions as well as their specifications are subject to change depending on the investigated elderly care system which might vary in different countries. The proposed approach allows for the dynamic extension or reduction of the set of utilized rating functions as well as for the modification of existing functions. By this means, the environment of the care decision is limited to and quantified by a set of functions. This enables a simple representation of an originally complex environment for use in an agent-based model. As a result of the first dimension, a set of n functions, only dependent on the objective situation S, is generated for further processing.

3.2 Objective Factors in Care Decisions

In addition to the environment of the care decision, the sociodemographic situation of each individual care recipient must be considered as well. Besides information on the context of the care decision, socio-demographic data on the investigated population is a second essential input for the evaluation of the rating functions. Such data is usually gathered when conducting a population census, similar data collections, or other empirical studies. In the presented rating functions, required data includes information on the care situation of each individual such as care level and current care service but also information about personal circumstances like households, family members, and residency. Accordingly, the assessment of the considered care decision is equal in case that the objective situation of two individuals is equal. At the end of the individual (objective) dimension, an n-dimensional output vector o_j is derived for every possible decision $j = \{FC, HC, NC\}$. In this subsection, the available data basis as well as necessary steps for the preparation of required data are presented.

A major piece of information that is required in most of the presented rating functions is the care status as well as the care level of an individual care recipient. Detailed information about the frequency of each care status and individual care level is given by the census data and mapped to each person from the artificial population as initial values. To assess the costs, additional information about income, care insurance, or financial support systems are required. While information about income is also accessible via census data, other sources must be accessed to realistically map other influences, e.g., statistics from insurance companies, federal ministries or care providing services. In contrast to this, the output of the effort function can be calculated based on the time of support needed, which is only represented by the care level.

For the assessment of social influence, information on care recipients in the neighborhood of an individual is required. Census data does not provide detailed information on neighborhoods. Instead, the residency of each individual that is considered in the census is anonymized in grids of $100m^2$ or $1km^2$. The combination of census data, map data (e.g., open street map), and georeferencing approaches allows the allocation of individuals to real households (Krause et al. 2017). The resulting GPS coordinates of each individual are used to calculate distances between individuals and thus for defining neighborhood relationships. Information on both care level and decision by all considered neighbors can be gathered from the census data set as well. The calculation of the social change is completely dependent on the output of the social influence function and therefore requires no further input. To determine the adequate type of care, recent social statistics are used. With these, generalized information about the average decision for every possible type of care combined with every possible care level can be created. Such statistics are often provided by the government and are accessible to the public (cf. Table 4). All this information needs to be provided as input data for the rating functions in order to determine the objective assessment.

Table 4: Care recipients in Germany by care level and type of care (Statistisches Bundesamt 2017).

	Care Level I	**Care Level II**	**Care Level III**
FC	923,958	365,195	95,451
HC	409,191	215,121	67,961
NC	304,237	309,936	160,549
Sum	1,637,386	890,252	323,961

3.3 Subjective Factors in Care Decisions

As in the previous step of the presented model, the objective situation of each considered individual was included in the care decision. For this purpose, the proposed rating functions were executed using common information on the context of the care decision as well as sociodemographic information on the individuals. Accordingly, equal objective situations of individuals lead to an equal objective assessment of the respective decision situation and consequently lead to the same care decision. Considering real-world care decisions, it must be assumed that not only the sociodemographic situation but also the individual character of each individual plays a major role in the decision-making process. While costs are a decisive factor for some care recipients, others might try to minimize the resulting effort or the social change they experience as a result of a specific care decision. In this subsection, we illustrate how the individual behavior of care recipients can be taken into account when simulating decision-making in elderly care.

To model individual behavior and preferences in complex decision situations, economic and social theories make use of actor types (Schimank 2010) to take competing preferences into account. In previous work, the suitability of the four actor types *Homo Economicus* (HE), *Homo Sociologicus* (HS), *Identity Keeper* (IK), and *Emotional Man* (EM) was shown for simulating individual decision behavior (Rodermund et al. 2017). In the following, these types are characterized in terms of elderly care decisions and standard decisions are defined. For this purpose, the importance of every presented rating function is assessed for every actor type and specified by an individual weighting vector. This enables a subjective assessment of the presented care contexts in terms of a specific score by reweighting the objective assessment o_j.

The weighting vector b_a is specified for each of the four presented actor types ($a \in \{HE, HS, IK, EM\}$). It consists of one entry per defined rating function b_a^k, $k = 1, ..., n$, whereby $b_a^k \in [0,1]$. Accordingly, the sum of all entires must be less or equal to n ($\sum_{i=1}^{n} b_a^k = m$, $0 \leq m \leq n$). As f_1 is defined as the rating function that assesses the *saving of costs* of the considered care decision, entry b_{HE}^1 represents the influence or importance *saving of costs* has in the decision-making process of a care recipient that can be characterized as *Homo Economicus*. While a low value b_a^1 (e.g., 0.05) defines that accruing costs are relatively unimportant, a high value (e.g., 0.85) indicates that the affordability of the care decision is important to an individual.

In the real world, it cannot be assumed that the decision behavior of care recipients can entirely be described using only one actor type. Thus, in the presented approach, each decision maker is characterized by a tuple c that expresses the percentage share of each of the four actor types of a care recipient. As an example, the tuple $c_i{}^\intercal = \{0.30, 0.05, 0.45, 0.20\}$ specifies that the decision behavior of individual i is motivated 30% by *Homo Economicus*, 5% by *Homo Sociologicus*, 45% by *Identity Keeper*, and 20% by *Emotional Man*. Accordingly, to interpret the objective scores calculated for each type of care, the weighting vectors of all four actor types are applied proportionally. This design decision facilitates the extension or modification of existing rating functions. Instead of adjusting the individual perception of each simulated care recipient, only the respective entry of the four weighting vectors of the actor types must be extended or modified.

The *Homo Economicus* is characterized as a rational individual which aims at the maximization of its own utility and well-being. It compares different opportunities and tries to gain maximum benefit with minimum possible costs. This results in selfish behavior with the focus on its own benefits. Social behavior does not result from empathy but is strongly coupled to utility maximization. Transferred to elderly care decisions, the primary goal of *Homo Economicus* is to minimize the effort and the resulting costs. In this regard, interpersonal relationships are not a factor that is relevant to this actor type. However, it still must be assumed that these factors are somehow considered by a human being.

In contrast to *Homo Economicus*, *Homo Sociologicus* represents an individual that takes on social roles and is obedient to social norms and values. The expectations this actor type tries to meet are defined by society and cannot be avoided. Its primary goal is to avoid sanctions from not satisfying these social expectations. In terms of elderly care, norms are defined by previous care decisions that were met by persons from an individual's social environment (e.g., neighbors, relatives, friends). Considering the rating functions presented in this work, the social pressure that is associated with different types of care mostly affects this actor type's care decision. To comply with these norms, this actor type is willing to take great efforts or financial burden. Accordingly, the price and effort of the different types of care are irrelevant. Compared to other actor types, *Homo Sociologicus* can be easily influenced. Hence, it questions the adequacy of the selected type of care and is afraid of social change.

The decision behavior of the *Identity Keeper* is characterized by conservative decisions and by its goal to establish and maintain a social role based on how it wants to be perceived by other individuals. This self-perception is the basis for all decisions this actor type makes as each action consequently contributes to and strengthens this image. In this regard, the *Identity Keeper* does not fear any negative consequences of its behavior as long as it is beneficial for maintaining its social role. This actor type does not want to give up its current living conditions, does not shrink from great effort or costs, and is not influenced by others. Its primary goal is to maximize the social steadiness that results from a potential care decision.

Finally, the *Emotional Man* is driven by uncontrollable emotions such as love, anger, respect, or disgust which it is not free to choose or influence (Flam 2000). This might lead to spontaneous emotional acts and affective behavior which results in negative consequences or efforts that are out of proportion and reminiscent of the *Identity Keeper*'s behavior. To outsiders, the behavior of the *Emotional Man* might seem inconsistent. A differentiation can be made between the *Pure Emotional Man*, which can rarely be found in the real world, and the *Constrained Emotional Man*, which is driven by emotionality but also tends to normative and rational actions. For the *Constrained Emotional Man*, none of the entries of the weighting vector stands out. Saving of costs and effort of the potential type of care are considered, however, they are not overrepresented in the decision.

Based on the specification of the behavior of the four presented actor types, the importance the result of each of the presented rating functions has on the care decision of each actor type can be determined. In the presented approach, weighting vectors are applied to reweight the objective assessment of each individuals' decision situation. By this means, the individual behavior of the respective individual can be considered in the model of the decision-making process. Taking all individual character traits of the actor types into account, the weighting vectors of each presented actor type are defined as follows:

$$b_{HE} = \begin{bmatrix} 1.00 \\ 0.20 \\ 0.05 \\ 0.05 \\ 0.50 \end{bmatrix}, \quad b_{HS} = \begin{bmatrix} 0.05 \\ 0.05 \\ 0.60 \\ 0.15 \\ 0.15 \end{bmatrix}, \quad b_{IK} = \begin{bmatrix} 0.05 \\ 0.05 \\ 0.20 \\ 0.65 \\ 0.05 \end{bmatrix}, \quad b_{EM} = \begin{bmatrix} 0.25 \\ 0.25 \\ 0.25 \\ 0.05 \\ 0.20 \end{bmatrix}.$$

In this section, we presented a three-stage process for modeling and simulating individual decision behavior when choosing a suitable type of elderly care. The context of the care decision is modeled, based on an extensible and customizable set of rating functions. By this means, regional or national differences between health care systems as well as different aspects of elderly care can be considered. In a second step, sociodemographic data is used to include the objective situation of a care recipient when simulating the decision-making process. To consider preferences and characteristics of care recipients, the individual behavior is modeled using sociological actor types for the subjective assessment of different types of care.

4 CASE STUDY: ELDERLY CARE IN RHINELAND-PALATINATE

The agent-based model for simulation of elderly care decision-making we presented in this work combines three perspectives on each individual's care decisions. Besides the context of each individual, data and information on its objective situation as well as its subjective preferences are considered. To evaluate the presented approach and to show its suitability for simulating care decision-making processes, care-related and other sociodemographical data is required. The case study presented in this section uses data from Rhineland-Palatinate, a federal state of Germany. It consists of large rural regions as well as a few cities and faces urbanization as the rural population ages. To meet the resulting care demand, e.g., by building new care facilities, it is necessary to forecast the type of care that will be requested. In this section, the current care situation of Rhineland-Palatinate is presented and the proposed approach is applied to it.

The dataset that is used in this case study consists of sociodemographic data from the German 2011 micro-census as well as from the 2013 care statistics provided by the Rhineland-Palatinate Land Statistical Office. In a first step, only the rural district Trier-Saarburg as well as the city of Trier surrounding the authors' institution are considered. As of 2013, 6,191 of the 247,899 inhabitants were considered care dependent in this region which corresponds to a care quota of 2.5%. The care levels of these individuals as well as the currently utilized type of care are shown in Table 5.

Table 5: Official data on elderly care demand in Rhineland-Palatinate.

Care Level	**I**	**II**	**III**	**Sum**
FC	1,427	996	324	2,747
HC	706	474	162	1,342
NC	1,049	780	273	2,102
Sum	3,182	2,250	759	6,193

In the presented approach, sociological actor types are used to characterize the subjective decision behavior of each individual. Yet, data is not available on how different actor types are represented in the population. The calibration of the model revealed, that $c_k{}^{\mathsf{T}} = \{0.55, 0.15, 0.15, 0.15\}$ seems to be an adequate representation of the population. Here, each individual consists of 55% *Homo Economicus* and only 15% of the remaining actor types. In this case study, a homogeneous population is used so that each individual is characterized by the presented vector. This configuration of the model is referred to as *standard settings* and is also used for all other scenarios presented as part of this evaluation.

In Table 6, the results are presented that are generated when simulating care decisions with this constellation of actor types. The ratio between the care decisions per care level corresponds to the one of the original data from Table 5. The majority of the care recipients chooses family care, while nursing care is the second most chosen type of care, and the least care dependent individuals make use of home care. Also, for all three types of care, a decreasing number of care recipients can be observed as the care level increases. Small deviations from the original data can be observed for both family care and home care and especially for care level II. Most likely this can be attributed to the homogeneous population used in this case study. If each care recipient is characterized by an individual constellation of actor types, improved results are expected. However, this data must be gathered as part of empirical surveys.

To illustrate the feasibility of the proposed models for forecasting care decisions in elderly care, three scenarios are defined which differ from the presented standard settings. By this means, the sensitivity of the model is analyzed and evaluated. In the first and second scenario, the actor type constellation of the care recipients is modified. First, the population is assumed to consist of individuals which consist of 100% *Homo Economicus* and accordingly 0% of the remaining actor types. Second, a population which consists of 100% *Emotional Man* is simulated. In both scenarios, assumptions are made in advance regarding both the expected behavior of the population and the resulting shift of the care decisions. It can then be analyzed whether the behavior of the model corresponds to the expectations. Finally, as a final scenario, one of the rating functions is modified so that attendance allowance is no longer granted for family care in order to evaluate how this influences care decisions.

When modifying the composition of the population so that all individuals consist of 100% *Homo Economicus*, personal feelings and emotions are no longer considered in the decision-making process. Instead, the cost efficiency of each type of care will be considered more closely. Hence it must be assumed that the share of home care will decrease while both family and nursing care increases. Home care is less cost efficient, as mobile nursing services are expensive but still result in effort on the part of the relatives. Family care results in even more effort, however, the relatives are compensated for this effort as they receive attendance allowance. Compared to home care, nursing care is less expensive as its own share is limited. Yet, in contrast to the other types of care, the effort is considerably lower. The results illustrated in Table 7 show that depending on the care level home care decreases by 8.1% to 36.5% while family care increases by 4.6% to 13.2% and nursing care increases by 1.1% to 4.1%. Overall, the ratio of care recipients that choose family care increases by 2.6% and 0.6% of those who choose nursing care. Especially for care level III, where both effort and costs of home care are notably higher, a strong decrease of over 35% can be observed. Those care recipients tend to choose family care as the granted attendance allowance is highest. In contrast to a population that only consists of *Homo Economicus*, the expected behavior of a 100% *Emotional Man* population differs considerably.

Table 6: Results with standard settings.

	I	**II**	**III**
FC	1,353	879	318
HC	764	611	148
NC	1,065	760	293

Table 7: Results with 100% Homo Economicus.

	I		**II**		**III**	
FC	1,430	(+5.7%)	920	(+4.6%)	360	(+13.2%)
HC	665	(-14.9%)	562	(-8.1%)	94	(-36.5%)
NC	1,087	(+2.1%)	768	(+1.1%)	305	(+4.1%)

In this work, the *Emotional Man* actor type is implemented as *Constrained Emotional Man* whose behavior is strongly influenced by emotions, yet, a normative decision component exists as well. The cost efficiency of each type of care is important to these individuals but has a lower priority compared to *Homo Economicus*. Moreover, the social pressure from other individuals as well as the type of care that objectively seems adequate are considered in the decision-making process of the *Emotional Man*. To ensure the best possible care, it must be assumed that home care seems to be the most promising type of care for this actor type. By this means, the care recipients remain in their familiar environment but are still provided with professional care services. Especially for higher care levels, a shift from family care to the utilization of professional care services can be expected. The results of the simulation (cf. Table 8) show a decreasing number of family care recipients as the care level increases. For care level I, the majority of the care recipients chooses home care. This can be explained by the fact that only a minimum of care is required and the recipients can remain in their home. As the care level increases, more extensive care is required which results in an increase of the care recipients that choose home or even nursing care. In the last scenario, one of the rating functions is modified to illustrate how the presented approach can be used to analyze the impact that changed circumstances have on each individuals' care decision. In the presented example, the environment of the care decision is modified so that attendance allowance is no longer provided for family care. As a result, it must be assumed that the ratio of family care recipients decreases sharply. Still, care recipients will choose family care as *saving of costs* is only one component of the decision for family care besides personal factors such as the strength of the family relationship or the emotional commitment. The results of the simulation (cf. Table 9) show a 35% to 50% decrease of the family care recipients, increasing as the care level increases. Moreover, and especially in care level III, most care recipients choose nursing care assuming that the most adequate care can be provided there.

Table 8: Results with 100% Emotional Man.

	I		II		III	
FC	1,297	(-4.2%)	777	(-11.6%)	248	(-23.1%)
HC	905	(+18.5%)	669	(+9.5%)	190	(+28.4%)
Nc	980	(-8.1%)	804	(+5.8%)	321	(+9.6%)

Table 9: Results without attendance allowance.

	I		II		III	
FC	874	(-35.4%)	482	(-45.2%)	158	(-50.3%)
HC	955	(+25.0%)	788	(+28.9%)	172	(+16.2%)
NC	1,353	(+27.4%)	980	(+28.9%)	429	(+46.4%)

In this section, we demonstrated the suitability of the presented model for simulating care decision-making processes by means of a case study. We were able to reproduce real-world care decision data and evaluated the model's sensitivity under different circumstances. As empirical data on both occurrence and distribution of actor types under care recipients is available, we calibrated the model so that the observed behavior is plausible. However, this sensitivity analysis is a first step in the validation process. The systematic evaluation of the remaining parameter space and empirical studies on how real world care recipients can be adequately represented using the four presented actor types is subject to future work.

5 CONCLUSION AND FUTURE WORK

The goal of this paper was the development of an agent-based model, that allows for the simulating of human decision-making in the context of elderly care. By including sociodemographic data, sociological theories, and actor types, it is possible to map systemic mechanisms and individual behavior realistically. Consequently, different social situations and individual human decision-making are taken into account. Furthermore, the design allows for adjustment and thus can be applied to different elderly care systems. The feasibility of the model was evaluated in a case study in which the sensitivity regarding different population types and rating functions was demonstrated. This work offers a first step towards Agent-based Microsimulation for forecasting elderly care demand, that allows for the forecasting of both amount and location of upcoming demand as well as the requested type of care. Due to a lack of suitable data, the configuration of the actor types was determined in a calibration process. While they are capable of reproducing real-world decision behavior, however, they do not accurately represent the personality of each individual. Hence, in future work we aim to collect empirical data on the characteristics of care recipients to more adequately model their individual decision behavior.

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