Planning for an elderly boom;

A System Dynamics Approach to strategic healthcare planning in Bergen, Norway.

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Thesis

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Abstract

The thesis addresses the future development and potential future scenarios of the geriatric health care situation in the city of Bergen.

Due to population dynamics and demographic processes the city of Bergen may expect increasing pressure on the geriatric care services. A system dynamics model is presented; The Geriatric Healthcare Projection Model is employed to project potential future scenarios in the geriatric health care sector.

The Geriatric Healthcare Projection Model consists of an underlying population model and model components simulating geriatric nurses, clients and infrastructure. The model is applied in policy testing of potential future strategies to counter the rising demands for geriatric care.

The thesis reveals that there are major challenges ahead and that the city of Bergen must move quickly to be able to face these challenges. Long delays in public policy making and implementation are identified as a significant problem when attempting to accommodate accelerating care demands in the population. The thesis also investigates the effects of introducing a private sector in geriatric care services. It appears that a private alternative may hold virtue and afford a relief of pressure on the public sector but may also lead to declining tendencies in the public geriatric health care sector.

Acknowledgements

I wish to thank my supervisor, associate professor Sigmund Nævdal, for his vast contribution to the work here presented. His deep understanding of dynamic processes and the system dynamics approach has been both a great inspiration and of significant practical application. His experience with population modelling and personal insight in the healthcare sector has been of great value to me and to the final product as it is here presented. Working with Sigmund has been a humbling experience and it is left me with a deep respect for the system dynamics discipline and for the man himself; thank you Sigmund.

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I would not be writing this had it not been for Bestefar. I know you would be proud to see me through my Masters degree. I am there now Bestefar, I finished. This work is for you.

Finally I must thank my fiancée Fine Christine. Your hands-on knowledge of the geriatric health care services has lifted this work in a very direct and tangible manner. As this work now is concluded I can start to repay you a great debt of affection, devotion and encouraging smiles. Although you will never admit it; you have kept me on track these last months.

Table of Contents

Figures

1. Introduction

Norway is on the verge of an elderly boom. The baby-boom generations of post world war two is coming of age and the effects of this phenomenon will shortly begin to be evident in a broad spectre of the Norwegian society. The demographic patterns causing this boom of elderly are evident when examining the Norwegian population pyramid.

Fig 1: Population Pyramid as of 2005

The pyramid shows that the size of the generations now approaching retirement age are significantly larger then the cohorts currently residing in this age segment. The pyramid also shows that the cohorts currently in teens and twenties are significantly smaller then the generation above. This suggests a pending era of demographic transition.

Norwegian Authorities recognize that this demographic transition will affect the Norwegian society in many areas, and specifically is an increased pressure on public health services to be expected (Helseplan-2015, 2006). Beyond the fact that there are large cohorts of people now coming of age in the Norwegian society, lies the notion that the Norwegian population is enjoying increasing life expectancies(Arne Andersen, 2005). The elderly boom is expected to commence around 2010. Whilst the cohorts older then 67 years accounted for 13 percent of the population in 2005, this percentage is expected to amount between 15 and

28 percent in 2050(Arne Andersen, 2005). Given the general assumption that older people require more healthcare services then younger people; it seems obvious that the Norwegian healthcare system needs to prepare for a considerable surge in activity levels.

The scope of the master thesis presented here is to investigate a number of dynamic aspects and effects of the future boom in healthcare requirements. The thesis is based on a rather extensive modelling project, simulating 50 years into the future. The model is developed based on a System Dynamics paradigm and applies System Dynamics modelling tools. Demographics constitute the driving engine behind the model's dynamic behaviour. A number of potential or plausible changes in system behaviour and feedback effects are also accounted for and incorporated into the model. These feedback effects produce, along with demographic fluctuations, complex and dynamic system behaviour. It is the intent of the author that the modelling work here presented may serve as a useful tool when planning for future healthcare services.

When simulating and predicting the future a number of precautions must be taken and numerous potential scenarios must be highlighted. Still, the future is never certain and findings here presented should be considered with a suitable level of uncertainty. This notion is further addressed later in the thesis. However, it should be stated already here, that the modelling work here reported on must be considered as exploratory. Rather then predicting exact numbers the modelling and simulation work is intended to explore plausible tendencies and trends arising from the internal plumbing and mechanics of the Norwegian healthcare system. The purpose of simulating as far into the future as this project does arises from the above stated assumption. Planning and developing a viable healthcare system takes time. To be somewhat prepared for what's up ahead is vital. Although this model is not suitable to dictate long term policies in terms of specific budget requirements it is able to suggest a number of important and overarching considerations that should be addressed.

The model here presented focus on the situation in the city of Bergen. Although the elderly boom is an issue of national address and actuality, it may give little meaning to aggregate the healthcare situation to this level. Norway is a highly differentiated country with respect to geography and demographics. There are vast qualitative and quantitative differences in population densities, education levels, and access to healthcare and age compositions within the Norwegian rural-urban continuum. To work with an overly large scope would give little meaning. However, the model is open-ended and is applicable to any given rural or urban community. By changing input parameters the model could potentially be applied by policy planners anywhere in Norway. In this respect the model here presented must be considered as a conceptual model. To apply the trends and findings here described as an inductive basis for planning in other communities is potentially hazardous as the trends in Bergen arise from the population and healthcare parameters found in the local community. The model structure is however universally suitable for all Norwegian communities and could be adapted to fit other geographic areas of interest.

The research presented here was inspired by an experimental project conducted by the author in spring 2007(Trellevik, 2007). The experiment suggested that the babyboom generation had high expectations to their quality of geriatric health services. In fact, the babyboomers expected a considerable lift of geriatric service standard, compared to what their parents are currently experiencing. This notion coupled with the notion of challenging population dynamics suggests a gloomy perspective for the future of public geriatric health services. The research presented here is intended to shed light on the future prospects of the babyboomers seniority. The research further attempts to test and analyze potential policies addressing the geriatric healthcare challenges ahead.

The thesis is organized in the following manner:

(1) Problem statement: The thesis presents the underlying problem providing rationale for this modelling project.

(2) Dynamic Hypothesis: The thesis addresses the plausible dynamic hypothesis sought to be addressed by the simulation exercises.

(3) Literature review: The thesis offers a brief literature review on similar modelling projects and other literature of relevance to the project.

(4) Conceptual Model: The conceptual idea and framework for the model is presented and discussed.

(5) Model Framework: The thesis presents issues relating to modelling horizons, universal assumptions data and parameter quality and uncertainty.

(6) The Model: the actual model structure is presented and discusses in light of Stock and Flow diagrams. This chapter addresses the most important structural variable connections, parameters and equations.

(7) Validation: The model is tested and validated in terms of robustness and sensitivity.

(8) Policy Testing: Different policies are tested by simulation. Findings and results are discussed.

(9) Conclusions: The thesis presents and summarizes the key conclusions to be derived from the modelling exercise.

(10) Further Research: Potential future development of the GHPM is suggested.

2. Problem Statement

Norway is headed towards a boom of elderly people. A boom of elderly must necessarily be reflected in the pressure on the healthcare system in general and on geriatric services specifically. The above can be reasoned from the simple and intuitively understood notion that as age increases health condition tends to decrease. When a society experiences an overall weight shift in its population's age composition it must also expect to have a shift in its demand for healthcare services. The elderly are, and always have been, suffering higher rates of disease and health related problems then the younger cohorts of the population. Accordingly geriatrics has developed into a vast field within the health sciences.

The underlying rationale for expecting a pending elderly boom can be accredited to two central dynamic elements. The first element is dictated by historic birth rates, and the second element is dictated by future death rates.

During the years following the end of the Second World War, Norway as most western countries experienced a sudden elevation of birth rates throughout the country(Arne Andersen, 2005). This is commonly accredited to growing optimism and increased faith in the future as the economic and humanitarian hardships of the occupation came to an end. Later on, these elevated birth rates started to diminish. This effect produce the bulge evident on Fig.1.

The second element inherent to a pending elderly boom is a change in death rates. Norwegians have over the last decades enjoyed longer life expectancies. As people in general live longer, further contributions to an elderly boom irrevocable.

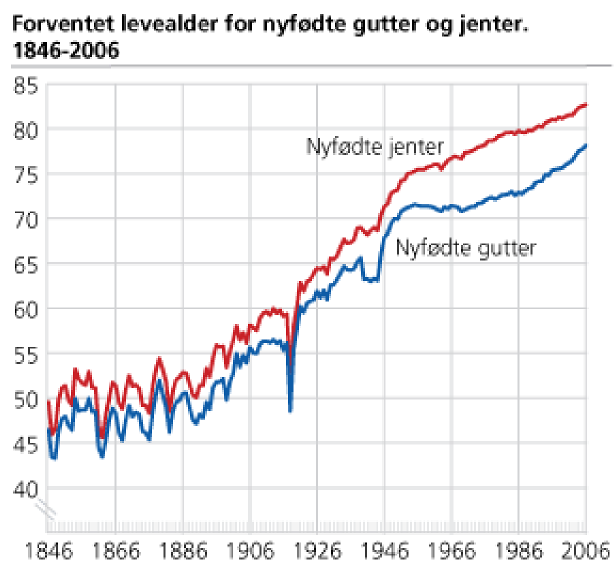

Fig 2: Life expectancy; as reported by the Norwegian Census Bureau

The above figure demonstrates a drastic increase in the life expectancies newborn males and females in Norway. A noticeable increase is evident from the late 1940s until 2006 whereas the life expectancy has increased by almost 15 years. An increase of this amount is likely, assuming ceteris parabus, to render a population with a higher fraction of elderly.

The dynamic phenomena orchestrating the elderly boom can be summarized in a CLD (Closed Loop Diagram). These dynamics are of the utmost important for the model here presented as they are assumed to be responsible for increasing the demand for future healthcare services.

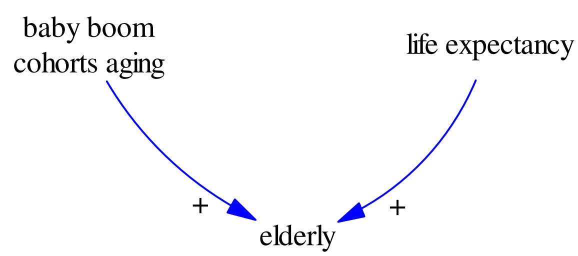

Fig 3: Baby boom cohorts and increased Life expectancy

The above CLD does not fully explain why the aging of a baby boom cohort and increased life expectancy will lead to an increased demand for health services as it does not fully capture the nonlinearities at play here. Firstly the babyboom generation must be revisited. The key point is not that this generation is large in absolute terms; rather the problems arise as the babyboom generations constitute a population that is relatively much larger then the younger generations.

In other words; it's the drop in birth rates during the babyboomers' own era of reproduction in which the nonlinearities and thereby the problem at hand is seeded. The babyboomers simply failed to reproduce their own numbers and henceforth caused an upwards drift of gravity with respect to population median age. Whilst this was happening the babyboomers where also gaining years on their expected life-span. Hence; more people are aging and they keep aging for a longer period.

2.1 Problem boundaries

To address the latter notion as a problem may come off as cynically or politically incorrect. Intuitively one would conceive that more people getting to live longer as a healthy sign, and indeed it is. On a personal level the above notion is obviously good news. The problem arises in the realm of public policy planning. In Norway as in other Scandinavian countries, health and elderly care is subject to public responsibility and administration. When a relatively large proportion of the population more or less simultaneously reaches the age where they are in the risk group of becoming dependant on the healthcare system to a greater or lesser extent, ripples will be felt throughout the Norwegian society. As the babyboomers have not completely reproduced their own numbers there is concurrently a lag between the boots to be filled and the feet to fill them as the current owners retire. Furthermore, as a relatively large proportion of the population suddenly may require professional care, a demand for professional care professionals, equipment and institution beds must also arise. But will the relatively smaller cohorts following the babyboomers have the manpower and financial assets to replace the workers retiring whilst providing care for increasing numbers of care receivers?

Herein lays the problem to be addressed by this thesis. Ripples of these dynamics will be traceable in numerous aspects of society, such as labour markets, real-estate markets, financial markets, national productivity and public services. All of these areas reach beyond the scope of this thesis. The thesis focus on the care services rendered to the elderly in specific. Clearly, with an increased proportion of the population allocated in the older cohorts, a surge in demand for general care services such as hospital beds etc is to be expected as older people tend to be over-represented also here. However, this lies beyond the modelling boundaries for this project.

In Norway elderly or geriatric healthcare services can be divided into two major concepts; Institutional Care Services and Homecare Services. As one is growing older, ones risk of encountering some level of need for one of these increases. As more people grow older, more service needs both in the homecare sector and in the institutional care sector is to be expected to be accommodated for. How this can be done is the core of the problem to be addressed by this modelling and simulation work here presented. The model and thereby also the thesis seeks to explore the problems and challenges arising in the Geriatric Care Sector as a relatively large proportion of a population reach ages where care is likely to be recruited.

As much as the demographic transition is true for Norway as a whole, the same basic trend is expected locally in the city of Bergen. Whilst modelling the geriatric care services on a nationwide level is impractical and probably hazardous, the same modelling task leds itself better to a smaller geographic and formal community. As mentioned, Norway is a vastly differentiated country with great differences within the rural-urban continuum. When considering that a major focus for geriatric healthcare is homecare this notion becomes very important. Where population densities are higher the productivity and efficiency of homecare services must be expected to be higher. The latter simply as less time is spent on commuting between patients and more time is free for actual care services. By choosing a rather uniform community with respect to population density this problem and error source is to a large extent omitted. Furthermore; the model employs a plethora of various parameters. The local variance between communities could potentially skew the simulation results dramatically if this model was to be approached with a national perspective. Over-aggregation could certainly render the model and simulation utterly meaningless. The geographic boundary for this thesis is therefore set to the city of Bergen and hopefully that boundary minimizes uncertainty and errors embedded in aggregation levels.

The model here presented is developed, parameterized and calibrated for a simulation period of 50 years; over 40 of which will be simulated beyond the point in time in which this work will be completed. The author will be the first to recognize the perils this introduces. To simulate anything into the future introduces a minefield of potent uncertainty and error and the further into the future one makes predictions the greater will these be. Nevertheless, one may learn important lessons from such simulation exercises. The model at hand is not designed to make predictions in fields that are subject to basic changes in their system structure. Rather, the basic system engines in this model are rather rigid and dictated by natural law. As an example it is fairly safe to assume that whilst time passes, people will get older. Furthermore; as people get older, their need for care will increase. Obviously it is not by that suggested that sudden systematic changes may not occur; it may be that humanity some time in the 2020ies discover a way to stop aging completely; the latter is highly unlikely. The author does not suggest that the simulation results straddling into the distant future are correct. It is however the hope that the system here modelled is based on assumptions that does lend itself to some level of accurate prediction. If this is the case a simulation exercise reaching as far as 2050 may prove meaningful. If the model is successful in capturing the essential structure of demographic transition and its effect on the demand for geriatric care, simulation may reveal important trends that policy makers should be aware of. Simulation also offers an opportunity to test different policies. These test results may provide valid lessons regardless of the model's prediction accuracy. Von Thunen suggested that: "All models are wrong, but some are still useful". It is the pronounced aspiration for the author that this model is a useful one.

2.2 Problem summary

The problem at hand is one of capacity and quality of geriatric healthcare. Modelling outcomes will be referred to in units expressing these two properties. Capacity and quality is in the health sector closely entwined. In fact, as a numerical unit of measure for healthcare quality a Personnel/Patient ratio is commonly referred to in the health-science literature. This will also be the case in this study. This point must be emphasised as it is a corner stone for the model. The problem under investigation is not a budgetary or economic one. In fact, for many policy tests conducted the author has assumed unlimited economical assets. Clearly a notion of unlimited assets is completely unrealistic in the context of public policy. To make such an unrealistic assumption may still be vital to fully explore physical capacity issues. One may discover that a capacity problem cannot simply be resolved by flooding the budgets. If there are too few trained nurses to man a hospital, one will not manage to man up completely regardless of the size of the pay checks offered; in capacity related issues there may well be problems other then financial shortage causing a lag of capacity. If model behaviour is dictated by a financial framework such capacity related issues could easily be accredited to budgetary constraints. By omitting financial assets in whole from the model, analysis will be better focused on other issues; which in this case is the scope of the research. Furthermore; this research is simulating into the future. To involve finances into a forecasting model raises many difficult questions with only ambiguous answers. Financial markets are subject to a plethora of various global and local dynamic effects and attempting to include these in a model for local geriatric health services would not only be presumptuous, it would be utterly meaningless. By omitting economic aspects of the model the forecasting made by the simulation suffers less uncertainty as the parameters simulated into the future is primarily subject to natural law and linear time rather then the moods of the global money market.

Capacity and quality of health geriatric healthcare services in the near future in the city of Bergen is the foci of this study. Quality of healthcare is by and large measured as Quality = Care Personnel/ Patients. Other units of measure on quality will however also be applied. An example of such units of measure could be "average time awaiting institution bed" or "stress amongst care workers". Units of this nature are largely qualitative and relative. Nevertheless; units of this nature are adequate indicators of dynamic trends and provides a basis for evaluating and comparing outcomes of various policies. This point is mentioned in this chapter to stress what the problem the study seeks to better understand really constitutes. Rather then answering questions like; "*how much money is needed?"* This thesis seeks answers to questions like: *"how many able hands are needed?"*.

In the introduction it is mentioned that the author has earlier conducted an experiment on the topic modelled here. In this experiment one of the key findings was that the babyboom generation exhibits a general demand of higher quality geriatric health services then what their parent generation is currently enjoying. This is potentially also an important dynamic in this puzzle. To formally model such expectations and mental constructs is problematic. In terms of prediction the latter is highly ambiguous. The notion of increased expectations is therefore not included in the model structure. It may still be important for the reader to keep this in mind when examining the results produced.

In summary the problem to be explored here can be defined in the following way. *"Due to population dynamics, the city of Bergen may expect a significant challenge with regards to the future quality and capacity of the geriatric healthcare services"*

3. Dynamic Hypothesis

The problem addressed in this work has multifaceted dynamic dimensions; it circumfences a number of intricate feedback loops and system links. To develop one single dynamic hypothesis may be somewhat presumptuous as the problem at hand is based on a complex web of dynamics. However, many of these are not the key dynamics for the analysis and will therefore be explained and outlined throughout the model description but not treated as a focal point for analysis. Other dynamics that are inherent to the system in the real world may also be omitted in the model. In these cases the dynamics have been considered as irrelevant, insignificant, or counterproductive to the targeted problem. These dynamics are explained in more detail under the section on problem boundaries, and will be revisited as the model and its boundaries are explained.

The primary dynamic engine in the model is population dynamics and a pending dynamic transition. This dynamic transition suggests a disproportionate growth of older to younger cohorts. The pool of geriatric patients may simply outgrow the pool of geriatric care workers and facilities. A mismatch between the amount of people requiring care and the amount of professionals and infrastructure providing care further suggests plummeting care capacity. Plummeting care capacity suggests a plummeting care quality.

A drop in geriatric care capacity and quality is in its own power a severe public concern. It is however imperative to recognize that the problem does not stop there. There are serious feedback effects to be expected from a situation of this nature. The drop in care quality and capacity is obviously dictated by an increased pressure on the care workers and facilities. Herein lies the key to the major feedback loops and a reason for furthered public concern. As the pressure on the geriatric care system increases, so does the wearing and tearing. Workers must work harder and more, at the expense of their attitude towards work and general health. It is widely recognized that there is a link between work pressure and worker burnout rates, sick leaves, and job swaps. Equipment will suffer higher rates for depreciation. Cars used in homecare will be driven further, linens worn out sooner, and buildings withering quicker. Altogether the entire geriatric healthcare system will go through a reduction of robustness; furthering the pressure on the system.

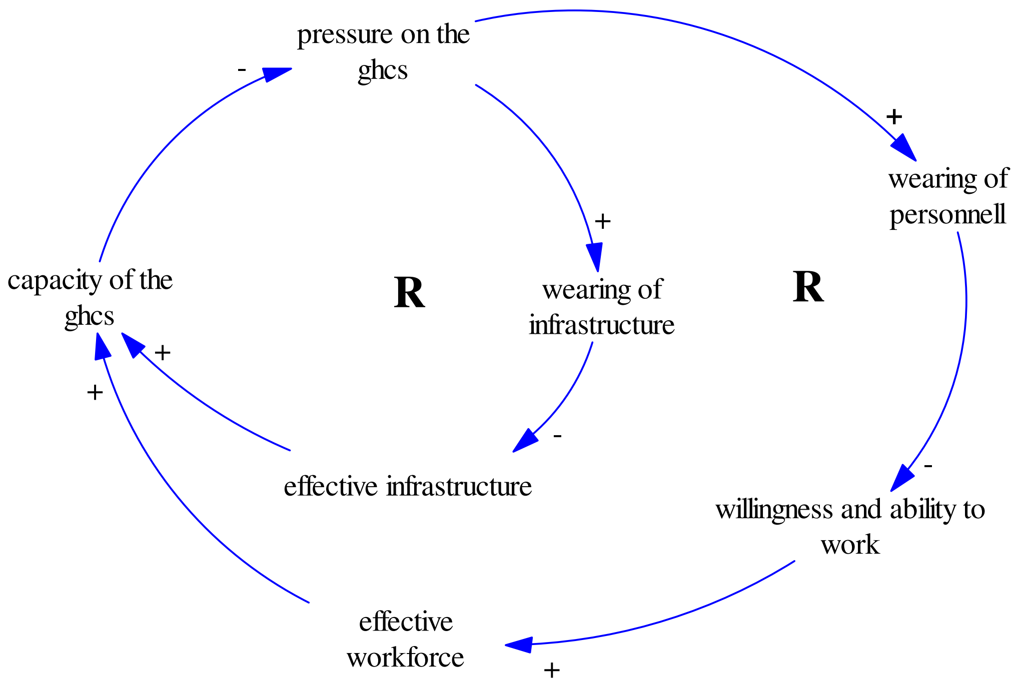

Fig 4: CLD: Reinforcing feedback loops in the GHCS.

Fig. 4 explains two important reinforcing feedback loops in the geriatric healthcare system (GHCS). The rightmost loop displays how a drop in capacity will drive the pressure on the GHCS upwards. Increased pressure will generate more wearing of the care workers. More wearing of care workers will reduce the willingness and ability to work in the Geriatric healthcare sector. Reduced willingness or ability to work leads to a reduced effective workforce and further reduced capacity in the GHCS. The leftmost loop demonstrates a similar chain of effects. As capacity drops, the pressure increases. Increased pressure causes more wearing of the infrastructure which in turn reduces the mass of effective infrastructure. A loss of effective infrastructure reduces the capacity of the GHCS.

The two reinforcing feedback loops described above has the potential to throw the geriatric healthcare system in Bergen into a negative spiral. This could easily happen if dynamics external to the GHCS were to lower the capacity of the GHCS to a critical point. A demographic weight shift in terms of an elderly boom is likely to have this effect. In Fig. 5 this external element is added to the CLD.

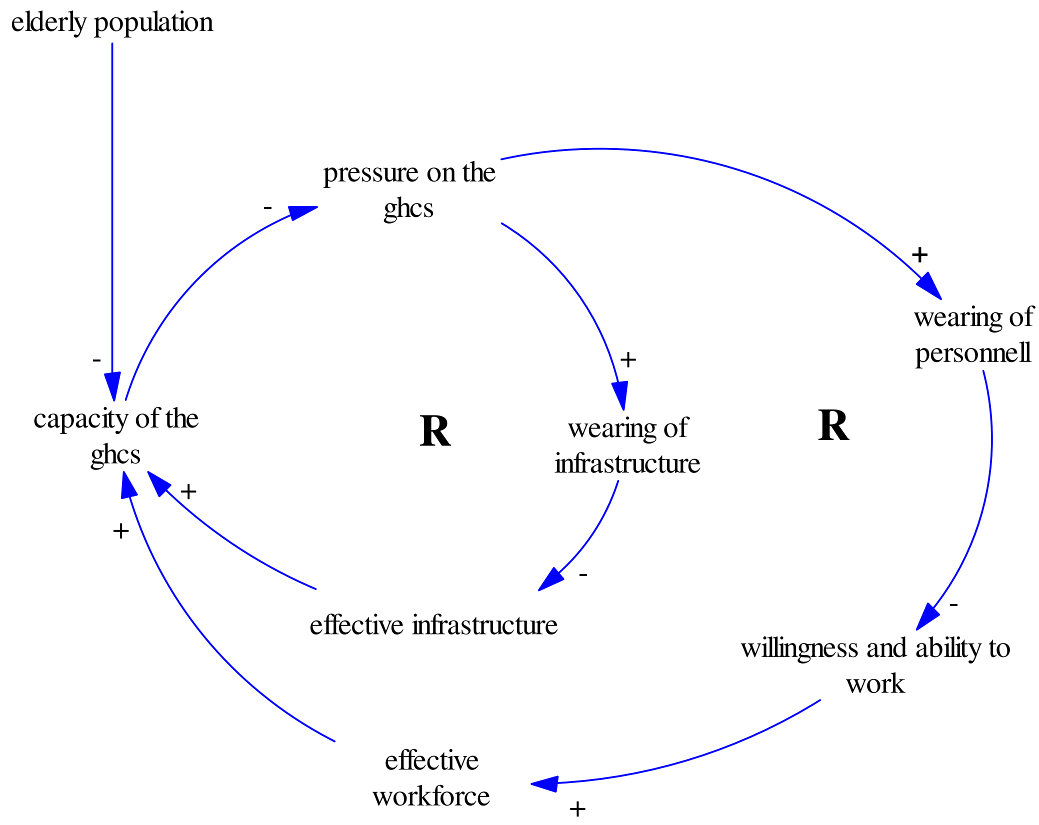

Fig 5: Elderly boom added as an external attractor to the system.

In order to counter a demographically induced vicious cycle in the geriatric healthcare system the city of Bergen, or any community facing a similar problem, must develop public policies and facilitate policy implementation in the GHCS. Although the real world contents of such policies can range widely; the goal for such policies is universal. The policies must aim to increase the capacity of the GHCS by improving or expanding the effective infrastructure and the effective workforce. If the policy implementation is successful they will supersede the external effects of the elderly boom and reverse the direction of the reinforcing loops in the GHCS. By adding this to the CLD the gloomy picture changes.

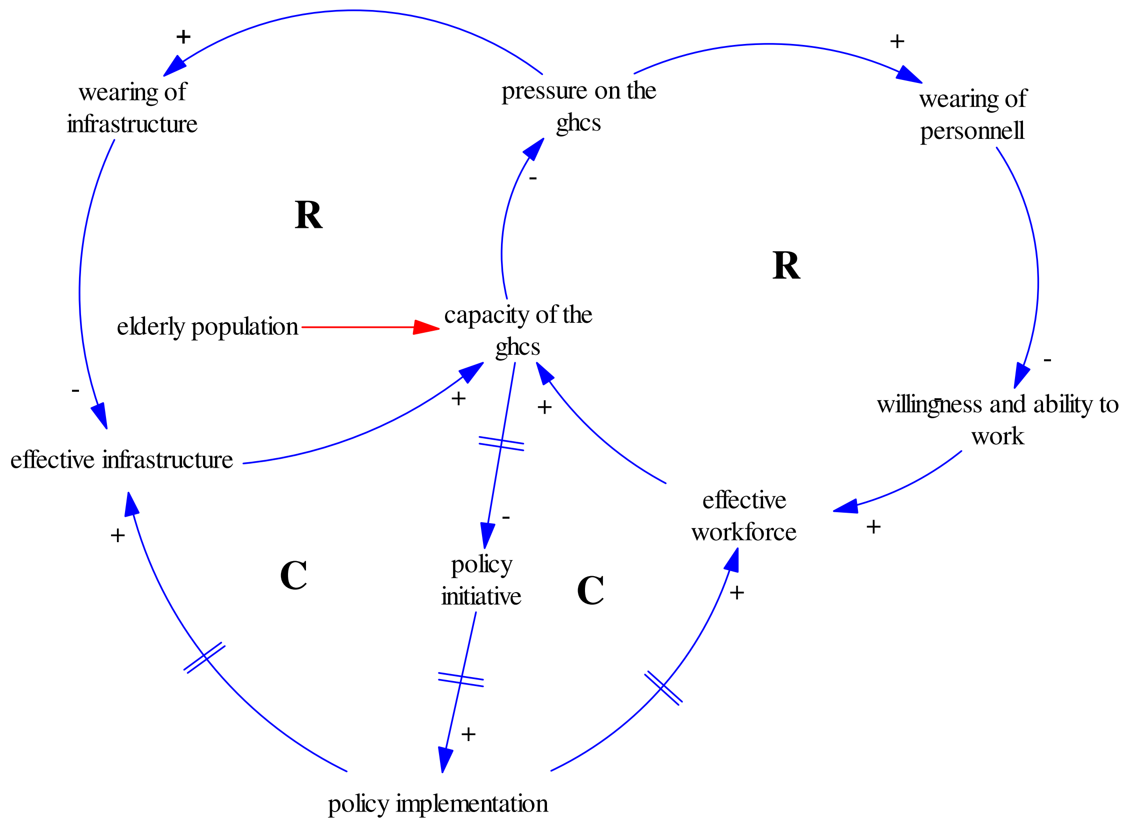

Fig 6: CLD with counteracting loops added

The CLD exhibits a very different story as policy initiative and policy implementation is added. Assuming that policy initiatives will occur as an effect of changes in the GHCS capacity it is reasonable to gather that reductions in capacity would generate more policy initiatives. Increased initiatives would again generate accelerated rates of policy implementation. Policy implementation would infer both an increased effective workforce and an increased effective infrastructure. Hence would two counteracting loops be in place; hopefully effective enough to counter the downward spiral induced by the elderly boom.

There is an important point to be highlighted in this respect. When dealing with public policy one must account for the considerable delays that are all-present in the realm of public policy. Delays must be expected in all steps of public policy making and implementation. When capacity in the geriatric healthcare system drops it will take time for this to be registered and reported to the political authorities. When capacity is reported it will take time for the political authorities to react. Before policies can be developed, the capacity issues must be evaluated: research must be conducted and reports must be written. When policies have been developed they must be accepted politically before they can be implemented. Depending on the political climate in the community this will also generate some degree of delay. When both plans and money is in place implementation can commence. At this stage one must expect considerable delays. Building geriatric institutions takes time; so does educating health care personnel.

Due to these delays it is imperative for policy makers to realize the dangers of the future elderly boom at an early stage. If the process of policy making and implementation is embarked upon at an appropriate point in time the effects of the potent reinforcing loops at play in the system may be countered. On the other hand, should the perils of the reinforcing loops be ignored for too long, policy implementation can commence to late for effectively facing up to the challenges. In that case the geriatric healthcare system will be thrown into a serious crisis. Considering the role the geriatric healthcare system plays in many peoples lives an ad-hoc approach to GHCS policy would ethically and morally wrong. It is the hope of the author that this thesis will better the understanding of the dynamics at play in the geriatric healthcare system.

The dynamic hypothesis suggested by this research accordingly express the following:

H_0: "Due to delays in the realm of public policy making and implementation the future strains imposed on the geriatric healthcare system by the pending elderly boom must be addressed at an early stage in order to maintain or better the capacity and quality of the services rendered. It public policy is engaged in too late a stage the reinforcing loops of the geriatric healthcare system generate a vicious cycle of degradation in the geriatric health service "

The alternative hypothesis infers that ad-hoc policy making will be sufficient and effective:

H_1: "The magnitude and effect of the reinforcing loops in the geriatric healthcare system are not sufficiently powerful to dictate long term planning regardless of delays in the realm of public policy. Capacity shortages induced by an elderly boom can be dealt with as they accent."

The modelling and analysis work will pursue the denunciation of the null hypothesis. Should the null hypothesis be denounced that would relieve much weight of the shoulders of the policy makers in the city of Bergen. As much as long-term planning in general is a goal on its own, it is without doubt a difficult and tedious political process. To spend money today on a problem of tomorrow is unquestionably a hard political sell. Should it be the case that the effects of the elderly boom could be dealt with as they arise then many policymakers would probably be rather relieved. If the opposite is the case then policy makers should gear up for the challenges as early as possible and thereby preparing the city of Bergen for the coming boom in the geriatric healthcare system.

4. Literature review

The system dynamics literature on the Norwegian GHCS is non-existing. The literature employed in this study is therefore drawn from a selection of related and relevant research articles, textbooks, governmental reports, statistical reports, and political documents. To readers unfamiliar to the Norwegian language a substantial proportion of literature referred to here is inaccessible. Although this is less then ideal it is a necessity, granted that the modelling work presented mimics a Norwegian realm of public policy. The Norwegian literature includes governmental reports, statistics and political documents. These are obviously quite central to the model structure and parameters in the model. Where paraphrasing is applied citations are translated by the author.

Literature addressing relevant issues in system dynamics and similar modelling initiatives is all in English. However, there appears to be little literature on topics closely related to this thesis subject. This may relate to the fact that not many countries have both an active system dynamics community and readily transferable conditions and structures within the geriatric segment of healthcare. On the other hand is there substantial literature on health services in general and much of this literature applies to the subject at hand.

The literature can roughly be divided in three categories. (4.1) The first category describes the Norwegian geriatric healthcare system. (4.2) The second category addresses population dynamics and population simulation. (4.3) The third category outlines relevant issues in system dynamics and similar modelling initiatives.

4.1 The Norwegian Geriatric Healthcare System

In St. Meld. Nr.25 "*Mestring, muligheter og mening*" (Helseplan-2015, 2006) the Norwegian Ministry of Health and Care reports the future care challenges in Norway. This report is ordered by the Norwegian government and aims to raise questions in a long term perspective and outline goals and strategies and to secure that these are carried through by effective and practical implementation. The report emphasize the formal local responsibility in care services and underlines that the government is providing supplemental funding to the local communities to ensure sufficiency in the care sector(Helseplan-2015, 2006) . This is of vital importance to the model as it is clearly stated that the responsibility for providing the required level of geriatric healthcare rests upon the local democracy and institutions. In terms of policymaking the GHCS is a matter for local politicians and bureaucrats and not the central government. The report is outlining a framework defining overarching objectives and policy boundaries for the local communities to work within. In legal terms the Norwegian care sector is covered by *"Kommunehelsetjenesteloven"*[1], *"Sosialtjenesteloven"*[2], *and*

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[1] Eng: " Law of *Kommune* (Lowest political-legislative unit in Norway) health services".

"Barnevernsloven"[3]*(Helseplan-2015, 2006).* These three laws are mentioned as a legal framework as the care sector is defined widely; the definition circumfence home-services, homecare services, care-housing, nursing homes, retirement homes, etc. To the subject matter at hand however, it is only the laws governing health services that is of relevance.

The report highlights a number of important imperatives for local policy making in the health sector. The report dictates that the individual is to expect a high level of influence on type, level and extent of the care services provided to them by the local community. Policy makers care professionals are urged to be sensitive and aware of their position of power and influence. The care client should enjoy the highest level of freedom of choice possible. The latter to ensure that care clients are granted an opportunity to a meaningful and independent life. The report further emphasize that the welfare state also has expectations to the care clients. Care clients have a responsibility to actively engage in their own wellbeing and not to exploit or misuse the care system.

The report advocates the importance of growth and development of competence in the care sector. Specifically the government expects a growth in the labour force, an increased level of competence amongst the care workers, investments in functional and robust infrastructure and bettered cooperation between different offices and care units. The discuss the potential of "*building partnerships with families and local communities*"(Helseplan-2015, 2006). It is suggested to facilitate opportunities for combining the provision of care for friends or family and professional careers. It must be possible to care for loved ones whilst

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[2] Eng: " Law of social services".

[3] Eng:"Law of child services".

maintaining a job. Cooperation with voluntary organizations is also important. Voluntary work has long traditions in Norway and constitutes an important resource. Precautionary work is also addressed. As one expects an increased pressure on the care services it is of the utmost importance that the general health of the population is addressed and that the local communities inspire and empower social and cultural networks. The report suggests the local policy units develop systems and routines for quality control of the care services (Helseplan-2015, 2006).

The report discussed above presents a conceptual framework for the modelling process. In setting a national standard for goals and strategies, all local policy makers must necessarily consult and abide by the regulations set by this report. Henceforth is the report vital for developing a model for the geriatric healthcare system also in the city of Bergen.

"*Eldreomsorgen I Bergen – avsluttning handlingsplan og videre utvikling*"[4] *(Byrådet, 2004)* is a legeslative document issued by the City Council of Bergen in 2004. The document presents the state of the geriatric care system in Bergen in 2004 as well a plan for the completion of an earlier development plan for the geriatric healthcare services. The document accounts for 2125 nursing home beds whereas 1995 are in one-bed rooms and 130 are in two-bed rooms. In addition the city of Bergen administrates 267 retirement home beds; most of which are located in one-bed rooms. The document further outlines the strategies developed to ensure a sufficient quantity and level of competence in the geriatric healthcare services. These strategies include: Better targeted use of institution beds, development of a relative

[4] Eng: Geriatric care in Bergen – concluding implementation plan furthered development

upsizing of home-care services, bettered coordination between care units, furthered development of quality assurance systems, increased recruitment initiatives, introduction of user participation in decision making and investigation of principles regarding private institution initiatives(Byrådet, 2004).

The document emphasizes a policy of "permitting elderly to reside in own homes for as long as possible". The city council reasons that with proper assistance from the home-care services, people with considerable physical need of nursing can continue to live at home. Also people in early stages of dementia can remain at home, if home-care services provide sufficient countermeasures. It is further a pronounced policy to prioritize people who are permanently unfit for caring for themselves for institution beds(Byrådet, 2004).

This document provides a transparent account of available services and service shortages. It presents concrete strategies and budgetary concerns as well as reasons for progression discrepancy from earlier plans. The document thereby offers important insights to the geriatric healthcare system and the strategies behind it. However, its relevance is somewhat hampered by the fact that it dates back to 2004. Since these policies and plans were issued much may have happened in the city's political environment. The document must therefore be seen as a supplemental document to a more recent plan issued in 2007..

"Plan for videreutvikling av pleie og omsorgstjenestene"[5] was issued in 2007 by the city council in Bergen. This plan outlines and discusses the wide range of services

[5] Eng: Plan for further development of the nursing and care services

administered by the department of health and care. The plan therefore addresses many issues that are irrelevant to the modelling of the geriatric health system and outside of the problem boundaries set for the modelling. Still, geriatric healthcare represents a major component in of the care service in Bergen and is accordingly devoted substantial attention in the document. The document underlines that the plans and strategies presented constitute a continuation of earlier plans. This lends important credit to the 2004 document and that is important as the 2007 plan assumes a rather opaque and ambiguous approach; the plan appears to be highly "political" in its form. "Political" is here referred to as an adjective. The report is presenting statistics and figures in a rather inconsistent and selective form, assumingly to present a different image of the current status of the public care services than might be the case. Nevertheless, the report is important as it is recent and introduces a number of important insights from a modelling perspective.

The 2007 plan states that the city will increase the devotion to the lower levels of the care hierarchy. The care hierarchy ranges between home-care services at the bottom and institutions further up. Most steps of this hierarchy are not included in the model as they are mainly designed for younger care clients. The city council express a clear political intention to shift as many responsibilities and care tasks as possible to the home-care service(Byrådet, 2007). In this respect the document is pursuing a more aggressive strategy then the 2004 plan. The 2007 plan states that the competence and capability of the care services are to be strengthened at all levels, that the tasks of the home-care services are to grow increasingly complex and that all home-care employees are to be educated in their field. The plan suggests that the institution capacity must be expanded in the future and expects a new institution with 90-110 beds should be finished by 2015. 30 of the new beds will be replacements for a closed institution. The document further suggests to dedicate 720 million NOK in the period 2008-2020(Byrådet, 2007).

Along with the 2004 plan the 2007 care plan forms the main body for modelling the geriatric healthcare system in the city of Bergen. There are however shortages in these plans that are somewhat challenging from a modelling perspective. The author has at several occasions attempted to retrieve supplementary data and information from the city council, but have consistently been referred back to the public documents. The implications of this will be discussed later.

4.2 Population dynamics

That there is a relatively large group of people on the verge of reaching retirement age is widely recognized, so is the fact that this will have implications for the geriatric healthcare services. Omsorgsplan 2015 states that in the near future there will be significantly more clients in the care sector. According to the Ministry of Health and Care the number of people above 80 years old will be doubled within 35 years. The highest client frequency is found among women, this obviously relates to the fact that women in general live longer then men. The occurrence of illness and injuries increase with age and it is therefore expected that increased numbers of elderly will lead to an increased demand for health services. The ministry of health and care expect further increasing life expectancy. As people live longer they remain old for longer and that creates an even further demand growth for geriatric health services(Helseplan-2015, 2006). The ministry of health and care support the idea of a pending elderly boom, manifested by relatively large cohorts aging and life expectancy increasing.

The conclusions regarding the future development of the population's age composition applied by the Norwegian ministry of health and care is based on statistics and population predictions developed by Statistics Norway[6]. Statistics Norway released the report *"Seniorer I Norge"*[7] in 2005. The report provides comprehensive statistical analysis of the living conditions for senior Norwegian citizens. The report goes far into the subject matter of demography and explicitly concludes that Norway is on the verge of an elderly boom. The boom is explained as an effect of two primary dynamics; the large cohorts of babyboomers born after the Second World War, and a substantial augmentation of life expectancy in Norway(Arne Andersen, 2005) The wave of elderly is expected to commence around 2010. By this time the proportion of citizens above 67 years will start to grow. From a 2005 level of about 13 percent this segment of the population may double by 2050. During this same period the percentage of people in the cohorts defining the labour force will shrink. In 1950 there were 7 people in the working cohorts per every person in the retirement cohorts. In 2005 this figure was approximately 4.4 and in 2050 it is expected to be as low as 2(Arne Andersen, 2005). Clearly these figures suggest that the geriatric healthcare services a face up to pace shift. Statistics Norway also offers interesting reading concerning the health of the babyboomers; compared to their parent's generation they suffer a much higher level of obesity. Along with obesity follows a number of cardiovascular diseases and other physical impairments(Arne Andersen, 2005). Henceforth will not only a large segment of the population live longer; the may also require relatively more extensive support from the geriatric healthcare services.

Statistics Norway is in their report addressing the elderly boom on an aggregated national level. Nevertheless; the practical policy implications of the boom will as outlined earlier be managed at a local level. The city of Bergen is aware of the demographic transition ahead. As much as the 2004 health plan does not mention the elderly boom, the 2007 plan identifies a growing demand for geriatric care services. The document states that as an effect of the *general population growth* the amount of people requiring care services will grow accordingly(Byrådet, 2007). The latter interpretation is perturbing. Throughout the document

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[6] Nor: Statistisk sentral byrå

[7] Eng: Seniors in Norway

there is no reference made to the dynamic properties of the elderly boom. Whilst realizing a growing demand for geriatric healthcare, the notion of the younger generations being relatively small in comparison to is not addressed. The city council is accounting for a need for increased recruitment to the geriatric health sector; they are not accounting for the fact that the labour force to recruit from is declining. The city council of Bergen appears to be oblivious to the dynamic implications of an elderly boom.

If the policy makers in Bergen indeed are unaware of the range of challenges an elderly boom they cannot be excused by a lack of information. In 2005 Norconsult, a Norwegian consulting company was engaged by the city of Bergen to produce a population prognosis for the city and its constituencies. The city council acquired this prognosis for planning purposes. Norconsult developed the prognosis for the years between 2005 and 2024 based the following factors:

-Current population: Age and gender composition.

-Migration patterns: People moving in of out of the city.

-Fertility: Births per woman.

-Mortality: Deaths in all age groups.

-Housing: The current and planned housing stock in the city.

Norconsult employed statistical methods to derive the population prognosis. As all prognoses involves uncertainty the company reports on three alternatives: A low growth alternative, a mediocre growth alternative and a high growth alternative. Norconsult differentiates the three alternatives by adjusting immigration rates and housing stocks whilst fertility and mortality are kept at constant levels. The company recommends employing the mediocre growth alternative when developing policies(Norconsult, 2005). Along with the report a data file containing the three prognoses alternatives was made available to the public. This data set is used in the modelling described in this thesis and will be discussed later.

The Norconsult report is a sober statistical document and offers no conclusions or analysis beyond the numbers presented. Still it is obvious from the figures and graphs enclosed in the document that Bergen should be preparing for an elderly boom. The report has two major shortcomings. The first shortcoming is generated by the temporal dimension of the prognosis. Statistics Norway suggests in their report on seniors in Norway that seniors in 2050 will constitute as much as 30 percent of the entire population. Norconsult have only produced prognosis until 2024. All senior cohorts are in steep incline at the end of the Norconsult prognosis time. It seems fair to assume that it would be beneficial to the city of Bergen to examine plausible demographic scenarios beyond 2024. The second shortcoming is equally important. Statistics Norway and the Norwegian ministry of health and care both emphasize the importance of increased life expectancy. As Norconsult have kept mortality at constant levels throughout their prognosis this dynamic is not accounted for.

The importance of population dynamics induced by augmented life expectancy is stressed by Manton in his article *"The Dynamic of Population Aging: Demography and Policy Analysis"* from 1991. Manton argues that demographers during the 1950's and 60's considered life expectancy to be fixed whilst fertility was considered to be the governing element in population dynamics. Demographers later abandoned this concept but not completely; the idea of an *absolute limit* to life expectancy was introduced in the 1970's. This notion leads to gross miscalculations in demography. A 1977 US Census underestimated 1990 population of the United States by 1.7 million persons. The estimation for 2020 was 7 million lower then the 1991 estimation(Manton, 1991).

Although Manton is discussing American conditions his point is universally valid in demography. If life expectancy does in fact vary, the variation must be accounted for in population estimations. In terms of prediction it is obviously problematic to account for variation; no one knows the future. Still, qualified guesses may well be appropriate to include in population estimations. If a distinct trend has been documented over a long period of time and appears to be robust then such trends should certainly be brought into the equation. Statistics Norway accentuate that there have been a long lasting increase in life expectancy over the past years and have employed the assumption that life expectancy will continue to increase in their demographic models. As Norconsult's estimations omit this important dynamic their prognosis is probably skewed towards an underestimation. As a basis for policy planning the Norconsult prognosis may therefore be less then a best guess.

4.3 System dynamics

The geriatric healthcare system in the city of Bergen is modelled and analyzed by the application of the System Dynamics paradigm and System Dynamics modelling tools. System Dynamics is defined by Sterman: *"System dynamics is a method to enhance learning in complex systems"(Sterman, 2000).* The geriatric healthcare system is indeed a complex system given its many dimensions, processes and underlying dynamics. The magnitude of the service demand is driven by complex population dynamic. The availability of care workers is dictated by a plethora of different factors. The quality and access to effective infrastructure is governed by public policy and budgetary concerns. The list of complexities is long. System Dynamics therefore appears to be a valuable approach to better the understanding of the geriatric healthcare system and enhance the quality of the planning put into it. In terms of public policy planning one must consider the delays involved in the process. These delays infer that planning should take place ahead of the arousal of problems; when the problem occurs it may be too late to react efficiently. Dörner suggests in his book "The Logic of Failure" that : *"Failure does not strike like a bolt from the blue; it develops gradually according to its own logic"*(Dörner, 1996). Policy makers involved with complex systems need to understand the dynamic logic of the systems they are involved with. A potential failure of the geriatric healthcare system is likely to develop over time due to misconceptions of how the system will evolve. Enhanced understanding of the geriatric healthcare system is imperative. As the literature review has suggested, the care authorities in the city of Bergen appear to have missed important dynamics regarding the future demands in the geriatric healthcare sector. A systems dynamic approach to the system has the potential to enhance learning and to avoid future failure.

Homer and Hirsh argues that *"The Systems modelling methodology is well suited to address the dynamic complexity that characterizes many public health issues"*(Homer and Hirsch, 2006). It is further suggested that *"System dynamics shows promise as a means of modelling multiple interacting diseases and risks, the interaction of delivery systems and diseased populations, and matters of national and state policy"* (Homer and Hirsch, 2006).

Old age can hardly be considered a disease; however, disease is commonly an effect of old age and the elderly tend to require health services. System dynamics should therefore offer equally important insights to the geriatric healthcare system as it does to the general healthcare system. Homer and Hirsch underline the fact that *"many public health interventions fall short of their goals because they are made in piecemeal fashion, rather then comprehensively and from a whole system perspective"* (Homer and Hirsch, 2006). A system dynamics model of the GHCS in Bergen allows for comprehensive and whole system perspective and could be an important tool for avoiding future shortcomings in the services rendered to the seniors of Bergen.

Taylor and Dangerfield propose a further applicability of system dynamics when examining strategies in health services. System dynamics allows for experimentation that in real life would be impractical, impossible or unethical. Real life experimenting in issues that directly affects a population's well being is at best questionable. *"Exploring the effects of policy changes and experimenting with alternative policy formulations is not feasible in the real world. However, simulation models can provide a flexible experimental environment for this purpose"* (Taylor and Dangerfield, 2005). The model here presented has the potential to be applied in various experiments. Experimenting may reveal important dynamics and feedbacks that would otherwise go unnoticed. Taylor and Dangerfield stress that system dynamics are well fitted for analysing feedback effects. *"The system dynamics method is specifically designed for the analysis of feedback mechanisms" (Taylor and Dangerfield, 2005).* A number of important feedback effects are at play in the GHCS in Bergen; these are incorporated in the modelling exercise presented in this thesis.

The article *Waiting Lists in Spanish Public Hospitals: A system dynamics approach* by Gonzalez-Busto and Garcia address the issue of reducing waiting time in the health system. Their work is devoted to Spanish hospitals, but the dynamics involved are relevant also to the geriatric healthcare system in Bergen. The article underline that waiting lists are manifestations of lacking efficiency in health services. Waiting lists "…*reveal the organization's incapability to satisfy their demand within a period of time considered as appropriate by their users"* (Gonzalez-Busto and Garcia, 1999). This article outlines several policies to reduce waiting lists. Most of these policies are not applicable to the GHCS in Bergen. One policy suggestion is however important. Gonzales-Busto and Garcia suggest subcontracting private services when the public institutions are generating excessive backlogs(Gonzalez-Busto and Garcia, 1999). This strategy may prove important in the future GHCS in Bergen; should the public health system fail to provide sufficient service a market for private institutions must be expected to arise.

There appear to be no published literature specifically addressing system dynamics modelling of geriatric healthcare services. According to Brailsford there was by 2004 surprisingly few applications of system dynamics in healthcare in general(Brailsford et al., 2004). Charles Tilquin agrees with this conclusion and states that: *"…it would be difficult to say that system analysts and researchers have played or play an important in the evolution of the concepts and practical aspects of health service management"* (Tilquin, 1976). Tilquin suspects that many health issues are analysed under the false pretence that the whole equals the sum of its parts and that whilst this is true in elementary arithmetic it is not necessarily so in system analysis(Tilquin, 1976). Tilquin further argues that many models that have been put forth have been to simplistic and therefore rejected(Tilquin, 1976). When proposing models addressing public health the latter should be kept in mind; if the model does not represent the system in an adequate way it is of no use. Dangerfield recognize two key areas where system dynamic modelling offers important qualities: As a tool of persuasion and as a frame for evaluation of tactical studies(Dangerfield, 1999).

4.4 Literature conclusion

The literature review here presented has discussed the Norwegian geriatric healthcare system, the population dynamics of Norway in general and Bergen in particular, and the applicability of System Dynamics as a tool in health modelling. From this literature review it is fair to conclude that:

- ✓ The citizens of Norway and henceforth also Bergen enjoy a public geriatric healthcare system. It is considered a responsibility of the welfare state to provide adequate healthcare services for the elderly. Although the legal and political framework for the extent and quality of these services are dictated by the Ministry of Health and Care on a national level; the responsibility for delivering the services relies on the local formal communities.

- ✓ The Norwegian population is due to a babyboom generation born after the Second World War and increased life expectancies throughout the nation headed towards a demographic transition. The elderly proportion of the total population will in the next decades increase dramatically. The City of Bergen has recognized that there in the near future will be more clients in the geriatric health system, but appear to have overlooked the fact that the younger cohorts are not proportionally large. The city of Bergen seems to be ignoring an important aspect of the population dynamics at play. The city has also failed to estimate the population development over a sufficient period of time. This may have grave consequences for the geriatric health service planning and implementation in the city.
- ✓ System Dynamics is a method well fitted for analysing public health issues. The method appears not to have been employed in geriatric healthcare modelling. System dynamics capture important feedback effects and allows for holistic and comprehensive understanding of complex systems, such as a public care institution. Despite of this System analysts have played only a minor role in health policy strategy and planning.
- ✓ Granted the virtues of System dynamics and the misconceptions of population dynamics that appear to be at play in the city of Bergen. A System dynamics model and analysis may prove offer valuable insights.

5. Conceptual Model

The purpose of this modelling project is to project plausible scenarios for the geriatric healthcare services in the city of Bergen during the next few decades. A model encompassing the geriatric healthcare service in Bergen needs to capture population dynamics, the nature of geriatric homecare services and the nature of geriatric institution services. The major influence on the demand for both geriatric homecare and geriatric institutional care is the relative affluence of elderly in the population. This logic is simple; more elderly→higher demand for geriatric care services. The following chapter presents conceptual models for the three major subcomponents of The Geriatric Healthcare Projection Model as these components are understood and modelled.

5.1 Population dynamics

The driving engine for the underlying dynamics in The Geriatric Healthcare Projection Model (GHPM) is the population model. As discussed in depth earlier the city of Bergen must expect the elderly population to account for larger and larger proportions of the population through the next decades. This will exert increased pressure on the geriatric healthcare system. The population projections applied by the city of Bergen are not accounting for important dynamics and are not extended sufficiently into the future. Applying the official population projections as external data input in a geriatric healthcare model is therefore likely to skew and limit the results and findings. To better capture these population dynamics, a population model has been applied in The Geriatric Healthcare Projection Model. The model is simplistic, but captures the few but central components of demographics.

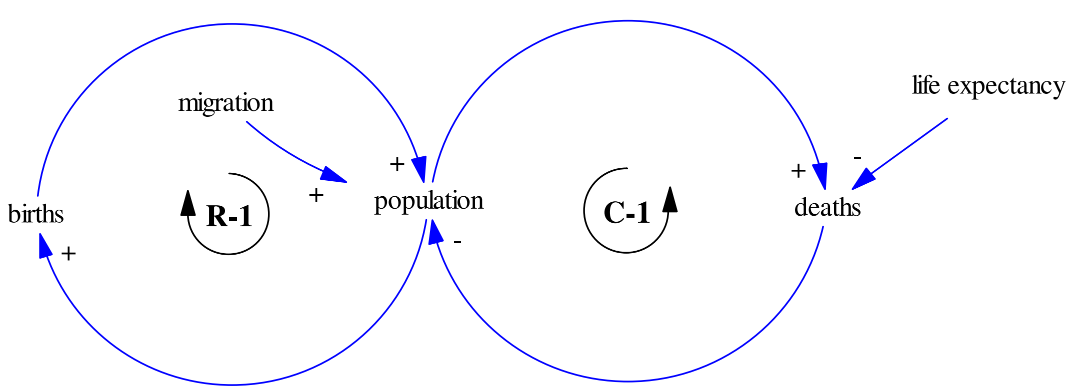

Fig 7: CLD: Conceptual model-Population

The CLD suggest that Population is affected by births, deaths and migration. The size of the population is dictating the amount of annual births. The annual births are dictating the population growth. This loop is reinforcing as both links are positive, henceforth will a large population produce an even larger population. The reinforcing birth loop is kept from indefinite growth by deaths. As the population grows, the number of annual deaths is following the trend. The annual deaths are reducing the population. The death loop is counteracting. The balance or lack of balance between the two loops is determining whether the population is growing, stabilizing or shrinking.

The projection applied by the city of Bergen is also considering housing as a separate variable. This is here captured by the migration parameter. The population model applied in the GHPM is not considering feedback variables affecting the migration. Rather, the migrational patterns are considered an external factor. Migration is positively linked to the population, suggesting that as migration goes up, the population increases and vice versa.

The official population projection is working with constant death rates(Norconsult, 2005). The population model developed for the GHPM is accounting for increased life expectancy through the simulation period. The latter is represented as an external factor in the above CLD. The condition of geriatric healthcare services is obviously affecting life expectancy; however how and to what extent life expectancy is affected by the geriatric healthcare system is a complex matter not encompassed by the GHPM's problem or model boundaries. Life expectancy is therefore modelled as an external element suggesting an increased life expectancy throughout the simulation period.

The official population projections as they are employed by the City of Bergen are applied in The Geriatric Healthcare Projection Model as comparison and validation input. The population model internal to the geriatric healthcare model is however expected to yield slightly higher estimates as increased life expectancy is affecting the simulated population dynamics.

5.2 Public Sector

The Geriatric Healthcare Projection Model is a rather large, complex and comprehensive system dynamics model. The main scope of the model is to assess potential development of the future geriatric health care services in the city of Bergen. The backbone of this care sector dwells in the public realm; the private alternative outlined in the GHPM is a hypothetical scenario developed for policy testing purposes. The public sector in the GHPM is henceforth in many respects the core structural element in the GHPM. It should at this point be noted that the public sector also encompass certain privately owned institutions; these are however administered by the public sector and is subjected to the same policies and priorities as other publicly owned institutions. The private sector as it is here defined is qualitatively different as it is hypothetically conceived as a fully privatized and privately administered care sector competing with the public care sector.

The geriatric health care system is divided in two qualitatively and conceptually different care categories; institutional and homecare services. In the GHPM institutional care capacity is limited by infrastructure whilst homecare services are not restricted by such limitations. In order to provide an institution bed for a client a bed must be available. Homecare will be granted anyone requiring it as well as a temporary service to clients awaiting institutional care. Waiting lists for institutional care will therefore affect the homecare services; when waiting lists accumulate due to institution bed shortage, the pressure on the homecare services increase.

The nurse per client ratios of the respective care services is in the GHPM conceived as an indicator of care quality as well as nurse workload. The following CLDs refer to workload variables; these variables are quantified as the nurse per client ratio. Workload is further assumed to be affecting the care workers willingness to work in the geriatric services as well as their tendency towards temporary sick leaves.

Nurses are recruited based on the number of positions established in the geriatric health care sector. The target number of positions is by the city of Bergen defined as a fraction of nurses per people(Byrådet, 2007). This notion is important as the recruitment goal is defined by the total population rather then by the number of clients; the population component of the GHPM therefore has direct influence not only on clients but also on the staff dynamics in the public sector.

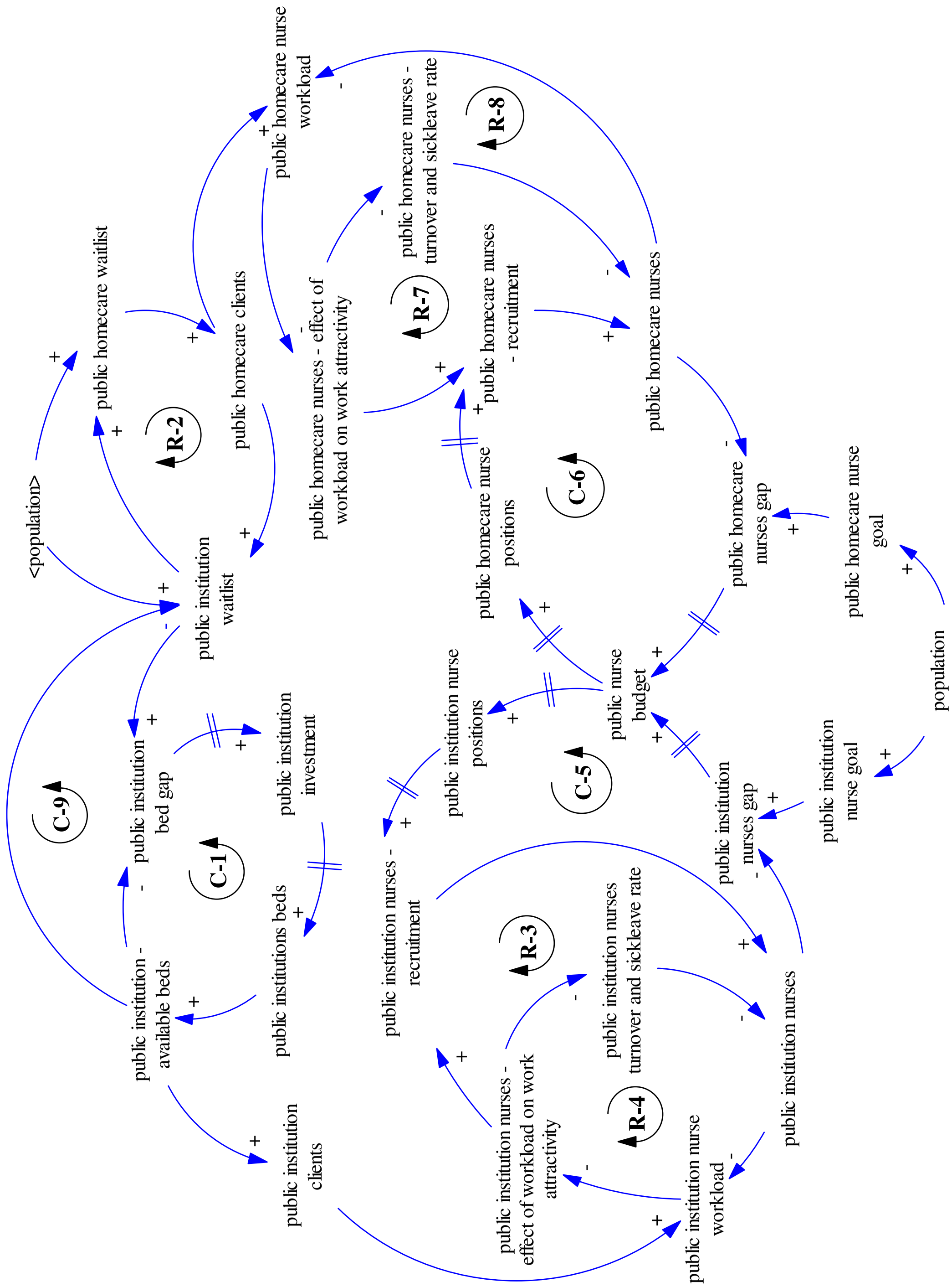

Fig 8: *CLD – Conceptual model - Public Geriatric Care Services*

A number of loops are evident in the conceptual model for the public sector. The underlying population model is providing input in two areas; clients and nurses. The reinforcing loop R-2 is capturing the client recruitment. Based on a constant fraction of the various age groups in the population model, people are becoming clients. Before receiving care they are entering a waiting list. As people are developing a need for homecare services, the homecare waitlist increase, this leads to growth in the number of homecare clients. As people are receiving homecare they may develop a further need for institutional care; increase in the homecare clients is therefore suggesting an increase of the public institution waiting list. People awaiting institutional care are receiving temporary homecare; growth in the wait lists therefore dictates a growth in the homecare wait list; R-2 is henceforth a reinforcing loop. The GHPM does not operate with different recruitment rates for institutional need amongst the population receiving homecare and the general population; it should however be stated that there are probably a higher fraction of homecare clients developing a need for institutional care then what is evident for the remaining population.

A growth of the institution waiting lists leads to a growing institution bed gap as more people require beds. A growing institution bed gap is generating increased public institution investment; increased investment will in turn increase the number of beds and henceforth also the number of available beds. When the number of available beds is increased the institution gap is reduced as is the institution wait list. These system links constitute the two counteracting feedback loops C-1 and C-9. These two loops are also subject to considerable delays as it takes time for the public policy makers to identify a bed shortage, to adjust budgets, define plans, initiate and complete construction of new beds. The delays are important and near governing parameters of the GHPM as the institutional capacity is linked directly both to institutional and homecare services.

The number of clients in the institutional and homecare services respectively is linking the client segment of the public sector to the nurses segment of the GHPM. As the public institution beds are increased, so is the number of institution clients. The number of institution clients is affecting the institution nurse workload by a positive link; suggesting that increased number of clients leads to an increased workload. The same relationship is manifested in the homecare services where an increased number of clients generate an increased workload on the homecare nurses.

As the public institution nurse workload is increased the effect of the workload on the attractivity working as a institution nurse is also increased. This effect is somewhat abstract; attractivity is conceived as a notion governing recruitment, turnover, and sick leaves. If attractivity goes down recruitment goes down and sick leaves and turnover goes up. Henceforth is an increased effect of workload linked positively to institution nurses recruitment and negatively to institution nurses turnover and sickleave rate. The latter two system components are linked to public institution nurses. As the sickleave and turnover rate goes up the number of institution nurses goes down and as the recruitment goes up the number of institution nurses follows. Two reinforcing feedback loops are manifested by these links. The feedback loops are named R-4 and R-3.

An increase of public institution nurses is reducing the public institution nurses gap. The institution nurse gap is also affected by the public institution nurse goal which in turn is affected by the population development. As the institution nurses gap increase the public nurse budget will be increased. Budgetary concerns are actually not included in the GHPM; it is still included in the conceptual model to emphasise the real world implications of the processes modelled in the GHPM. As the nurse budget is increased the public institution nurse positions are also increased. More positions to be filled calls for increased recruitment which in turn increase the number of public institution nurses by closing the counteracting loop C-5. C-5 is subject to considerable delays as it takes time for the public policy makers to identify and react to changes in the gap between the nurse goals and the actual nurses employed. These delays are significant and affect the behaviour of the GHPM.

The same processes as described for nurse segment of the institutional services are at play in the homecare segment. As the number of public homecare clients increase the public homecare nurse workload is pushed in the same direction. The increased workload has an decreasing effect on the homecare recruitment and an increasing effect on the sick leave and turnover rate. As the recruitment goes down so does the number of public homecare nurses; rising rates of sick leave and turnover is also acting to reduce the number of homecare nurses. When the number of homecare nurses drops the workload is further enhanced; closing the two reinforcing feedback loops R-7 and R-8.

When the number of homecare nurses are reduced the public homecare nurses gap is increased. The homecare nurse gap is influenced by a positive link from the public homecare nurse goal, an element defined as a function of the total population. As the homecare nurse gap increases the public nurse budget is, after considerable delays, increased. Increased budgets suggest an increased number of homecare nurse positions and more positions are generating increased recruitment. The latter two system links are hampered by significant delays embedded in the public policy and implementation processes. When recruitment goes up the number of homecare nurses is increased as the counteracting loop C-6 is closed.

The delays present in the public geriatric care system are likely to cause important dynamic attractors in the care system; delays may lead to oscillation and backlogs. The behaviour of the system is by and large governed by the balance of power between reinforcing and counteracting feedback loops. The reinforcing feedback loops may act to better or worsen the situation in the geriatric health care system; the counteracting loops will act to cancel out the reinforcing effects. Successful public policy depends on the policy makers' ability to drive the reinforcing loops in the desired direction, maybe by allowing counteracting loops to dampen undesirable development and to stimulate reinforcing loops in the desired direction.

5.3 Private sector

As discussed earlier the private geriatric care sector model structure in the GHPM encompass a hypothetical scenario; the private sector is added to the GHPM in order to test the various effects the introduction of a fully privatized geriatric care alternative could have on the overall geriatric health care services. The privately owned care institutions already in place in the city of Bergen are administered by the city and is therefore considered as public enterprises in the GHPM

In principle the conceptual outline of the private sector is very similar to the public care sector. There are however a few but important differences.

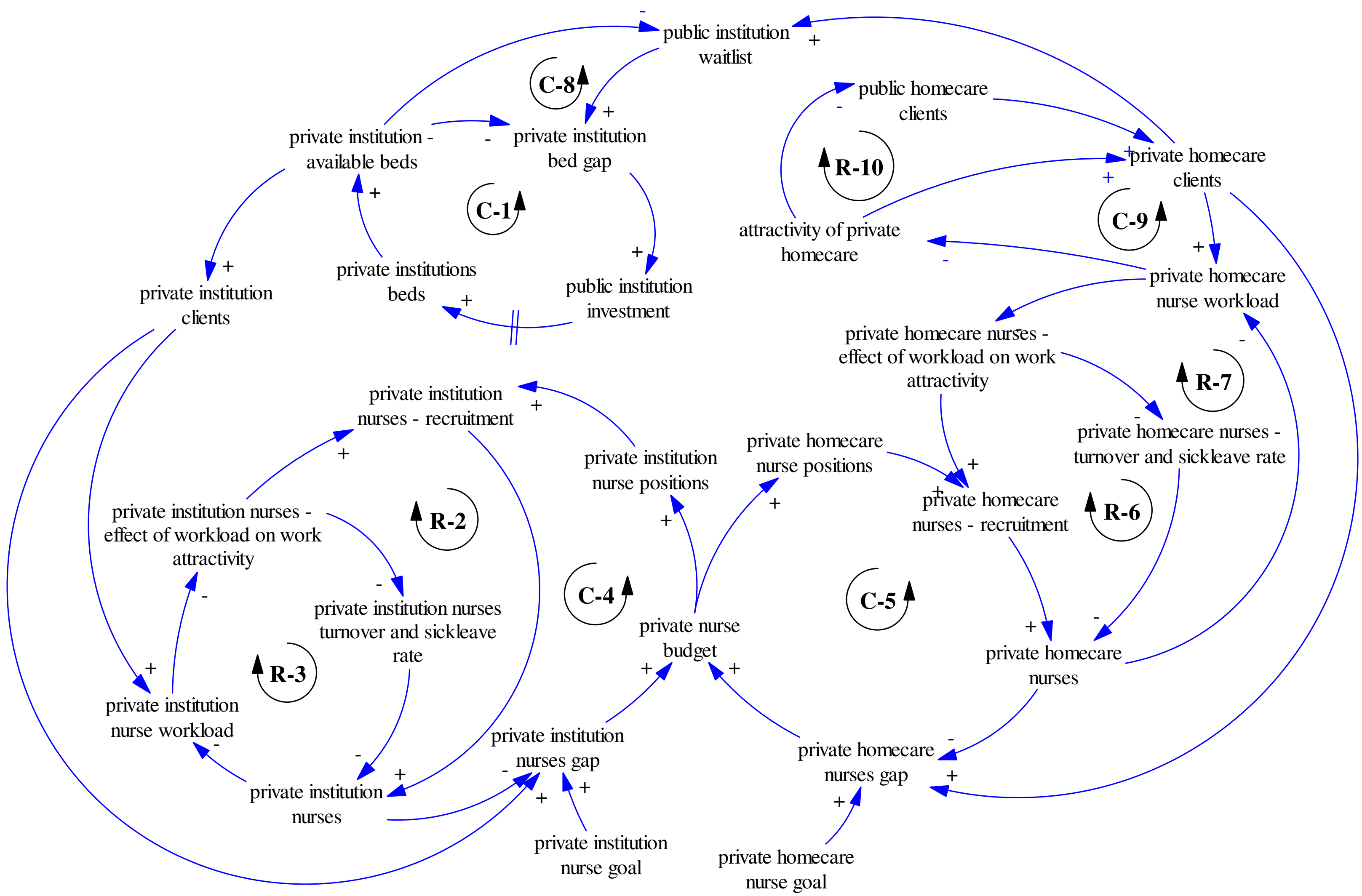

Fig 9: CLD – Conceptual Model – Private sector

The private sector draws institution clients from the public institution wait list and homecare clients from the pool of public homecare clients. People entering the private sector are henceforth conceived as already having needs for geriatric care services. The staff goals in the private sector are defined as constant and pre-defined nurse per client ratios; the private sector is assumed to move quickly to adjust the staff levels to the predefined staff goals and only insignificant delays are expected in this. The same is partially true for institution investment; although it takes time for the private sector to construct and facilitate new institution beds the private sector are not suffering the same delays in the decision making process as is experienced in the public sector.

The reinforcing feedback loops R-3, R-2, R-6, and R-7 along with the counteracting feedback loops C-1, C-8, C-5 and C-4 are identical to feedback loops in the public sector and therefore need no further explanation. They are however different with respect to delays; delays are in the GHPM of much less magnitude in the private sector then they are in the public sector.

As mentioned the nurse recruitment dynamics are somewhat differently defined in the private sector. Nurses are recruited based on a set constant nurse per client ratios. The private homecare nurses gap and private institution nurses gap is therefore defined by this defined nurse goal, by the number of actual nurses and by the number of actual clients. Adjustments of staff are adjusted to approach the nurse goals.

Some attention must be devoted to the client recruitment dynamics. Private institution clients are recruited or drawn from the public institution wait list; depending on the public wait list beds will be facilitated and eventually this will reduce the public wait lists. Reducing the public wait lists will also reduce the number of public homecare clients; these dynamics are captured in the public sector conceptual model and not visible in the above CLD covering the private sector conceptual model. The reader should however keep this underlying relationship in mind when examining the private sector conceptual model.

Private Homecare clients are recruited from the public homecare clients; the GHPM conceives the people choosing private homecare as people who are already public homecare clients and who believe to be better served in the private sector. A nuance must here be highlighted; clients choose the private sector based on the achievements of the private sector, not on the relative difference between the two sector or the shortcomings of the public sector. As the number of private homecare clients increase so does the private homecare nurse workload. Workload is in the GHPM defined by the client per nurse ratio; this ratio goes along way as an indicator of the quality of care. And increasing workload thus suggests a dropping client per nurse ratio. An increased workload thereby suggests a reduced attractivity of private homecare and reduced attractivity reduce the number private homecare clients and increase the number of public homecare clients rendering the closure of the reinforcing loop R-10 and the counteracting loop C-9. the GHPM is not accounting for people leaving the private sector; the model assumes that people who enter the private sector will remain in the private sector unless they are private homecare clients who develop a need for institutional care; in this case they would enter the public institution wait list from where they could obtain either a private or a public institution bed.

5.6 Composite conceptual model

The above sections outline the conceptual models for the three major subcomponents of The Geriatric Healthcare Projection Model. The Causal loop Diagram does not properly accommodate for explaining the relationship between the three subcomponents as they are not linked together my closed feedback loops. One may well argue that in reality the three subcomponents are indeed linked by a number of feedback loops, *e.g.:*

The development of life expectancy is likely to be a feedback function of the quality and availability of geriatric health care services.

However; feedback functions of this nature are extremely complex and a quantification or assessment of the relationships and magnitude of effects of these feedback loops goes far beyond the scope of The Geriatric Healthcare Projection Model as it is here presented. The model can be developed further to encompass also these subcomponent links;

the model is open-ended in that respect. Nevertheless, in order to challenge the hypothesis presented in this thesis, some practical simplifications have necessarily been made.

It is still useful to present a simple diagram of how the three subcomponents on the model are interconnected. The following diagram should not be confused for a CLD, rather addressing polarity of connections and behaviour of feedback loops, the simplified diagram visualize how the subcomponents are connected and the directions of flows between the different subcomponents. Fig: 12 will provide a convenient tool for interpreting the Stock and Flow diagrams of the Geriatric Healthcare Projection Model.

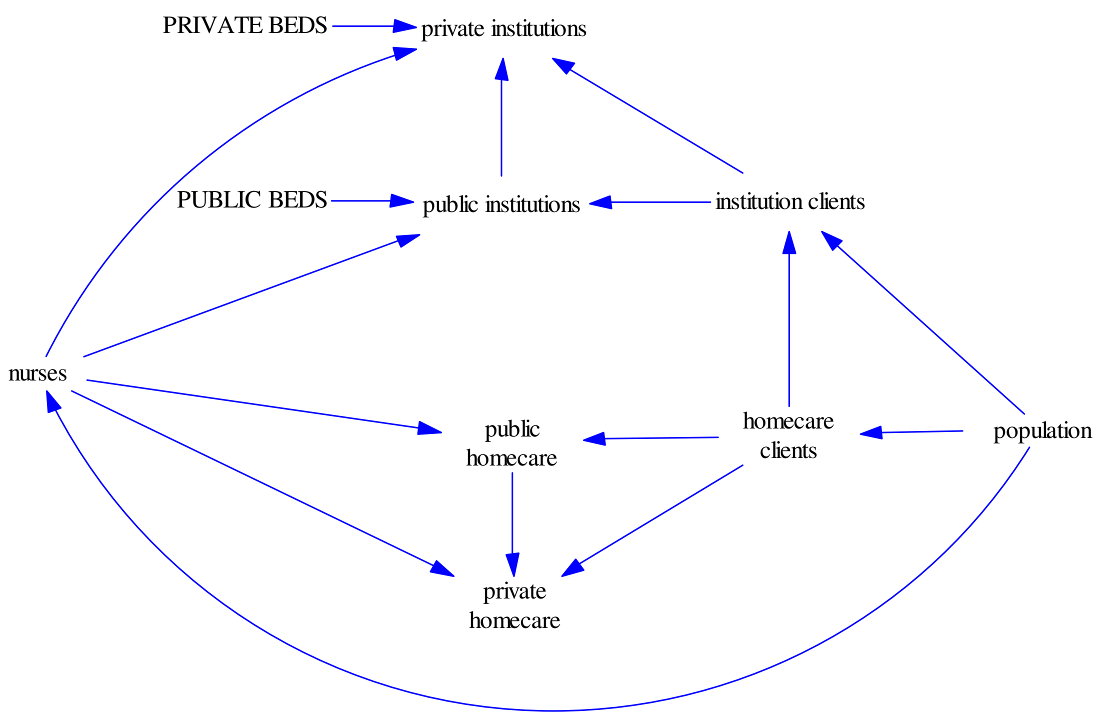

Fig 10: Schematic view of GHPM subcomponent structure.

The above diagram indicates the development of the age composition and size of the population provides input to a pool of nurses, homecare clients and institution clients. Homecare clients can become institution clients if their psychosocial or physical impairments develop(Byrådet, 2004). Nurses can work in private or public sector, either as institution nurses or as homecare nurses. Homecare clients can choose either public or private alternatives depending on the quality of care provided. Institution clients will initially be granted a public alternative, but if there are no available beds the clients on the waiting lists will chose a private alternative. The number of public and private institution beds is treated as policy-input variables and determines the total institution capacity.

6. Universal Assumptions – The Model Framework

The following chapter will present the Geriatric Healthcare Projection Model. The chapter addresses the Stock and Flow structure of the model, the arrays and ranges applied in the model and the most important parameters and assumptions implemented in the model's structure. It must be emphasized that the chapter does not provide a complete model description as this would be superfluous and only complicate and impair the understanding of the model's structural composition. The complete list of equations is enclosed as an appendix and may be consulted for detailed information on non-central parameters and equations.

6.1 Modelling software

The Geriatric Health Care Projection Model is developed and applied in Powersim Studio 7. The software was chosen based on an evaluation of different System Dynamics simulation software packages. The criteria for choosing Powersim included:

1. **Powerful and efficient array functionality**: From the very start of the process of developing The Geriatric Healthcare Projection Model it became clear that the model's applicability and validity would depend on the models dimensional accuracy. Powersim offers practical and an easy to use array functionality enabling the user to introduce and keep track of several dimensions of the model's variables.
2. **Data interoperability and exchange:** As the Geriatric Healthcare Projection Model was likely to require external data input it was important to choose a software package that with ease would allow for application of external data formats. Particularly was this important for applying multi-dimensional time series population data. It was also considered to be important to be enable data output of simulation results to other data formats commonly used outside the system dynamics community. Powersim affords these qualities.

3. **Functions library:** Powersim has well developed library of built-in functions. This simplifies the modelling process as one does not have to develop and program all expressions from scratch. This makes Powersim a efficient software package for developing large models.
4. **User Interface:** The Powersim Studio 7 user-interface is easy to use and allows for a tidy modelling process. The user-interface provides quick access to all levels of the model. The user-interface is also intuitive and the user is allowed to focus on the modelling rather then the software.
5. **Experience:** The author and the thesis supervisor already had experience using Powersim. Furthermore; Powersim is developed in Bergen and the company has been most helpful in providing assistance on software related challenges during the modelling process.
6. **Powerful simulation:** As The Geriatric Healthcare Projection Model was dependant on simulating over a rather extensive real-time period employing as rather short integration time-step, the software chosen needed to provide a powerful simulation algorithm. Powersim has this quality.
7. **Graph tools:** The geriatric Healthcare Projection Model was expected to require a number of various graph outputs. Powersim is fitted with a number of graph output alternatives and the functionality is easy and intuitive to use.

Altogether Powersim Studio 7 met all important requirements and was chosen therefore chosen as the primary software tool for the model development, implementation and testing. Beyond Powersim, Microsoft Excel has been applied as a useful supplementary tool. In principle Excel has only been used for sorting datasets and deriving variables from other datasets. Excel has also been applied to produce certain graphs and tables.

6.2 Units

The Geriatric Healthcare Projection Model is not encompassing a vast plethora of variable units as often is the case in many System Dynamics models. Rather, the GHPM employs one sole material unit; people. The unit “People” is applied throughout the model although some variables easily could be argued to better be represented by units such as

"Nurses" or "Institution Beds". Although the latter may be true, that unit approach could also lead to confusion. It is a major point to the author and a prerequisite for this model that the question at hand here is real breathing people who may or may not be accommodated by acceptable levels of care. By giving the care clients a unit of "Clients" rather then "People" some of the human focus of the model may be lost in semantics. It is the wish of the author that this model produces insights to the future care situation on a personal level, although the model assumes a quantitative approach; it is the intent to remind the reader that a client or a nurse are people and therefore should not be considered as a widget or other impersonal unit. Secondly there is a strong argument for applying "People" as the only unit of measure in terms of modelling efficiency. Should a number of other units be introduced, the complexity of the stock and flow structure would increase further as a number of unit-converter operations would have to be added. This appears superfluous as *e.g.:* a nurse is also a person, or a institution bed has no meaning beyond accommodating for a person. Where additional information about a unit is required the GHPM solves this through the array function. By applying "People" as a only unit of measure the model is avoiding complexity and is reminding the user about what is at stake behind the user interface and output graphs.

The GHPM treats people at an aggregated level. The unit people is therefore allowed to be defined by decimal numbers although people can clearly only be counted in whole numbers. In a theoretic perspective it is meaningful considerer people by decimals during calculation and estimation processes. Rounding of numbers can be carried out for final analysis and conclusions. Should the model continuously round values of people, much information would be lost during the simulation and the results would be skewed. Variables defined by probabilities would certainly be affected by forced rounding. All variables preceding the probability calculations would henceforth be subject to propagating error.

The temporal unit applied in the model is "years". Although the actual timestep applied is much smaller, a smaller time unit would only cause confusion. After all the GHPM is simulating over a period of about 50 years and the scope of the model is to learn about long term trends and tendencies. To operate with a higher resolution time units would not only be perplexing it would be presumptuous; as the model simulates far into the future it should not assume a high resolution temporal accuracy.

6.3 Arrays

As mentioned the GHPM applies a number of arrays. Arrays are in the modelling language a term applied for ranges or dimensions of various units of measure in the system. The GHPM employs two primary arrays; *Age* and *Bydeler*[8] . Both of these arrays annotates properties or qualities of the unit "people".

Age is a numerical subrange. It spans between 0 and 100 years. *Age* is a property assigned to all the "people" in the simulation. As the name of the array suggests-*Age* identifies a person's age. The model is initialized with a given number of people assigned in each age cohort. As the simulation proceeds, all the "people" in the various stocks get one year older as a year passes. That is; at the beginning of each simulated year, each age cohort is shifted up one cohort.

The *Age* array is obviously of central importance for the GHPM. Without the *Age* array the population simulation subcomponent of the model would not be very realistic. By introducing the *Age* array the model is able to keep track of the age distribution throughout the population. As the age composition of the population and the pending demographic transition is the driving engine behind the looming elderly boom(Arne Andersen, 2005) it is obvious that any population model applied towards questions concerning geriatric health care needs to differentiate between old and young people. The latter as probabilities for requiring geriatric healthcare services depend on age. Furthermore; keeping track of age is important also for the younger cohorts; nurses retire at some point in their life and as this is a major limiting variable for the stock of nurses this must be accounted for in a model simulating the geriatric health care services.

Bydeler is a Norwegian word meaning constituency, township borough or community. As the model was developed the Norwegian term *Bydeler* was applied due to data

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[8] Eng: Constituencies or "City regions" or Communities.

interoperability issues. It would be possible to translate the term, but that would infer interfering with contents of external datasets used for initialisation, calibration and reference. To avoid any problems regarding the authencity of external data, the model was developed applying the Norwegian word *Bydeler.* There are eight *Bydeler* or boroughs in the city of Bergen. The boroughs can loosely be classified as urban, suburban or rural. The boroughs are:

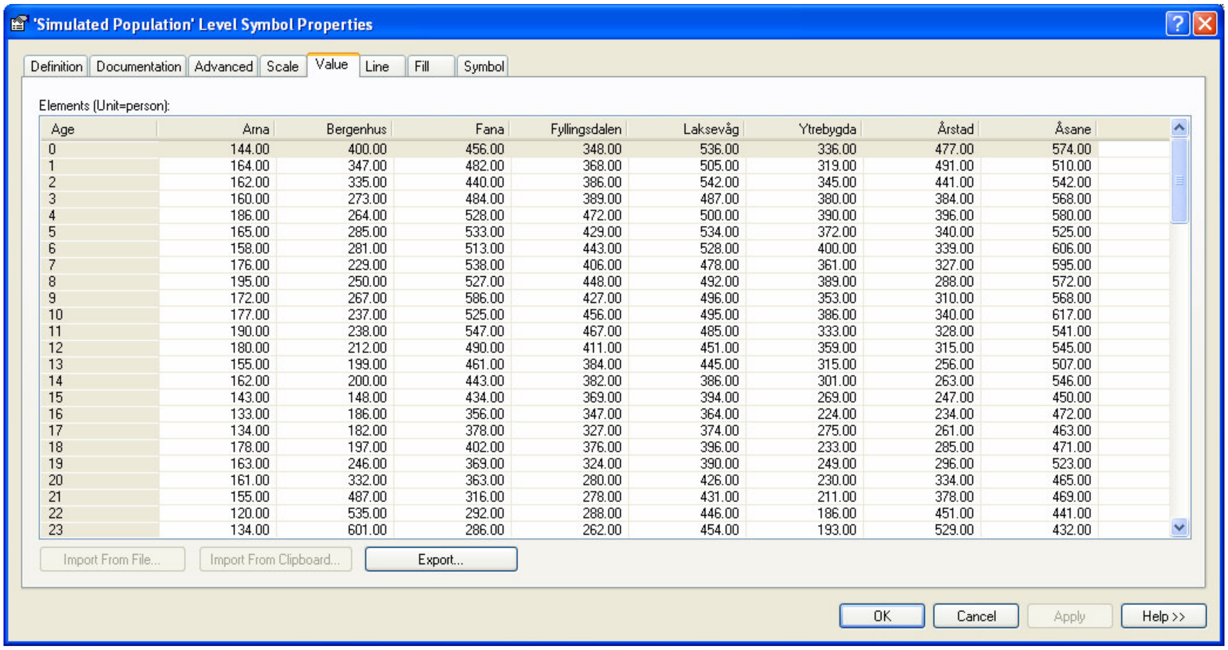
1) Bergenhus (urban)
2) Årstad (urban)
3) Åsane (suburban and rural)
4) Fana(suburban and rural)
5) Laksevåg (suburban)
6) Yttrebygda (rural)
7) Arna (rural)
8) Fyllingsdalen (suburban)

This dimension is important in the GHPM for many reasons. Population dynamics are very different in the various boroughs of Bergen; whilst some boroughs are rural some are urban. Depending on a number of reasons people at different ages gravitate towards different types of environment; whilst many students tend to seek to the city core, young families tend to seek towards more quiet and safe environments. Furthermore, some boroughs (due to their environment and local business) attract people of different professions and socioeconomic backgrounds(Chan, 2001). These are variables that may be reflected both in birth, death and migration rates. Keeping track of where people live is important for these reasons; geography matters in demographics(Paul L. Knox, 2001) and demography lies in the very core of the problem at hand.

The arrays *Age* and *Bydeler* are defining the dimensions of most stocks and flows in the GHPM as the primary unit of measure throughout the model is "People". This infers that each simulated or hypothetic person in the model is defined by his or her age and approximate address. The array definition is carried for the majority of various stocks in the model. Thus will all simulated nurses, clients and institution beds be allocated to a given age and borough. Although age and residence are obvious properties of nurses and clients, this may not be intuitively comprehendible with respect to institution beds.

Institution beds are, as discussed above, assigned “people” as the unit of measure. This is done partly to preserve consciousness about a bed’s significance and partly for technical modelling reasons. By assigning beds the unit “people” beds can be defined by the same dimensionality as clients. As a client is defined by age and borough, beds must be defined in accordance, in order to keep track of the amount and properties of people occupying the institution beds. This notion may only be problematic if the *age* and *bydeler* definitions for available institution beds restrict the allocation of these beds to clients awaiting a bed. *E.g.*: If an available bed is defined as 87 years (*age*) in Arna (*bydeler*) and a person defined as 85 years (*age*) in Bergenhus (*Bydeler*) was awaiting a bed opening, the awaiting person would not be able to occupy the available bed due to an array mismatch. This is not the case in the GHPM; Available beds are treated on an aggregated level; available beds are not subject to array definitions. Rather, the probability for getting a bed is assigned to each person waiting for a bed based on the total number of available beds, and the total number of people waiting in line. When people move from a waiting line to a bed, the bed they are in predefined by the array definition of the person laying in it. Hence, the array definition for beds is not restricting the inflow to available beds as array definitions for beds are defined by the people occupying them and not by the bed itself. This allows for modelling the aging of institution clients and that is important for the validity of the model as aging governs a plethora of other in and outflows to the respective stocks.

Fig. 12 is a screen dump from a Powersim variable definition window. The figure shows the dimensionality of “people”; defined by *age* and *bydeler. Age* is displayed vertically and *bydeler* is organized horizontally.



'Simulated Population' Level Symbol Properties

Definition | Documentation | Advanced | Scale | Value | Line | Fill | Symbol

Elements (Unit=person):

Age	Arna	Bergenhus	Fana	Fyllingsdalen	Laksevåg	Ytrebygda	Årstad	Åsane
0	144.00	400.00	456.00	348.00	536.00	336.00	477.00	574.00
1	164.00	347.00	482.00	368.00	505.00	319.00	491.00	510.00
2	162.00	335.00	440.00	386.00	542.00	345.00	441.00	542.00
3	160.00	273.00	484.00	389.00	487.00	380.00	384.00	568.00
4	186.00	264.00	528.00	472.00	500.00	390.00	396.00	580.00
5	165.00	285.00	533.00	429.00	534.00	372.00	340.00	525.00
6	158.00	281.00	513.00	443.00	528.00	400.00	339.00	606.00
7	176.00	229.00	538.00	406.00	478.00	361.00	327.00	595.00
8	195.00	250.00	527.00	448.00	492.00	389.00	288.00	572.00
9	172.00	267.00	586.00	427.00	496.00	353.00	310.00	568.00
10	177.00	237.00	525.00	456.00	495.00	386.00	340.00	617.00
11	190.00	238.00	547.00	467.00	485.00	333.00	328.00	541.00
12	180.00	212.00	490.00	411.00	451.00	359.00	315.00	545.00
13	155.00	199.00	461.00	384.00	445.00	315.00	256.00	507.00
14	162.00	200.00	443.00	382.00	386.00	301.00	263.00	546.00
15	143.00	148.00	434.00	369.00	394.00	269.00	247.00	450.00
16	133.00	186.00	356.00	347.00	364.00	224.00	234.00	472.00
17	134.00	182.00	378.00	327.00	374.00	275.00	261.00	463.00
18	178.00	197.00	402.00	376.00	396.00	233.00	285.00	471.00
19	163.00	246.00	369.00	324.00	390.00	249.00	296.00	523.00
20	161.00	332.00	363.00	280.00	426.00	230.00	334.00	465.00
21	155.00	487.00	316.00	278.00	431.00	211.00	378.00	469.00
22	120.00	535.00	292.00	288.00	446.00	186.00	451.00	441.00
23	134.00	601.00	286.00	262.00	454.00	193.00	529.00	432.00

Import From File... | Import From Clipboard... | Export...

OK | Cancel | Apply | Help >>

Fig 11: Array definition for "people"

Although institution beds are defined by the unit "people" the Geriatric Healthcare Projection Model apply an array definition to capture different categories of institution beds. A geriatric institution is an aggregated term: there are qualitatively different classes of institution beds provided for the elderly. Their common denominator is that they are in fact institution beds, the difference between them is how they are administered and to whom they are catered. The different bed dimensions are:

1. Care beds
2. Geriatric Beds
3. Private Centre Beds
4. Public Centre Beds

Care beds are beds allocated to people with physical or psychosocial impairments that require a high level of professional medical care. *Geriatric Beds* are beds intended for people with physical or psychosocial impairments due to high age, requiring a lesser level of medical care then the *Care Beds* clients. *Private Centre Beds* and *Public Centre Beds* are beds operated as a collective of apartments or housing units with 24 hour attendance and assistance by medical personnel. The centre beds are primarily intended for people with impairments who require more assistance then the homecare services can provide but less assistance then what is required by clients in *Geriatric Beds* or *Care Beds.* It is important not to confuse

Private Centre Beds with private care services as these are conceived and modelled in the GHPM. *Private Centre Beds* are in this respect privately owned and operated institution beds, however the *Private Centre Beds* are subcontracted, subsidised and administered by the city authorities. *Private Centre Beds* are therefore considered as part to the public institutional services. The following figure is a screen dump from Powersim exhibiting the dimensionality of institution beds.

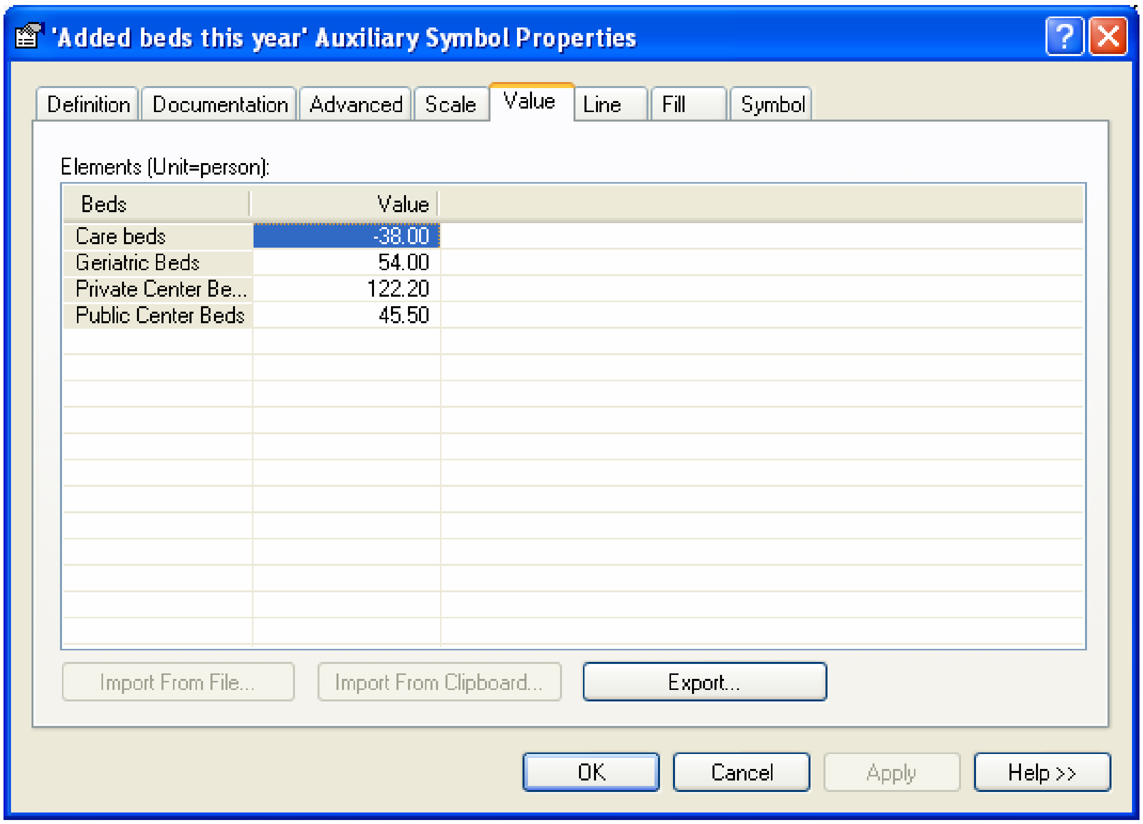


Fig 12: Arrays used to define institution bed categories.

The different categories of institution beds have been applied in the GHPM as data was available on current distribution of beds of the various types. Alas, the differences between the nurse-capacity required by the different categories of beds are not incorporated in the model; no useful information was available to model this matter. By introducing the concept to the model, the model is nevertheless open-ended towards expanding or further development of these parameters. The GHPM is treating all care beds equally and is working with institution beds on an aggregated level. Should it in retrospect be of interest to expand the model to capture dynamics arising from the distribution between the different categories of institution beds; the model can easily be modified to accommodate such dynamics. Before that can be done a number of parameters regarding nurse capacity and efficiency have to be researched and clarified.

6.4 Spatial Autocorrelation, Spatial Aggregation and Ecological Fallacy.

The latter section touches on important issues regarding spatial-autocorrelation, spatial aggregation and ecological fallacies that must be addressed in particular. These concepts are central as they directly affect the rationale behind the modelling strategy applied as well as the concepts affect the validity of important parameterisation assumptions and analysis options employed in the GHPM.

Spatial autocorrelation is a concept suggesting that: *"The presence, absence or characteristics of some spatial objects may sometimes have significant impacts on the presence, absence or characteristics of the neighbouring objects. The relationship between objects and their neighbouring objects is called spatial autocorrelation"*(Albert Yeung, 2002) . Spatial autocorrelation can further be classified as:

1. Positive autocorrelation: When spatial objects with a particular property group vary together(Albert Yeung, 2002).
2. Random autocorrelation: When spatial objects with a particular property show no patterns of clustering(Albert Yeung, 2002).
3. Negative autocorrelation: When spatial objects with a particular property are distributed evenly over a large geographic space(Albert Yeung, 2002).

Spatial autocorrelation is in other words a measure of the degree to which phenomena or objects that are close are more similar then phenomena or objects that are distant. This is relevant as people can be considered to be *spatial objects* and their age distribution can be considered a *particular property*. Historic population data of Bergen shows that there are significant differences in age distribution between the city's eight different boroughs(Norconsult, 2005). This infers that there is a positive spatial autocorrelation of age distribution within each borough. Furthermore; Goodchild suggests that *"Spatial autocorrelation can shed light on the spatial structure of uncertainty or the spatial patterns of error"*(Goodchild, 1995). As the different boroughs exhibit positive spatial autocorrelation this should be accounted for in the model as age distribution is a key influence on the pressure on the geriatric health care services; spatial autocorrelation is a source of uncertainty and error if it is ignored.

The problem of spatial autocorrelation and uncertainty and error is closely linked to the notion of spatial aggregation. Spatial aggregation is a term coined to describe the process of aggregating or reclassifying spatial entities, objects or phenomena(DeMers, 2000). In the process of aggregation spatial variance is inevitably lost as the data resolution is decreased. The loss of resolution may introduce great deal of uncertainty or error to the dataset; if the aggregation process generates an unrepresentative mean value for the original spatial entities, derived analysis may be rendered meaningless. The latter would be the case if spatial autocorrelation suggest different life expectancy in the different boroughs and an aggregated life expectancy was derived from this data. When applying this aggregated life expectancy to all boroughs in the simulation model, the demographic development in the various boroughs would be skewed by the aggregated life expectancy. These problems arise as a consequence of ecological fallacy and will be discussed in the following paragraph. When aggregating spatial data it is therefore important to assume an aggregation strategy that captures a meaningful level of spatial resolution and accuracy. When investigating a dynamic demographic processes in Bergen this notion must be kept in mind in order to produce a model and analysis tool that provides a basis for meaningful policy testing.

Ecological fallacy is important when there is a positive spatial autocorrelation is evident and spatial aggregation is being considered or applied. Ecological fallacy occurs when conclusions drawn from spatially aggregated data is transferred to smaller areas or to the individual level. A transfer of this nature is invalid(Monroe, 2000). The example stated above concerning life expectancy constitutes an ecological fallacy. That something is true on an aggregated level does not mean that it is also true on a local or disaggregated level. Further conclusions drawn from invalid assumptions are dogmatically questionable and should be avoided.

The GHPM is developed to preserve validity by considering spatial autocorrelation, spatial aggregation and ecological fallacy during the structural and parameter development process. This is also the reason for employing the population arrays in the model; by treating different boroughs differently a number of validity issues are omitted. As birth, death and migrational patterns vary between rural, suburban and urban communities the variance is not lost in aggregation as the various communities are treated differently by the application of arrays.

6.5 Timestep

The simulation runs applied in the validation and policy testing chapters are run with a timestep of 0.1 year. This timestep is slightly shorter then 50 percent of the shortest adjustment time. If the timestep is increased beyond this level the risk of integration error will increase. Reducing the timestep below this figure is significantly reducing the simulation efficiency of the GHPM.

7. Stocks, Flows and Parameters

The following chapter is devoted to presenting the stocks, flows and important governing parameters of the Geriatric Healthcare Projection Model. As the GHPM is a rather large model with a great many variables only the central elements of the model structure and parameters will be presented. Variables of less importance to the model's basic behaviour and structure are available for review as an appendix. The model applies a number of array variables as parameters. As these variables are both complex and space consuming they are made available in their complete form in the appendix and are only partly exemplified in this chapter.

The GHPM is a comprehensive model requiring a number of quantitative parameter inputs. Many of these are simply not available and have to be deduced from national level statistics and to some extent also from common sense. Furthermore; the reports released by the city of Bergen are as mentioned somewhat political in their form and language. This leads to situations where model parameters must be calculated or derived from statistics and documentation of different origins. This obviously introduces a level of uncertainty to the parameterisation process. However, the purpose of the GHPM is not to provide exhaustive and high accuracy predictions but rather to reveal important dynamic behavioural patterns and trends arising from the system structure. If the model proves to be robust, the actual parameters will primarily be affecting the quantitative results of the model and not the basic behaviour. Sensitivity analysis will on its hand reveal the models sensitivity to important parameters and will therefore also suggest a level of certainty applicable to the parameters applied. This note will be revisited in the following chapter on addressing validation of the GHPM.

The Geriatric Healthcare Projection Model is as mentioned a rather extensive model developed in Powersim Studio 7. Powersim allows the user to organize the model structure in different sheets or views. This feature is applied in the GHPM and affords the user to evaluate and work with the model in an organized and accessible way. The different views applied in the GHPM constitute logic entities or subcomponents of the model. The chapter will from address the various model components as they are organized in the different views in the Powersim model.   These views or components are:

1. Population-Data
2. Population-Simulation
3. Nurse-Pool
4. Care Beds
5. Care Clients
6. Care Nurses
7. Private Sector
8. Care Capacity

7.1 Population – Data

Population-data is a model component wherein the population projection developed by Norconsult on behalf of the city of Bergen is introduced to the GHPM. This data is available in excel format from the city of Bergen's website. To implement excel data in a Powersim model is a very simple procedure as Powersim is highly integrated with the excel format. Data can simply be dragged and dropped into the Powersim model. It is however important that the catalogue structure inwich the excel data and the Powersim model is introduced is not changed when copying or transferring the model. Should the data path that is established between integrated .xls files and a .sip files be changed the data link will be broken and the model will hence be corrupted.

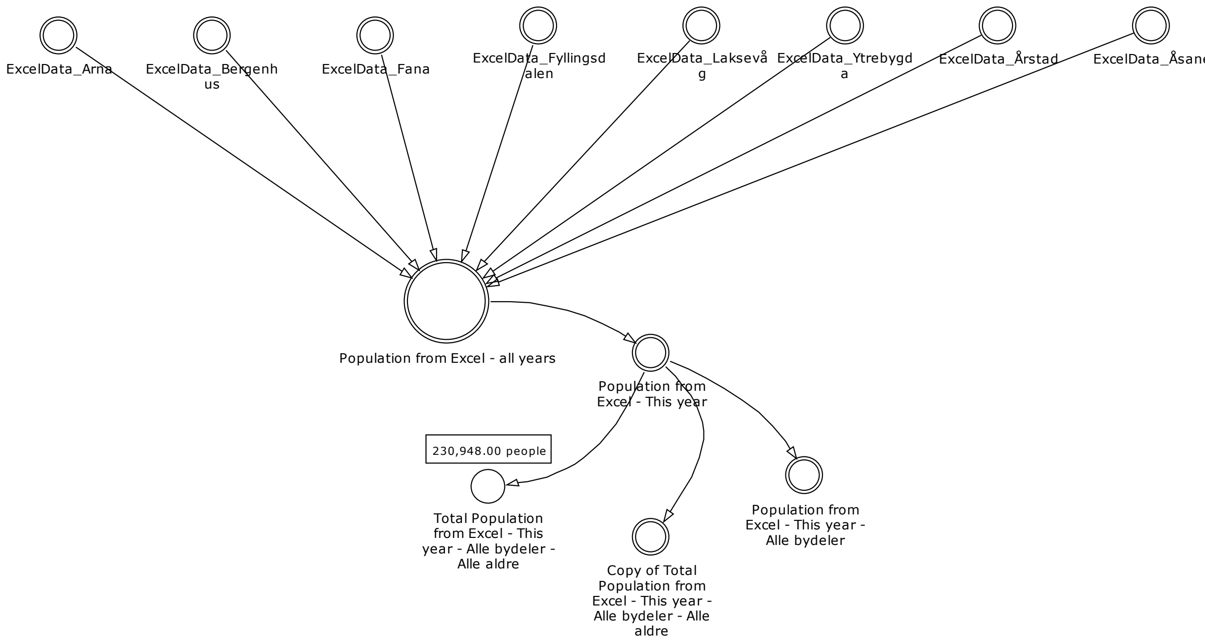


Fig 13: S&F: Population-Data

Population data for each *Bydel* is integrated in the Powersim model separately and then accumulated into a variable containing data for all boroughs and all ages. A number of array functions are applied to organize the data in a way that is applicable for the GHPM. Norconsult produced as discussed in the literature review three projection alternatives. The alternative recommended by Norconsult, the mid-range alternative, is applied in the GHPM.

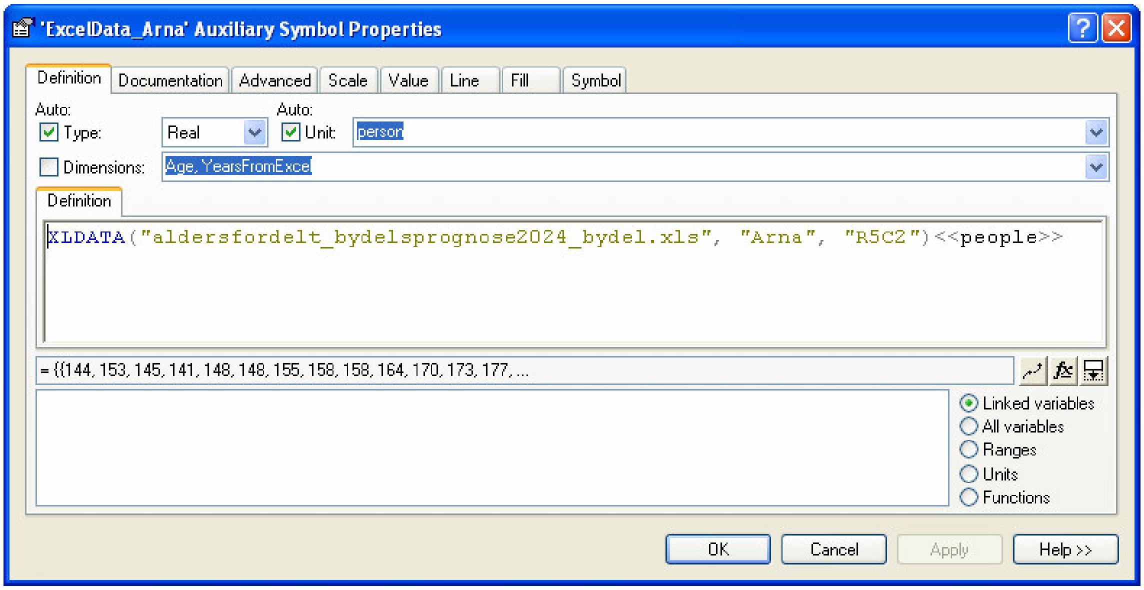


Fig 14: Equation: Using external .xls data

The above figure demonstrates how external excel data is introduced to the model. The function XLDATA is applied. This function requires input on the name of the .xls file, the sheet name for the data to be applied, and the cell range to be incorporated. The Powersim variable is given the unit People and the dimensions *Age* and *Bydeler.* The same function is applied to all boroughs and summarized in the Auxiliary "Population from Excel-All years" by the equation: $\{Borough_1, \ldots, Borough_n\}$. This equation simply summarizes the various boroughs into one auxiliary variable but does not organize the arrays in a way that is further applicable to the model:

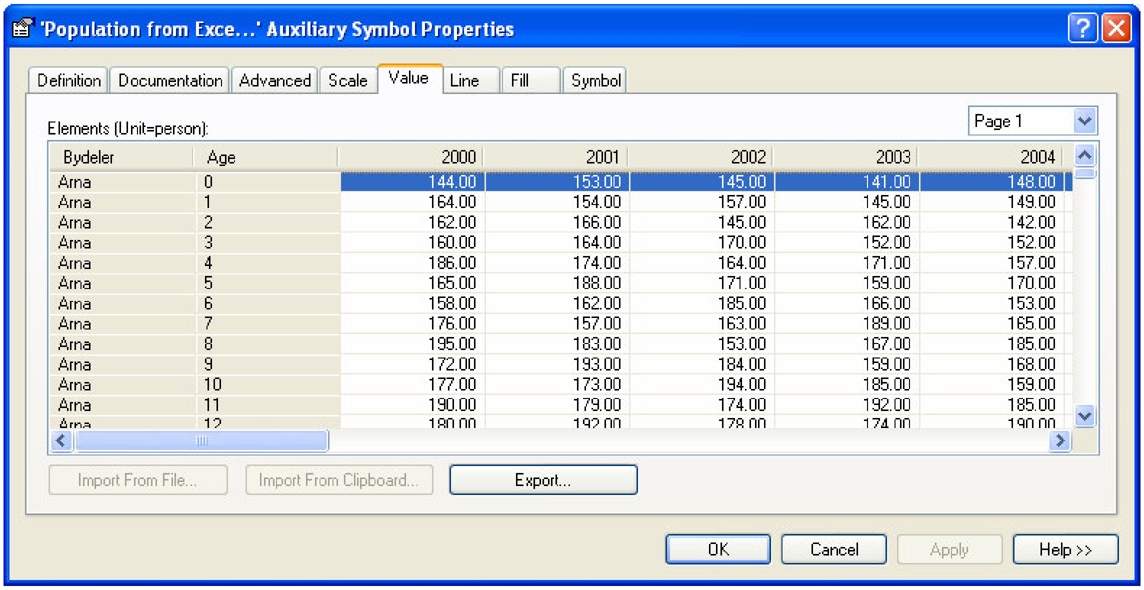


Fig 15: Auxiliary values in "Population from Excel-All years"

As the figure above shows, the arrays *age* and *Bydeler* are here organized parallel along the horizontal axis along with the all of the prediction years available in the data. The GHPM requires a different data structure and is only reading one year at the time. The data is therefore reorganized in the auxiliary "Population from excel-This year".

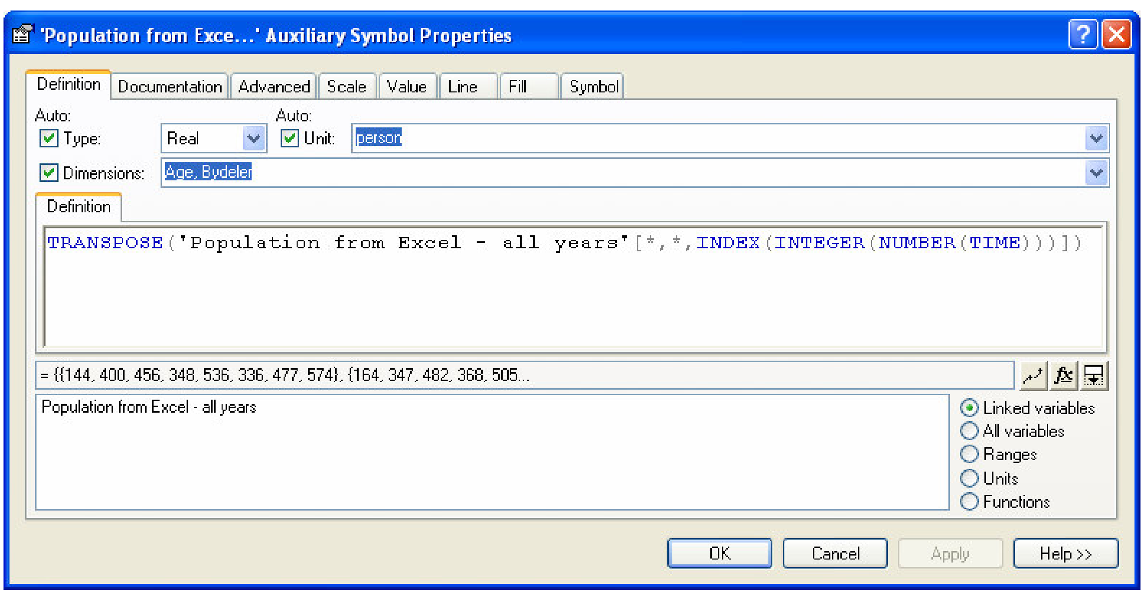


Fig 16: Auxiliary functions in "Population from Excel-This year"

The function TRANSPOSE is applied here; this function reassigns values from a horizontal direction to a vertical direction. Whilst the expression [*, *, INDEX (INTEGER (NUMBER (TIME)))] removes time as a dimension and rather treats time by the current simulation time in the model. The resulting values of this expression are applicable to the GHPM:

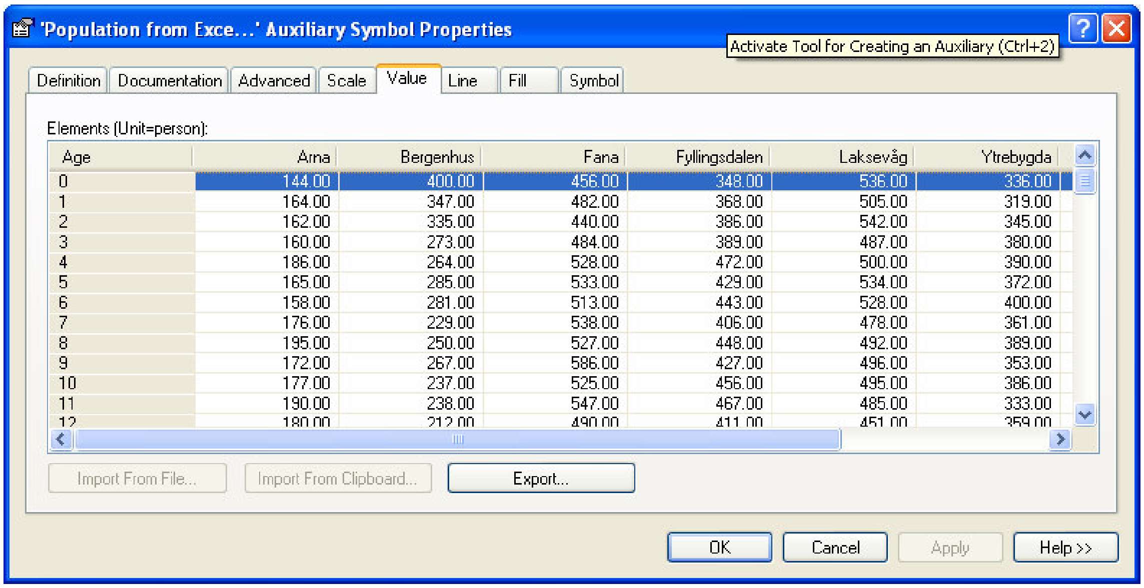


Fig 17: Auxiliary values of "Population from excel-This year"

The auxiliary "Population from Excel-This year" is the only variable that is applied towards other variables or components of the Geriatric Healthcare Projection Model. The external data is however not applied directly as active model variables but are used towards validation and calibration of the population simulation.

7.2 Population-Simulation

As discussed in the literature review the Norconsult population prediction is not accounting for an important dynamic affecting the demographic development of a population; a growing life-expectancy or a reduced mortality rate. The Norconsult report is furthermore only predicting the population until 2024. The Norconsult prediction is therefore only of limited interest to the Geriatric Healthcare projection model as it is not accounting for important dynamics directly affecting the geriatric healthcare sector and it is overly constrained in the temporal dimension. For this reason have s system dynamics population simulation module been developed and implemented in the Geriatric Healthcare Projection Model. This module or subcomponent of the model is the driving engine behind the staff and client budgets in the GHPM. Elements ingrained in the population module are also directly applied in other areas of the model; such as death rates and processes of aging. The population simulation module consists of one stock and three governing flows. The flows governing the stock “Simulated Population” are “Births”, “Deaths” and “Net-Migration”. Unlike the Norconsult projection the GHPM population simulation is not considering housing development as a governing factor for the population development. This is done for three reasons: (1) The influence of housing development is conceived as inherent to the influence of migrational patterns. (2) Housing development can be conceived as an effect of migrational patterns as well as an effect of the overall population development. This can be suggests as housing development must be seen in relation to supply and demand. (3) Norconsult works with static and absolute annual housing development. This seems unrealistic considering supply and demand as a governing factor for housing development. Housing development is likely to be a dynamic property of societies, to incorporate housing development therefore calls for a separate housing module in the GHPM and this lies far beyond the limitations of the problem here to be analyzed.

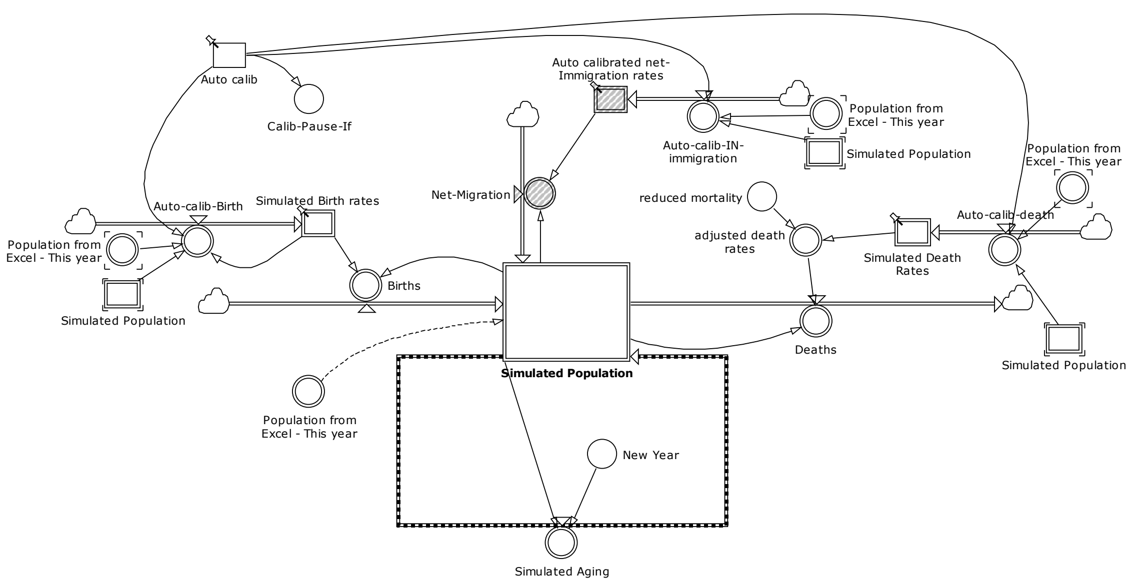


Fig 18: S&F Simulated Population

The above figure shows the stock and flow diagram of the Population simulation model of the GHPM. “Simulated Population” is the primary stock containing the simulated population of the city of Bergen organized by the arrays *Age* and *Bydeler*. “Simulated Population” is initialized with external population data from year 2000. The stock is increased by inflow from “Births” and reduced by outflow from “Deaths”. The flow “Net-Migration can both increase and decrease the stock. “Simulated Population” has the dimensionality *Age* and *Bydeler* and the unit People:

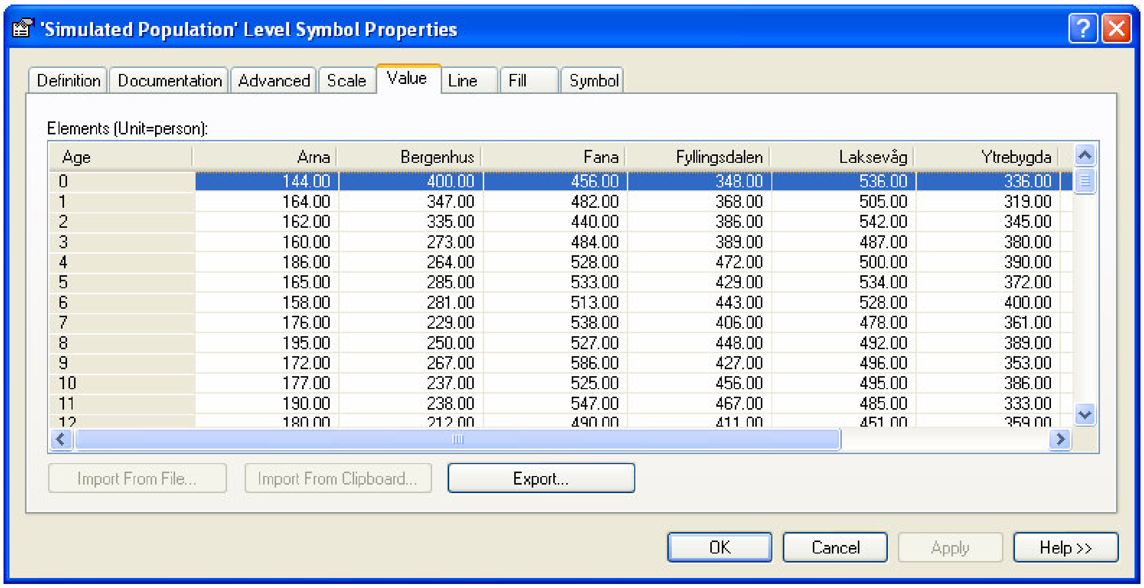


Fig 19: Stock Values “Simulated Population”

The flow “Births” is an inflow to “Simulated Population”. “Births” is defined by the following equation:

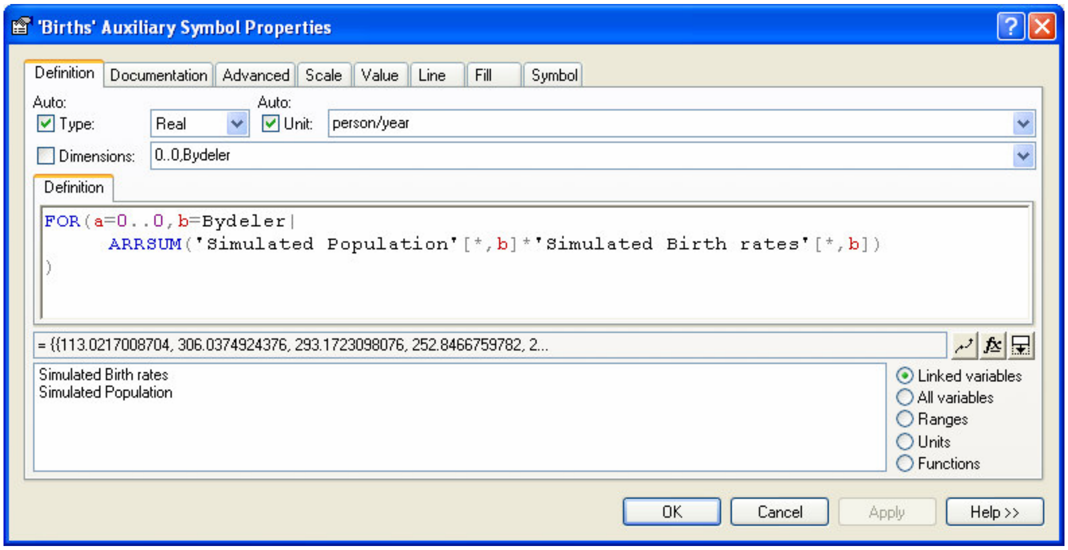


Fig 20: Auxiliary equation definition for "Births"

The FOR expression defines the array dimensionality of the expression; as every newborn baby necessarily is zero years old the *Age* dimension of "Births" is also defined by the numerical subrange 0..0. The ARRSUM expression allows for a summary across arrays. The linked auxiliary "Simulated Birth rates" identifies the actual birth-rates for *Age* and *Bydeler.* As people at different ages and in different socio-economic communities tend towards different birth-rates, birth-rates are also defined by *Age* and *Bydeler.* "Simulated Birth rates" is given the unit %/Year. Each borough is assigned with slightly different birth rate curves, allocated between 14 and 49 years old. The borough Åsane is assigned the following curve:

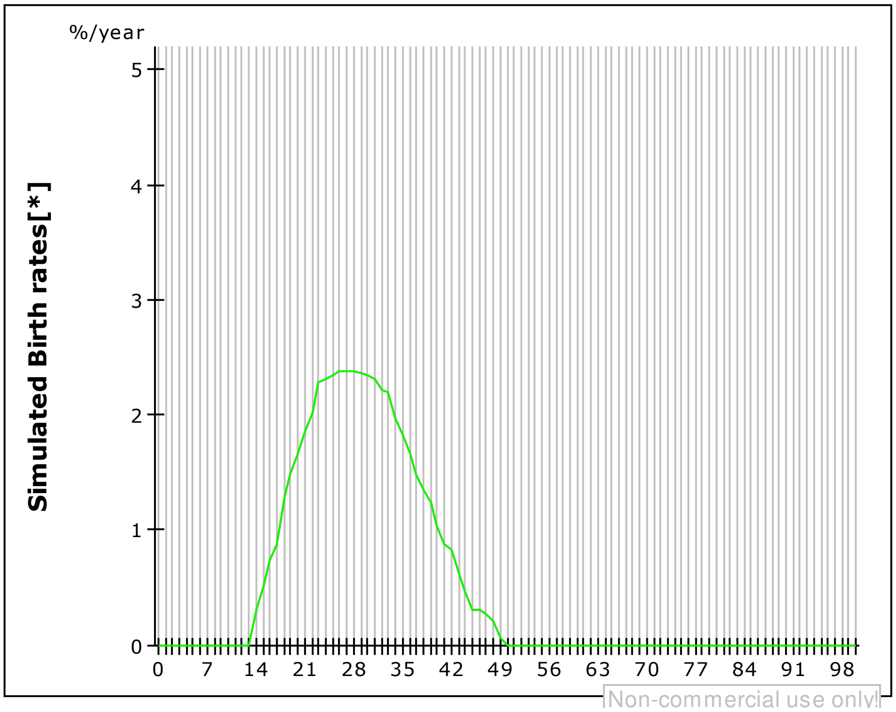


Fig 21: Simulated Birth Rates for Åsane

For all graphs identifying population; percentages or people are identified along the Y axis; age cohorts are identified along the X axis. The population graphs are henceforth snapshots of a given moment in time and not time graphs.

The eight different birth rate curves have been developed based on the fertility rates asserted by Norconsult. Based on the historic data available in the Norconsult predicted data set; the years between 2000 and 2005 as well as the statistic documentation provided though the Norconsult report; birth-rate curves have been inferred. The Norconsult prediction is based on constant birth rates(Norconsult, 2005). The Population Simulation module allocates births to people between 14 and 49 years of age. This is an important dynamic attribute in the population module; if a constant and absolute number of births is assumed each year the natural fluctuations in fertility arising from variance in the size of the birth giving age group is neglected. The Norconsult prediction appears to have ignored this effect. As the GHPM population model does not discriminate between sexes, the derived birth rate for this age group was divided by two as Bergen roughly has 50% women. The reason for applying birth rates as a curve and not as a constant rate for the birth giving age group relates to the centre of gravity of birth giving age; Norwegian women commonly give birth between their mid twenties and early thirties. Some do however give birth at earlier or later stages in life. The centre of gravity of birth giving age also varies somewhat over space; as people in urban areas tend to delay maternity somewhat compared to people in more rural areas(Paul L. Knox, 2001). As an initial birth rate curve was developed for the eight different boroughs the birth-rates was calibrated.

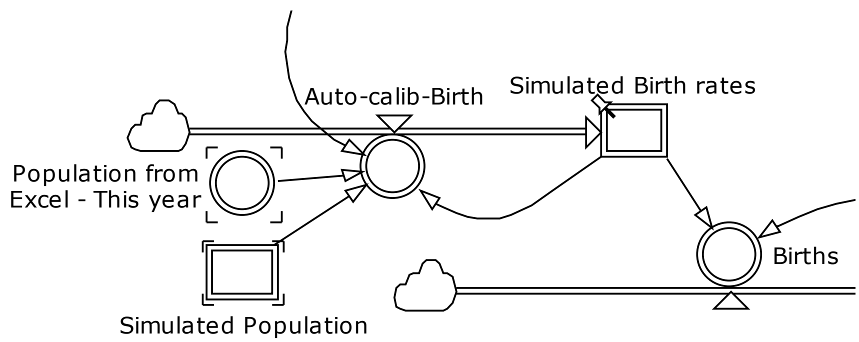


Fig 22: S&F Birth-Rate Calibration

The calibration process is based on the external data presented in the previous section. Calibration is only carried out over a five year period between 2000 and 2005 where the Norconsult data is in fact historical data and not predicted data. The calibration considers the difference between the historic data "Population from Excel – This year" and the value for "Simulated Population" at the same point in simulated time and adjusts the stock variable "Simulated Birth rates" through the flow variable "Auto-calib-birth". "Auto-calib-birth" is defined by the following equation:

```
IF('Auto calib'=NUMERICAL('calib birth'),
        FOR(a=Age |
        ('Population from Excel - This year'[1,*]-'Simulated Population'[1,*]) *
        'Simulated Birth rates'[a]/ 1<<person>>
        ) / 900<<years>>)
```

The IF expression is an on/off switch applied during calibration; unless the variable "Auto calib" is set to calibrate birth rates no calibration will be carried out. The FOR expression allows for discrete treatment of the variable's dimensions. Further the equation adjusts the difference between the actual population minus the simulated population multiplied by the birth-rates and divides this over a long time period. The long time period allows for refined calibration. As this equation is a flow regulating the level "Simulated Birth rates" the latter variable will be adjusted according to the difference between actual and simulated population.

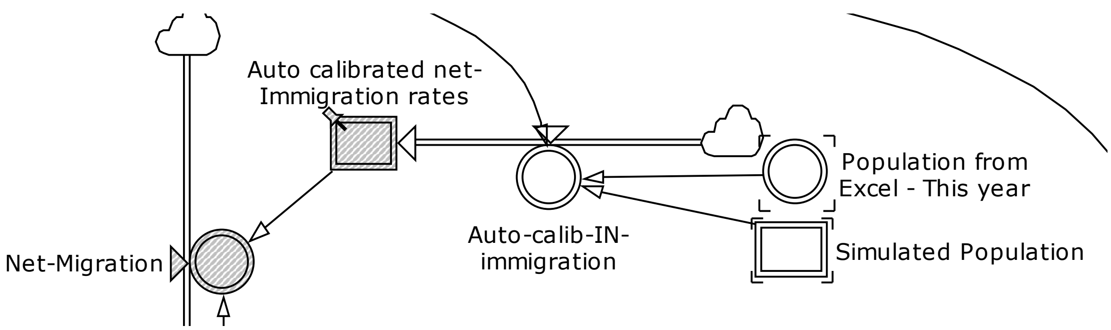


Fig 23: S&F - "Net Migration"

The "Net-Migration" flow is coined to either increase or decrease the level "Simulated Population". "Net-Migration" has been developed along the same line of thought as the "Births" variable. "Net-Migration" is initially developed as a curve varying across ages and boroughs. This graph assumes that people move more during their younger years and less as they get older. When people in their early thirties move they tend to move from urban towards more rural areas, and they often bring young children with them. When people in their late teens or early twenties move the migration is commonly related to studies; most commonly located in urban areas. Based these rough assumptions eight different migrational curves was developed. The main criterion for developing a curve for a borough was the degree of urbanity in the borough. After considerable manual adjustments through trial and error, the eight migrational curves were calibrated using the same calibration logic as applied for births.

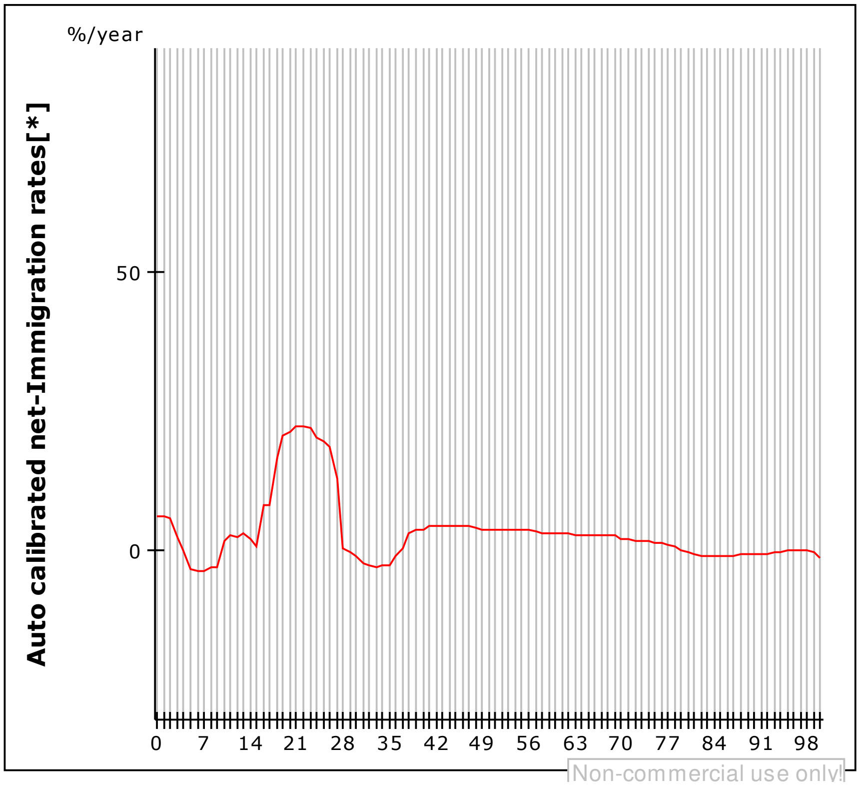
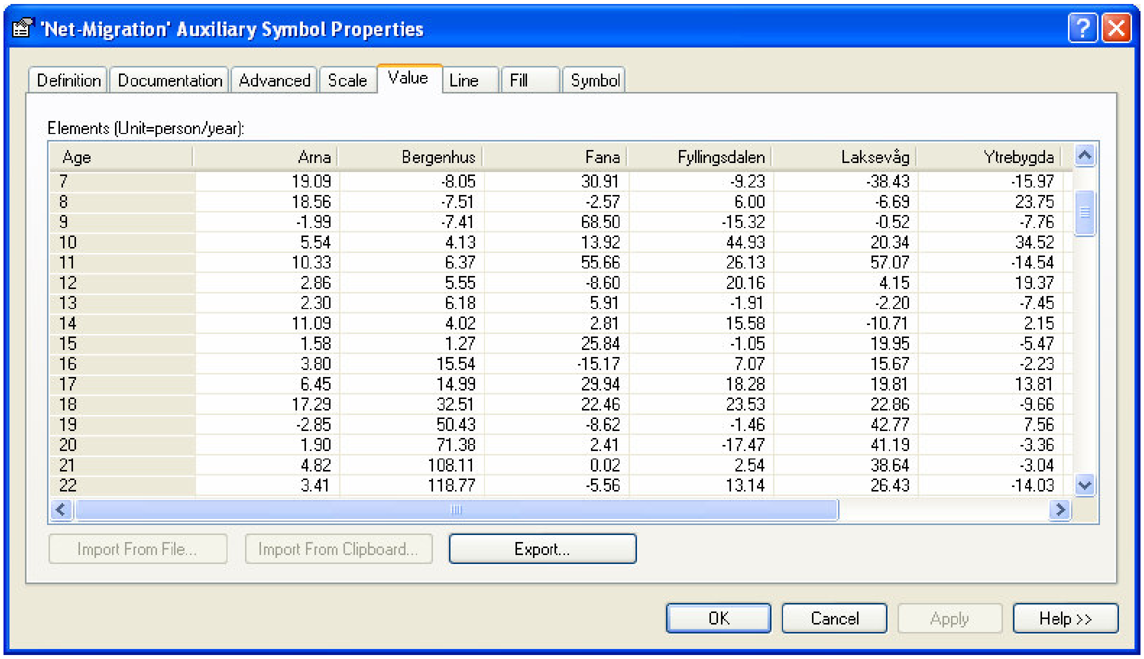


Fig 24: Auto calibrated net-migration rates for Bergenhus

It is important however to underline that whilst “Births” is only introducing people at the age of 0, “Net Migration” introduce or remove people from all age cohorts to the “Simulated Population” level. This suggest that whilst there might be emigration of people at the age of 18 in one borough there might be immigration of people at the age of 18 in another borough.



Age	Arna	Bergenhus	Fana	Fyllingsdalen	Laksevåg	Ytrebygda
7	19.09	-8.05	30.91	-9.23	-38.43	-15.97
8	18.56	-7.51	-2.57	6.00	-6.69	23.75
9	-1.99	-7.41	68.50	-15.32	-0.52	-7.76
10	5.54	4.13	13.92	44.93	20.34	34.52
11	10.33	6.37	55.66	26.13	57.07	-14.54
12	2.86	5.55	-8.60	20.16	4.15	19.37
13	2.30	6.18	5.91	-1.91	-2.20	-7.45
14	11.09	4.02	2.81	15.58	-10.71	2.15
15	1.58	1.27	25.84	-1.05	19.95	-5.47
16	3.80	15.54	-15.17	7.07	15.67	-2.23
17	6.45	14.99	29.94	18.28	19.81	13.81
18	17.29	32.51	22.46	23.53	22.86	-9.66
19	-2.85	50.43	-8.62	-1.46	42.77	7.56
20	1.90	71.38	2.41	-17.47	41.19	-3.36
21	4.82	108.11	0.02	2.54	38.64	-3.04
22	3.41	118.77	-5.56	13.14	26.43	-14.03

Fig 25: Auxiliary values "Net migration"

As the above auxiliary values show there is a positive migration of 16 year olds to *Bergenhus* whilst this flow is negative for 15 year olds in *Fana*. Suggesting that the cohort of 15 year olds in *Bergenhus* is increasing and the same cohort in *Fana* is decreasing.

The outflow "Deaths" is modelled and parameterized by the same logic as "Births" and "Net-Migration". There are however some important differences between "Deaths" and the previously described flow variables governing "Simulated Population"

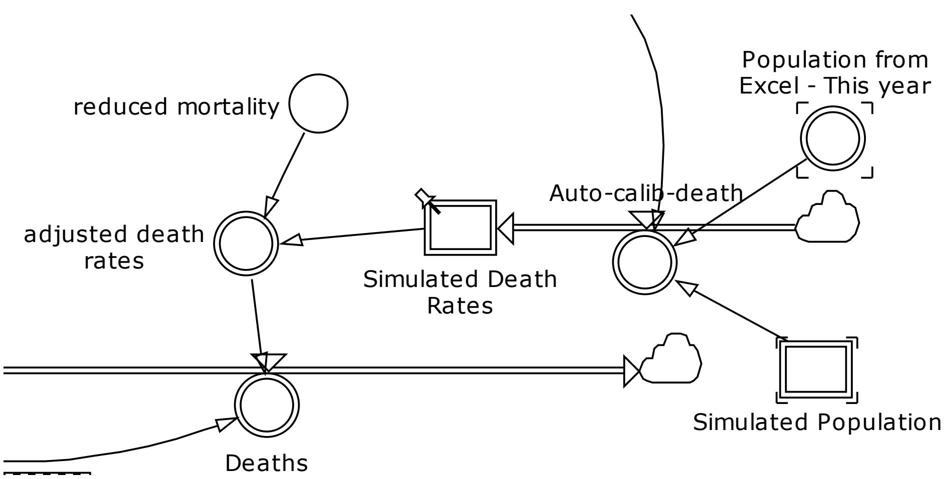


Fig 26: S&F - "Deaths"

Whilst "Births" is exclusively an inflow and "Net-Migration" is a bidirectional flow, "Deaths" is exclusively an outflow. The latter is obvious by default. The death rates for the different boroughs are developed with the same technique as the other tow flows. Initially a rough curve was developed for each borough, the curves were adjusted through trial and error, and finally the curves were adjusted by auto calibration. The underlying hypothesis for developing the initial death curves was that mortality is a function of age; the probability of dying increase as a person gets older. The relationship is however not linear through life, the death rate or probability of dying is initially kept stable at a low label until reaching the early fifties, from hereon the mortality is increasing.

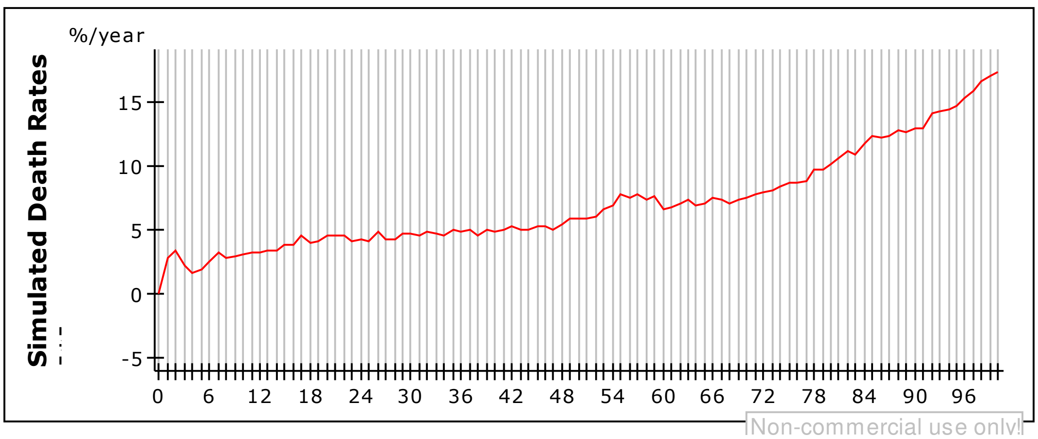


*Fig 27:	Simulated death rates for Åsane*

The above simulated death rate shows a slight peak during the first few years, then remaining rather stable before gradually increasing after fifty years. The outflow "Deaths" is also defined by a MAX function. The latter is to ensure that the variable under no circumstance can become negative, and hence increase the "Simulated Population" level.

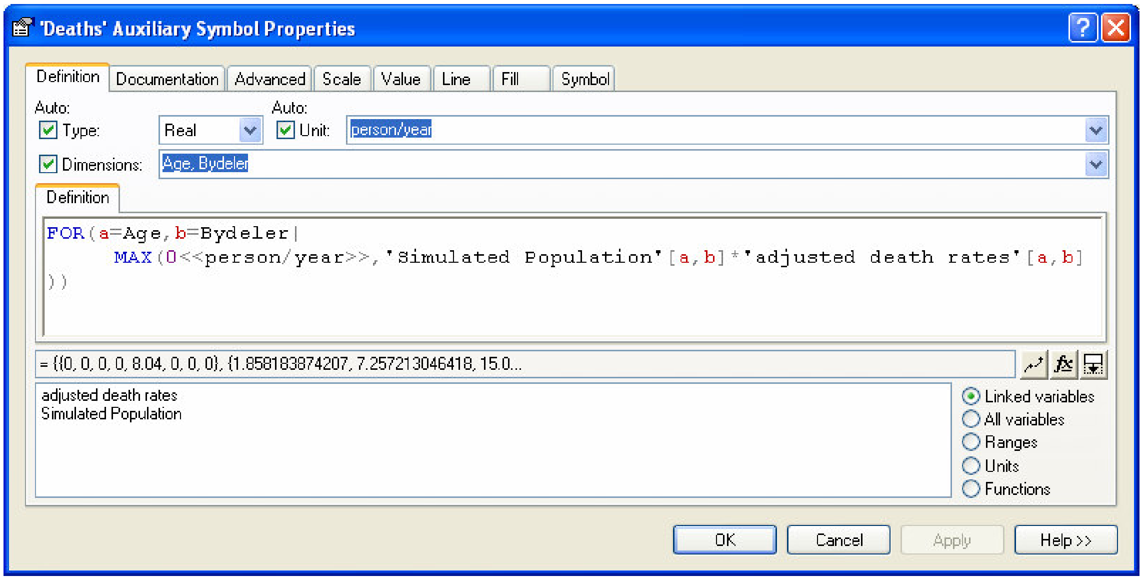


Fig 28: Auxiliary equation for "Deaths"

The above equation is by employing a MAX function insuring that deaths cannot be negative. Beyond that the function simply states that the number of deaths equals the "Simulated Population" multiplied by the "adjusted death rates".

The Death component differs from the other two flows in an important respect; additional model structure is added to the death component to capture the expected increase of life expectancy during the next few decades through witch the model is simulated. This effect is modelled and parameterized by employing a GRAPH function that is adjusting the "Simulated death rates" in the auxiliary "adjusted death rates". "Adjusted death rates" simply multiplies the "simulated death rates" by the auxiliary "reduced mortality"

"Reduced mortality" assumes the following: over the last fifty years life expectancy has increased by 15 percent for both men and women and I similar development is expected also in the future.(Arne Andersen, 2005). The GHPM has somewhat arbitrarily chosen to assume that life expectancy will increase with 10 years over the next 45 years, a figure somewhat lower then the increase experienced during the last fifty years period. By calculating the 10 years as a percentage of an average life time of 70 years one lands on an approximate 15 percent reduction of mortality through the next 50 years. The graph function employed in "reduced mortality" therefore simply infers a linear reduction of the factor 1 to 0.85 between the years 2000 and 2050. This factor is multiplied by the "Simulated death rates". In 2050 the mortality of 2000 will henceforth be reduced by 15 percent.

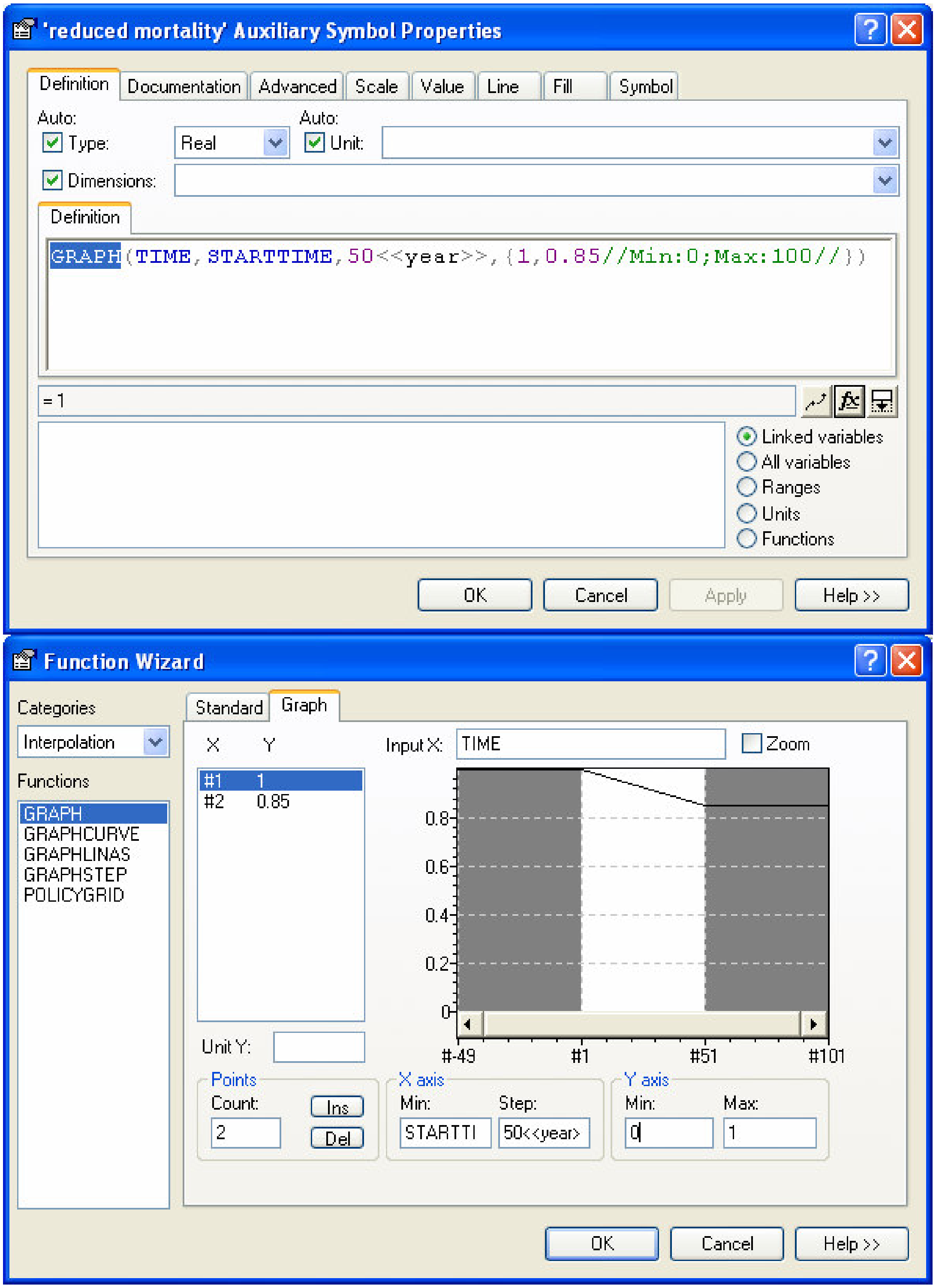


Fig 29: GRAPH function for "Reduced Mortality"

As *Age* is an important dimension of the entire Geriatric Healthcare Projection Model, the model must necessarily also account for aging processes. Simulated aging is carried out for all levels in which people accumulate. Aging is modelled as an internal flow to the various stocks in witch aging occurs. The aging structure will only be elaborated in this section as the process is identically modelled in all other similar levels.

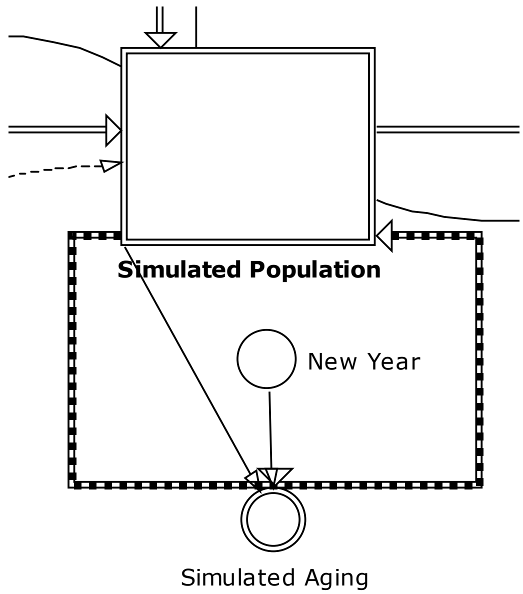


Fig 30: S&F Aging in "Simulated Population"

As the stock and flow diagram above shows, "Simulated Aging" is a flow to and from "Simulated Population". This structure indicates that the flow occurs within one single stock. What the flow does is simply to shift all people in all Boroughs up one age cohort at the turning of a simulated year. The auxiliary is getting input from the variable "New Year". "New Year" is defined as:

FLOOR (TIME)>FLOOR (TIME-TIMESTEP)

The FLOOR function derives a whole number by rounding down a value; in this case TIME witch is a functional expression for the current simulation time. If this value is larger then the rounded down number of current time minus a timestep the equation returns the value *true*, if not the value *false* is returned. Hence; if the equation returns the value *true* a simulated year has passed. This value gives input to the auxiliary “Simulated Aging” whether to act or not.

The actual aging of the level “Simulated Population” is carried out through the auxiliary “Simulated Aging”, if and only if a year has passed as indicated by the value of the logic expression in “New Year”. “Simulated aging” is defined as zero order integration and the following equation:

```
IF ('New Year',
    FOR (a=FIRST (DIM ('Simulated Population',1))..LAST (DIM ('Simulated
    Population', 1)) - 1,b=DIM('Simulated Population',2)|

            'Simulated Population'[a, b])

                    , 0<<people>>)
```

The equation is a logic expression and returns zero People if “New Year” is false. The FOR expression employs the FIRST and LAST functions that returns the first and last value of a range. The DIM function returns an integer indicating a dimension in a FOR function. As the *a* definition returns a value one less then the actual range of “Simulated Population” and the *b* definition returns the dimensionality of “Simulated Population” the FOR expression shifts the entire age array one dimension up as “Simulated Population is defined by *a* and *b*, if the “New Year” condition is true.

Auto calibration raises questions as to whether the model is creating the right behaviour for the right reasons. The auto calibration routine described above therefore requires further explanation. To calibrate three different flowrates is an iterative and tedious process. It is an absolute prerequisite that only one flowrate is calibrated at the time. The routine is henceforth carried out in iterative steps. As all initial flow rates are assumed to be approximately correct; the curve shape of the flowrates must be based on knowledge about underlying structures and qualities of demography and human geography. The mismatch between the simulated and the historic data indicates which flow rate that must be adjusted to better the simulated result. The key to understanding which flowrate to adjust lies in the qualitative difference between the flow rates. If there are too few children under five years of age in the simulated population this suggests that the birth rate is to low and should be calibrated. If there is a great surplus of people in their late teens and early twenties this suggests that the immigration rate is too high and must be adjusted downwards. If there are too few people older then 50 years the mortality rate is likely to be exaggerated. By considering these underlying structures the flowrates can be calibrated iteratively to better fit the historic population data. The auto calibration will only work if the basic shape of the flowrate curves is correct as the auto calibration only adjust the details of the flowrates rather then completely changing the flowrate behaviour. It is the hope and ambition of the author that the population module of the GHPM is generating a simulated behaviour that not only matches the historic data, but does so for the correct reasons. This issue will be revisited in the following chapter on validation.

7.3 Nurse Pool

The nurse pool view in the Geriatric Healthcare Projection Model is a minor subcomponent added primarily to create boundaries for the amount of nurses that potentially could be recruited to the geriatric health services. The nurse pool is however more or less arbitrarily parameterised. There are several reasons for this. The majority of nurses are not working in geriatric care; nor is it plausible that there ever will be a requirement for the majority of nurses to do so. There is a plethora of health services requiring nurses, geriatric care is but one of them. Furthermore; there are no available statistics on the actual number of educated nurses in the city of Bergen. Health worker statistics tend to be aggregated into statistical classes non applicable to this model. In September 2008 statistics Norway will release disaggregated statistics on health workers; at this point in time the nurse pool subcomponent of the GHPM may be further parameterised. For the purpose of the analysis here to be pursued this data is not required; it is assumed that there will always be enough educated nurses to run the geriatric healthcare sector if the incentives to recruit them is sufficient. The geriatric healthcare sector will only employ a fraction of the total nurse pool;

however, the model structure circumfence this area to facilitate further model development at later stages.

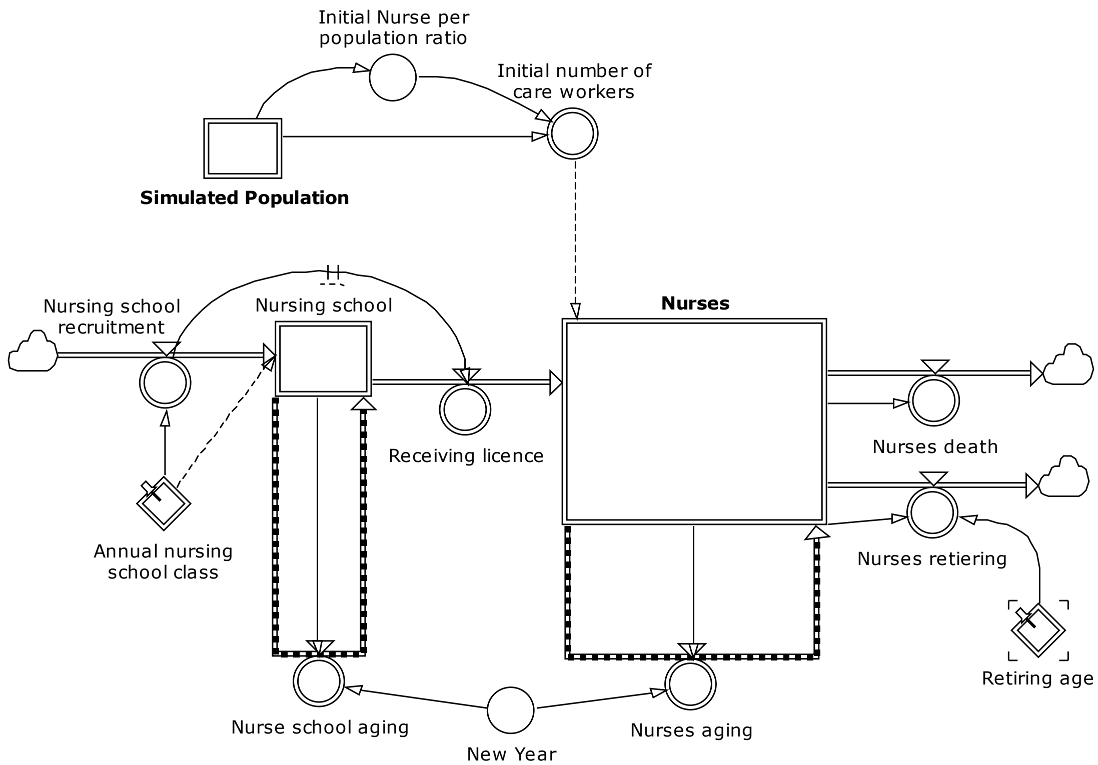
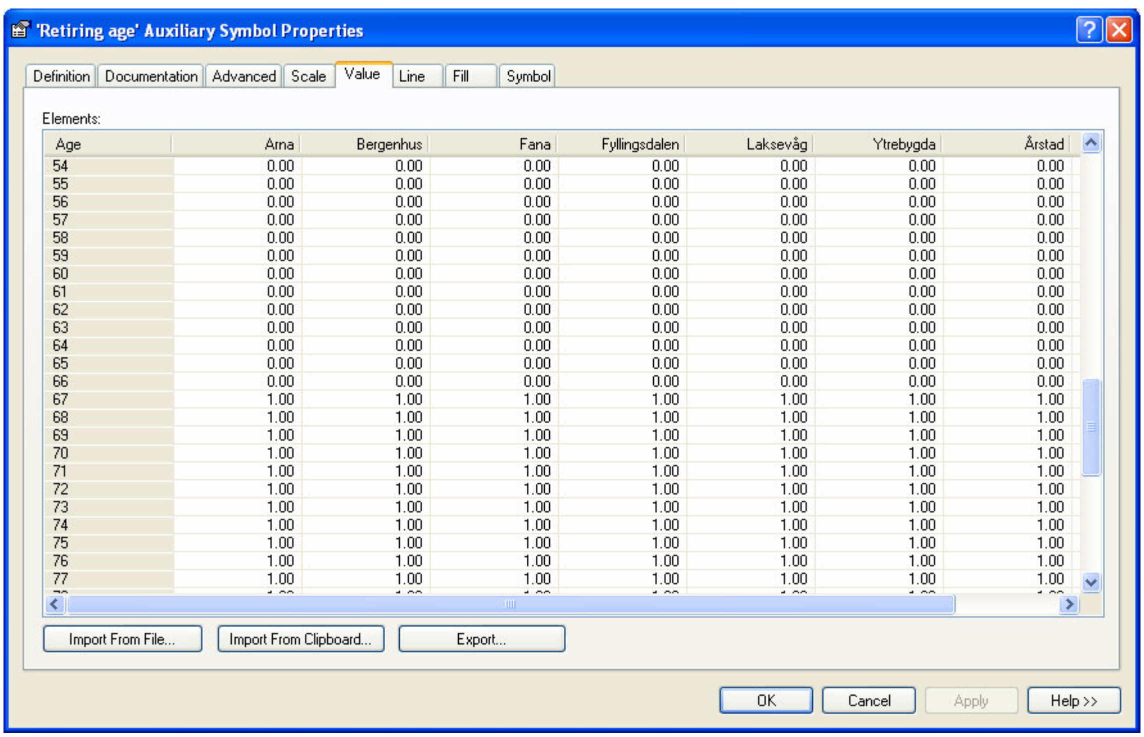


Fig 31: S&F Nurse Pool

The level “Nurses” is initialized with the auxiliary “Initial number of care workers”. This number is a very approximate number derived from county level data. Statistics Norway reports that there are about 16000 nurses in Hordaland County. All of these are obviously not residing in the city of Bergen; however, they may be conceived as within the available Nurse pool in Bergen as they all live relative proximity to the city. To distribute the initial nurse pool over boroughs and ages the percentage of nurses in the population of the city of Bergen is calculated and then applied as an initialization value. Clearly this figure is not neither correct nor well conceived; the Nurse Pool is intended as an open end in the GHPM and is not a well functioning model component. It does however allow for examining tendencies in labour requirements in the future.

"Nursing school recruitment" defines the flow of people entering "Nursing School". The constant "Annual nursing school class" is defined as 70 people per each 18 year old borough cohort. It is here assumed that people only enter nursing school at the age of eighteen and that an equal number of people enter nursing school from each borough. Clearly this is far from realistic but for the purpose of this model and the accuracy required in this respect the nursing school dynamics is of little or no importance.

As people enter nursing school they age. Nursing school spans over three years; hence with a three year delay the people in "Nursing School" flows into the level "Nurses. People remain defined as nurses until they decease or retire. Retirement age is defined as 67 years. The retirement outflow is modelled in the auxiliary "Nurses retiring"; defined as the product of "Nurses" and "retiring age". Retiring age is a simple Boolean multiplicator matrix where all values of *Age* and *Bydeler* younger then 67 years is assigned the value zero and all above is assigned the value one.



Age	Arna	Bergenhus	Fana	Fyllingsdalen	Laksevåg	Ytrebygda	Årstad
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	0.00	0.00	0.00	0.00	0.00	0.00	0.00
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	1.00	1.00	1.00	1.00	1.00	1.00	1.00
68	1.00	1.00	1.00	1.00	1.00	1.00	1.00
69	1.00	1.00	1.00	1.00	1.00	1.00	1.00
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00
71	1.00	1.00	1.00	1.00	1.00	1.00	1.00
72	1.00	1.00	1.00	1.00	1.00	1.00	1.00
73	1.00	1.00	1.00	1.00	1.00	1.00	1.00
74	1.00	1.00	1.00	1.00	1.00	1.00	1.00
75	1.00	1.00	1.00	1.00	1.00	1.00	1.00
76	1.00	1.00	1.00	1.00	1.00	1.00	1.00
77	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Fig 32: Constant values "Retiring Age"

The auxiliary “nurses death” governing the deaths outflow from “nurses” is identical to the “Deaths” auxiliary in the population module; with the only difference being the level from witch deaths are subtracted. Death rates are thereby assumed to be the same for nurses as a group as for the population in general. This may not be true, granted collective group variance arising from work related differentiation of mortality. These differences are regarded as insignificant and irrelevant to the GHPM.

7.4 Care Beds

Care beds in the Geriatric healthcare services in the city of Bergen are accounted for in a separate model view. Existing and planned care beds are modelled as external data; there are plans as far ahead as 2011. After this point in time the addition or removal of care beds is considered self regulating variables in the GHPM; decisions in that respect are henceforth internally integrated in the model as effects of rising or diminishing demand for care beds.

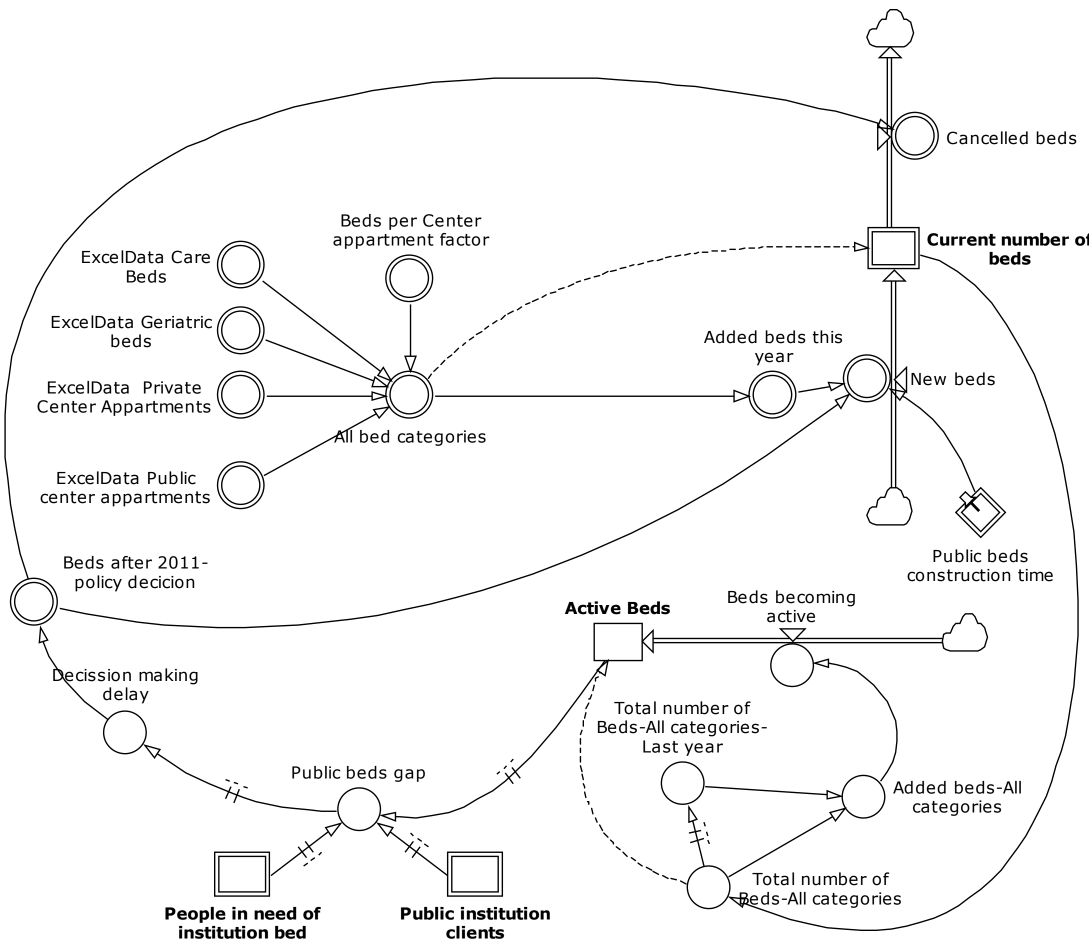


Fig 33: S&F - Care Beds

The external data is drawn from an excel file outside the Powersim model. The excel data is included by the same function as applied in the population data Powersim view:

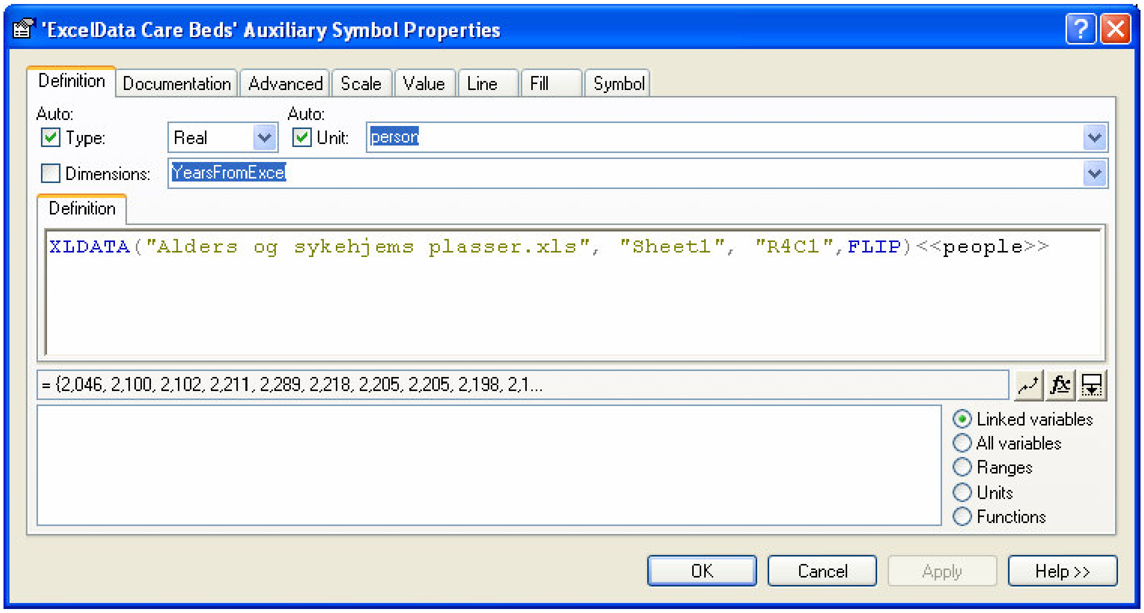


Fig 34: Auxiliary data import for "Care Beds"

The Function XLDATA points to the .xls file "Alders og Sykehjemsplasses.xls"[9], where "sheet1" is the active data sheet wherein data is located in the cells "R4C1". The Function FLIP shifts the data from a horizontal to a vertical orientation. The data is assigned the unit People and has the dimension YearsFromExcel. This dimension is self explanatory and simply enumerates the years 2000 to 2024. For the GHPM to work the .xls file must be available.

As there are four different categories of beds, there are four different auxiliaries importing excel data to the Care Beds subcomponent of the model. The different categories are Care Beds, Geriatric Institution Beds, Public Centre Apartments and Private Centre Apartments. The differences between these are described in chapter 6. The two centre apartments categories account for apartments rather then beds. It is estimated to be about 1.3

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[9] ENG:Geriatric and Care institution beds

beds per centre apartment. The number of actual centre beds is calculated in the auxiliary "All Bed Categories" where the four different categories are summarized and the centre apartments are multiplied with the auxiliary "Beds per Centre Apartments factor". "All Bed Categories" assigns the various beds with array definitions identifying the bed category of the various beds. As discussed earlier this is not actively used in the GHPM. It has however been added to simplify potential later model development. As the different beds are qualitatively different it is plausible that there are different requirements to staff and client types for the different bed categories. This can easily captured by adding additional model structure. Parameterization is however problematic and requires further research. The GHPM treats all bed categories equally and therefore aggregates the different bed categories to a single class of beds. "All Bed Categories" is the initialisation value of the level "Current Number of beds".

"Current Number of beds" is regulated by the flow auxiliaries "New Beds" and "Cancelled beds". Prior to 2011 beds are both cancelled and added through the variable "New Beds; the equation here is simply adding the difference between beds in the current year and beds in the preceding year, calculated in the linked auxiliary "Added beds this year" to the "Current Number of beds" level. "Current Number of beds" is after 2011 regulated as an effect of the shortage or surplus of care beds defined in the auxiliary "Beds after 2011-Policy decision". The latter auxiliary is also governing the outflow auxiliary "Cancelled beds" when there is a need to reduce bed capacity due to bed surplus. "Cancelled beds" is given a flow time of three years; it is expected that the city administrators do not jump quickly to reduce capacity). "Beds after 2011-Policy decision" is distributing the value of "Decision making delay" evenly over the four dimensions of *beds.* "Decision making delay" is an auxiliary defined by a pipeline delay of the "Public beds gap". The delay period is set to 4 years; this period is not chosen arbitrarily, rather it mirrors the time it took from when a bed shortage was outlined in 2000 and when a final decision to acquire more capacity was in place in 2004. “Public beds gap” is defined as the difference between the sum of the levels “Public institution clients” and “People in need of institution bed” and the level “Active beds”.

“Current Number of beds” is defined by the array *Beds*. As this array is not applicable to the further modelling the total number of beds is therefore accumulated in the level “Active Beds”. “Active Beds” is adjusted by the auxiliary flow “Beds becoming active”. This auxiliary is adding the difference between the current and the past year to “Active Beds” through a bidirectional flow. This aggregated difference is calculated in “Added beds-All Categories” where “Total number of beds-all categories-Last Year” is subtracted from “Total Number of beds-All categories”. “Active Beds” is initialized by “Total Number of beds-All categories”.

“Total Number of beds-All categories” is defined as

ARRSUM (‘Current number of beds’)

“Total number of beds-all categories-Last Year” is defined as:

DELAYPPL ('Total number of Beds-All categories',1 year)

The DELAYPPL function is a delay function that induce a 1year delay to “Total number of Beds-All categories”

7.5 Care Clients

The Care clients view in the Powersim model is larger and more complex then the previously outlined model views. The care clients sub component has two categories; Homecare and institutional care. These two different care sectors are qualitatively different from a logistic point of view. Whilst homecare is provided to anyone requiring a need for it, institutional care is limited by capacity. If someone requires a need for homecare services they will be added as homecare clients, the nurses in the home care sector thereby have their workload and responsibility expanded. If someone requires an institution bed, they will only receive institutional care if there is an available bed, if not they will have to await a bed to clear in their homes receiving temporary homecare services. The workload on nurses in institutions will therefore be a function of the bed/nurse ratio as the number of clients is restricted by the number of beds.

The client recruitment fractions are based on figures from the city of Bergen. These recruitment fractions are obviously central to the GHPM. Safely determining the recruitment fractions for the various ages is not an exact science. The fractions applied here are derived from available statistics but these statistics are made available by the city of Bergen through political documents; their validity is therefore somewhat questionable. A key concern is that the city of Bergen is only accounting for the people receiving care, not for the people actually needing it; the latter figure is likely to be larger then the former. By employing figures for actually served clients as a basis for simulating future client recruitment one therefore ignores potentially important grey figures in the geriatric sector; there may be many elderly requiring care but not receiving care. On the other hand; using these figures probably provides a sound basis for evaluating the basic trends and tendencies of the future care supply and demand behaviour. Miscounts due to underestimated care requirements must be considered as a systematic error as long as constant recruitment rates are employed throughout the simulation. Systematic error can be adjusted or removed through further research in later stages.

The recruitment fractions are derived from figures made available in the city of Bergen’s 2007 and 2004 reports. It is suggested that only people above 80 years of age require institutional care; this is not a reasonable assumption. The author has therefore expanded the institutional subjects’ age group somewhat. The following recruitment rates are employed for institutional care:

Age 0-66	0%
Age 67-75	11%
Age 76-80	13%
Age 81-89	25%
Age 90→	49%

Homecare is provided not only to elderly but also to younger citizens with a need for care. These care clients are not of interest to the GHPM but they must be included in the modelling as they exert pressure on the homecare services. Although the rate of people younger the 67 requiring homecare services is very low, the age group is large and the sum of younger clients is therefore significant. It should further be noted that the younger homecare clients commonly require a care intensive service. This aspect of the care sector is not modelled in the GHPM. The homecare recruitment fractions are:

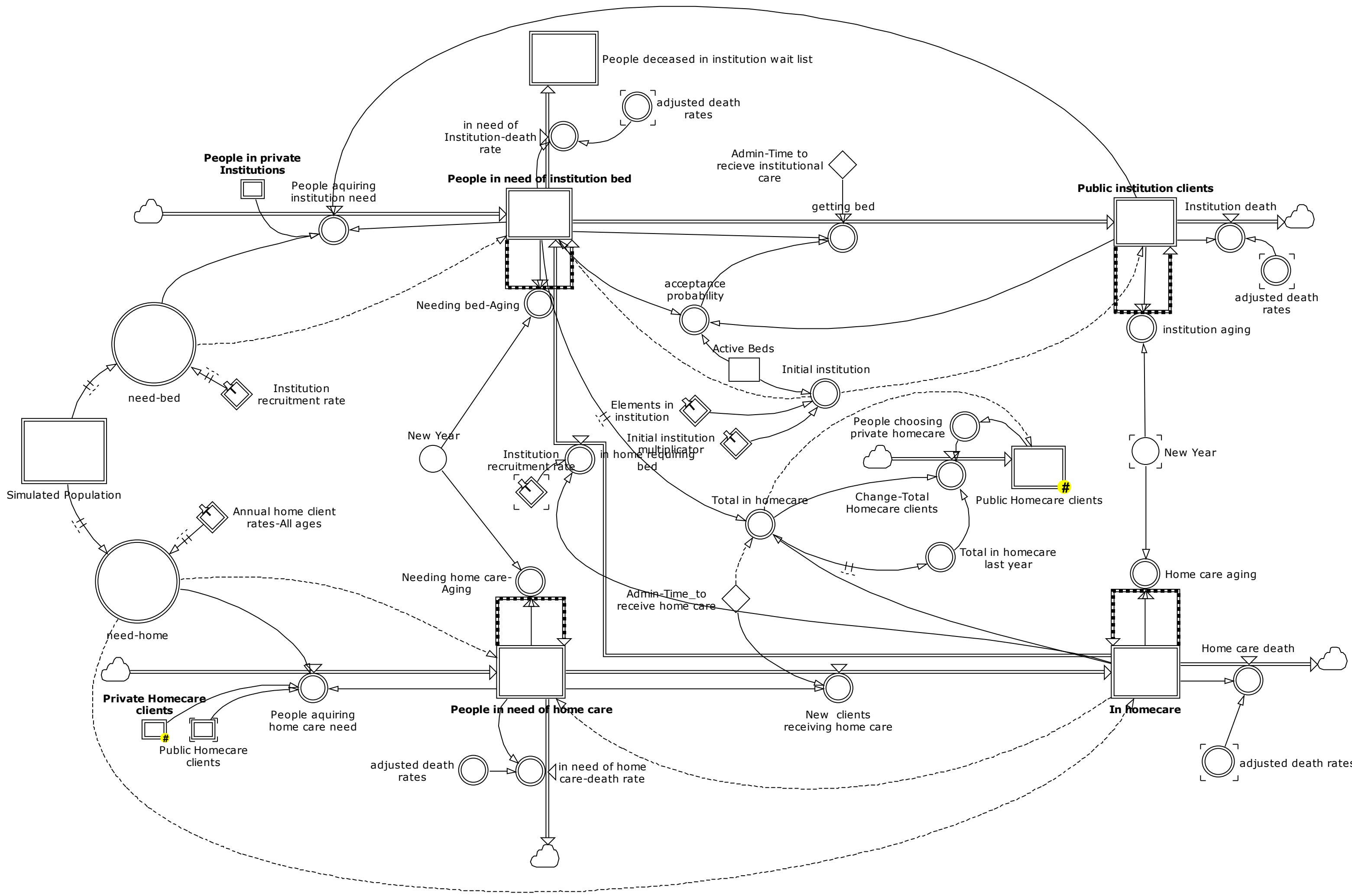
Age 0-66	0.89 %
Age 67-79	15%
Age 80-89	41%
Age 90→	50%

As mentioned the recruitment fractions must be considered with a decree of uncertainty arising from a systematic error. There is little available research and statistics on care requirements. Furthermore; as the policy of the city of Bergen is to develop the capabilities of the homecare services the very requirement definitions are likely to change during the simulation period. It is however useful and meaningful to use the recruitment rates as they are here presented; they do provide for analysis of the development of pressure on the geriatric health care sector; care requirement is and always will be a function of age.

The GHPM model the care clients subcomponent as a co-flow structure where homecare and institutional care clients are recruited in parallel from the "Simulated

Population” level, based on the respective sectors’ recruitment rates. Whilst homecare clients may elapse and require institutional care, clients with an institutional care requirement will not “get better” and only require homecare. However, as homecare services is required to anyone needing whilst institutional care only is provided when there are available institution beds; people on awaiting an institution bed will receive home care. The total number homecare clients are therefore the sum of people in the levels “People in need of institution bed” and “In homecare”.

Fig 35: S&F Care Clients



Clients are recruited from the "Simulated Population" by multiplying a SLIDINGAVERAGE of the simulated population age cohorts by the two sets of annual recruitment rates. The SLIDINGAVERAGE function is employed to get an annual mean value for each year. The SLIDINGAVERAGE function is therefore given a averaging period of one year. This function is used in the auxiliaries "Need Home" and "Need Institution". These two auxiliaries are then linked to the respective flow auxiliaries "People acquiring homecare need" and "People acquiring institution need" where the levels "People in need of homecare" and "People in need of institution bed" are subtracted from "Need home" and "Need institution" to remove the people who already have developed a need from the recruitment pools.

From this point on the two co-flows are modelled differently due to the qualitative difference between the two care categories. The Homecare path is the least complicated structure as homecare service is not constrained by capacity issues.

As people enter the level "People in need of homecare" they will age, and potentially decease. The waiting time for receiving homecare is short and people will flow into the level "In Home" after a short period of administrative time. Once receiving home care people age, decease or acquire a need for institutional care; represented by the flow from "In Homecare" to "People in need of institution bed". The auxiliary "In home-requiring bed" is defined as "In Homecare" multiplied with "Institution recruitment rate" per year. It may well be that people already in need of homecare services in reality are subject to different institutional care recruitment rates then the general population. However; no research or quantification of this relationship appears available. Death rates for "People in need of homecare" and "In Homecare" are the same as for the general population. Also this may not be entirely true in reality but again the modelling detail is restricted by limited available research.

The institution bed flow path of the care clients' subcomponent is slightly more complex. As people enter the level "People in need of institution bed" they will not receive a bed and thereby entering the stock "Public institution clients" before a bed clears. As people are accounted for by decimal values in the GHPM this is solved by a probability calculation where the number of institution beds ("Active beds") is divided by the number of clients in the institutions (”Public institution clients”). As the level “Public institution clients” is an array, and “Active beds” is not, the ARRSUM of “Public institution clients” is used in the calculation. The probability for receiving a bed is estimated in the auxiliary “Acceptance Probability” defined as:

```
IF ('People in need of institution bed'<=0<<person>>,
        0,
        MAX (0, ('Active Beds'-ARRSUM('In institution'))
        / (ARRSUM (MAX (0 people, 'People in need of institution bed'))))
```

Where the IF function activates the calculation if and only if there in fact are people awaiting a bed. The bed availability is the number of active beds minus the people occupying a bed. This difference is divided by the sum of people awaiting institution beds. The MAX functions are technical additions ensuring that no negative probabilities are assigned by always choosing the largest value of zero and the calculated value. “Acceptance probability is defined by the ranges *Age* and *Bydeler*; henceforth have people from any age or borough an equal probability of receiving a bed as any other.

The flow auxiliary “Getting bed” is then defined as “People in need of institution bed” multiplied with the “Acceptance probability” and divided by the administrative time required to provide a bed defined in the constant “Admin-time to receive institutional care”. Once in an institution bed, people are not conceived to recover; people will remain in the institution until the point of death. This is a simplification of reality, however; it is not far from the truth considering that people are in the institution primarily because of age related health issues and institutions do not stop the aging process. Hence; ”Public institution clients” is subject to aging and death. Also in this case and for the same reasons as stated above are the death rates of the general population applied.

The level “People in need of institution bed” is subject to aging and death. Death rates are equal to the general population. The latter is probably not true, as it is likely that people awaiting institutional care are more likely to suffer higher death rates then the general population; as no statistics on this matter is available the death rates of the general population is applied. The reader should however consider these rates as underestimated and therefore also subject to uncertainty or systematic error. The deaths of people awaiting institutional care are accumulated in the stock “People deceased in institution waitlist”. This stock variable may prove as an important indicator of how well the care sector is performing. Ideally this stock should be very little; if not the institutional care sector is failing to provide sufficient capacity at a great cost of human suffering.

The people awaiting institution beds are granted homecare services. The total sum of people receiving home care is therefore calculated in the auxiliary “Total in homecare”, defined as the sum of the level “In Homecare” and the level “People in need of institution bed”. To account for the delay induced by administrative time to receive homecare the constant “Time to receive homecare” is applied in a DELAY function for “People in need of institution bed” in the “Total in homecare” calculation. It is however required for the Private Sector subcomponent of the GHPM to have the total sum of people receiving homecare modelled as a stock. This stock is labelled “Public Homecare Clients” and is governed by the flow auxiliary “Change-Total Homecare clients”. “Change-Total Homecare clients” is defined as the difference between “Total in homecare” and “Total in homecare last year” per year. The auxiliary “Total in homecare last year” is simply defined as “Total in homecare” delayed one year. The level “Public Homecare Clients” is hence regulated by the change in the levels accounting for homecare clients and people receiving temporary homecare whilst awaiting an institution bed. “Public Homecare Clients” is therefore not subject to aging and death; the latter would generate double counting as these dynamics already are accounted for in the two subsidiary stock variables. When the private sector is activated the total change in “Public Homecare clients” is defined also by an outflow in to the private sector; to avoid double counting the outflow to the private defined in the auxiliary “People choosing private homecare” is removed from the “Change-Total Homecare clients” by subtraction.

7.6 Care Nurses.

Care Nurses is a large and complex structural component of the Geriatric Healthcare Projection Model. The subcomponent is structured based on the qualitative difference between institutional care and homecare services. The dynamics and the model structure capturing the two different care categories is more or less identical; differentiated only by few parameters. Both categories draw nurses from the Nurse Pool subcomponent of the GHPM. For both categories it is important to distinguish between nurse positions and actual working nurses. Positions are economic entities that may or may not be filled by nurses. There may be several challenges to filling nurse positions. The GHPM regards these challenges as dynamic feedback of the nurse per client ratio; which is inversely related to the nurses' workload.

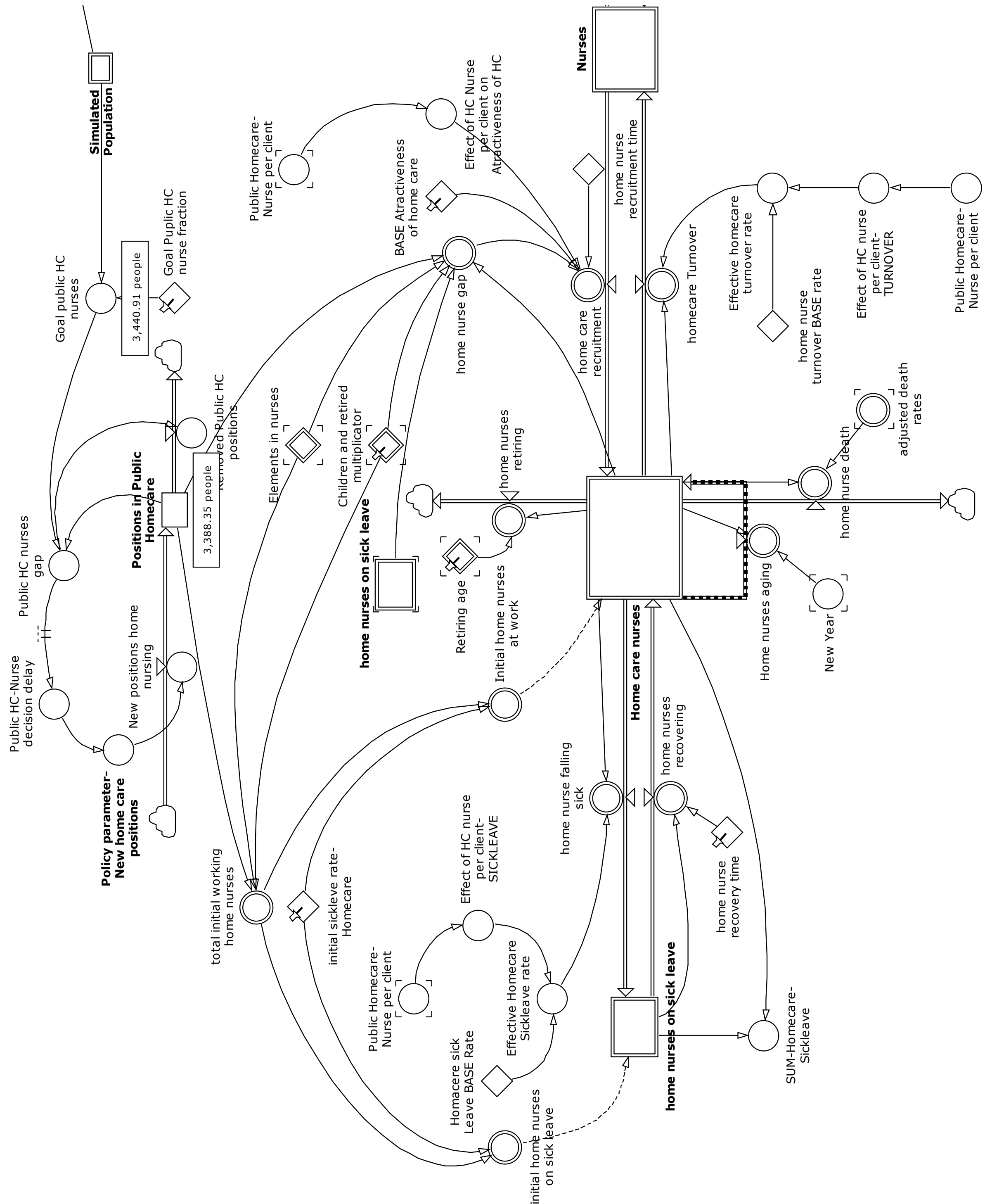


Fig 36: S&F - Homecare Nurses

The level “Positions in Home nursing” is initialized with 940 nurses. This figure is available in the 2007 report provided by the city of Bergen(Byrådet, 2007) and is the sum of nurses, nurses aids and unskilled labour working as care personnel. It is a pronounced political goal to have a homecare staff consisting entirely of nurses; the GHPM therefore simplifies reality and consider all care personnel to be nurses and all new employees are assumed to be trained nurses. New positions in the public realm are a political issue; it is however expected that the public realm will move to accommodate for changing service demands. The latter will be a process subject to delays due to the political process. New positions are modelled by the inflow “New positions in home nursing”, flowing into the level “Positions in Public Homecare”, when fewer positions are required this is captured by the and the outflow “Removed Public HC positions”. The amount of required positions is defined in “Goal public HC nurses”. The latter variable reflects a goal expressed by the city of Bergen as having 8.4 positions per 1000 citizens(Byrådet, 2004). It should in this respect be noted that the only way the city is close to that goal is by counting all managerial, maintenance and other miscellaneous staff as caregivers; this seem to be the case in the 2007 document. The gap between the goal and the actual positions is defined in “public HC nurses gap”; this variable is delay from being activated by a pipeline delay with a period of two years; the period of two years is a qualified guesstimate of the time required to identify and suggest increased funding for homecare nurse positions. The variable “Policy parameter-new homecare positions” is defined as:

IF (TIME < 2008, 0 person, 'Public HC-Nurse decision delay')

This suggests that no additions to staff are made prior to 2008. After that point in time the GHPM simulates political decisions to adjust the staff; the actual increases are made in the variable “New Positions in home nursing” where the decisions are implemented over a one year adjustment time. Decisions to reduce staff is modelled by the same logic through the variable “Removed public HC positions”

The level “Homecare nurses” is initialized by the auxiliary “Initial home nurses at work”. This auxiliary is defined as the “Total initial working home nurses” minus the initial nurses on sick leave. The constant “Initial sick leave rate-Homecare” is set to 10%; a figure that is somewhat arbitrarily chosen, based on general numbers for nurses drawn from Statistics Norway. The variable “Total initial working home nurses” is making an arbitrary allocation of nurses throughout the A*ge* and *Bydeler* dimensions by dividing 90% of the "Positions in Home nursing" by the number of elements in the working age group across the different boroughs. The function ELEMCOUNT is used for this; ELEMCOUNT simply retrieves the number of elements in an array variable. The constant "Elements in nurses" is a variable defined with the dimensions *Age 18-67* and *Bydeler.* The constant "Children and retired multiplicator" is a binary array multiplicator defined as one for all ages between 18 and 67 years for all boroughs and zero for all ages younger or older then the 18-67 age group. This variable is used to remove the probability for anyone outside the labour force to be included in the initial homecare nurse workforce.

"Homecare nurses" is subject to aging and death. Nurses also retire at the age of 67. This is modelled by the outflow "Home nurses retiring" from "Homecare nurses". "Home nurses retiring" is defined as "Homecare nurses" multiplied by the constant "Retiring age" per year. "Retiring age" is a binary multiplicator array constant where all ages below 67 has an element value of zero and all ages above 67 has an element value of one. Henceforth are all nurses growing older then 67 being removed from "Homecare nurses". This is obviously a simplification as not all people work until 67 years of age and some work longer.

"Homecare nurses" are recruited from the level "Nurses". When Nurses chose to no longer work as homecare nurses they re-enter the level "Nurses" Recruitment is governed by the flow auxiliary "Homecare recruitment". "Homecare recruitment" is defined by the equation:

MAX (0 person/year,

('home nurse gap'*

('BASE Attractiveness of homecare' * 'Effective Attractiveness of homecare'))

/ 'home nurse recruitment time')

The MAX function ensures that there cannot be negative recruitment. “Home nurse gap” is defined as

('Positions in home nursing'

/ ELEMCOUNT ('Elements in nurses')*'Children and retired multiplicator')

-'Home care nurses'

“Home nurse gap” constitutes the difference between homecare nurse positions and the actual nurses working. “Homecare recruitment” is therefore a goal seeking auxiliary; it is however constrained by the variables “BASE attractiveness of homecare” and “Effective attractiveness of homecare”. “BASE attractiveness of homecare” is a constant set to 0.9 suggesting that assuming ceteris parabus one will always be able to recruit at least 90 % of the staff required from the nurse pool. This factor is set slightly below zero based on the assumption that homecare nursing is competing against all other forms of nursing on the nurse labour market.

“Effective attractiveness of homecare” is a more complex and dynamic auxiliary; this auxiliary is a function of workload and defines a multiplication factor affecting the “BASE attractiveness of homecare”. “Effective attractiveness of homecare” is a GRAPHLINAS function where the auxiliary “Public Homecare-Nurse per client” constitutes the input variable. “Public Homecare-Nurse per client” is a variable located in the Care Capacity view of the Powersim Model and is a variable defined as the sum of public homecare nurses divided by sum of public homecare clients. The GRAPHLINAS function is suggesting that the higher the nurse per client ratio the higher should the attractiveness of becoming a homecare nurse; this ratio is inversely related to workload:

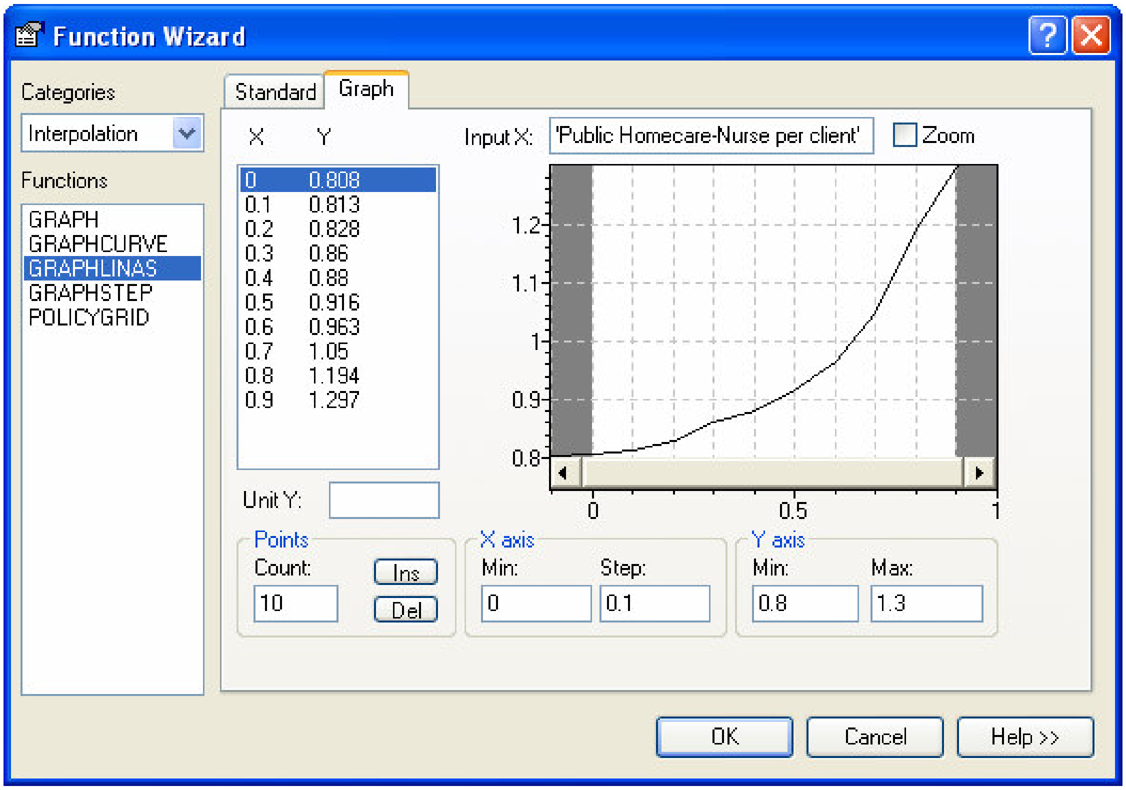


Fig 37: Graph function-Effect of HC nurse per client on attractiveness of HC"

The above graphical function is a modest estimate of how the author suspects that workload is affecting nurses' propensity to work; the lower the workload the higher the chance of attracting new ones. This same graphical function employed for the variables mirroring "Effect of HC nurse per client on attractiveness of HC" in the institutions nurse component as well as in the private sector components of the GHPM. The graphical function is probably not correct as it is simplistic and crude but its logic is obvious. This graph may be better parameterised through more thorough research. The point of employing such modelling techniques here is merely to capture an important dynamic feedback in labour relations.

"Homecare Turnover" is an outflow auxiliary governing the nurses who decide to leave the Homecare nurse workforce. Also this auxiliary has a base rate defined in the constant "Home nurse turnover-BASE rate" and set to 6 %. This base rate is affected by a graphical function which in turn gets input from the "Public homecare-Nurse per client" variable. The product of "Home nurse turnover-BASE rate" and the GRAPHLINAS function defined in "Effect of HC nurse per client-TURNOVER" form the variable "Effective homecare turnover rate". The turnover outflow from "Homecare nurses" is in "Homecare Turnover" defined as:

'Home care nurses' * 'Effective homecare turnover rate' / 1 year

The GRAPHLINAS function in "Effect of HC nurse per client-TURNOVER" is suggesting that as the nurse per client ratio increases the turnover rate is reduced and vice versa if the nurse per client ratio drops the turnover rate is increased. The below graphical function is employed for all effects of workload on turnover and sickleave for homecare nurses and institutional nurses in both public and private sectors. As the graphical function described above also this function is parameterised based on the authors intuition and is likely to be off; however, its purpose is soly to capture an important feedback dynamic and not estimate it accurately.

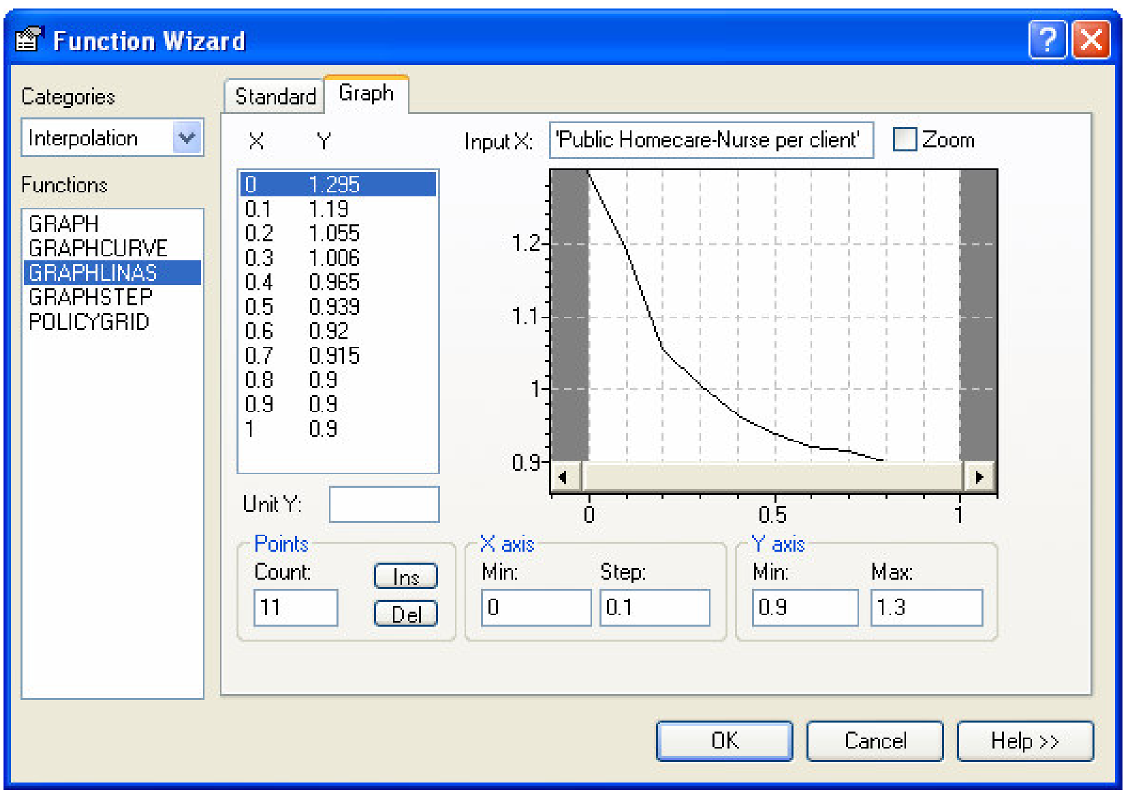


Fig 38: GRAPHLINAS function in "Effect of HC nurse per client-TURNOVER"

Nurses, like all other professionals will at times fall sick and leave work for shorter periods. The GHPM assumes that there is a relationship between the rate at which employees call in sick and the workload vested upon them. The homecare nurses on temporary sick leave are accounted for in the level “Home nurses on sick leave”. This level is initialized by the auxiliary “Initial home nurses on sick leave” defined as “Total initial working home nurses” multiplied by the “Initial sickleave rate-Homecare”. Sick nurses recover and flow back to the “Homecare nurses” level through the flow auxiliary “Home nurses recovering” after approximately two weeks; defined in the constant “Home nurse recovery time”. The level “Home nurses on sick leave” is subject to neither aging nor death. The latter is a simplification expected not to introduce any significant error to the model; this as the recovery rate and hence outflow is very rapid.

The inflow to the “Home nurses on sick leave” stock is governed by feedback introduced by effect of workload. “Homecare sick Leave BASE Rate” is set to 10 %. The base rate is affected by workload by a factor defined in the auxiliary “Effect of workload-home care-SICKLEAVE” by the same GRAPHLINAS function as outlined for turnover. The graph function suggests that as the nurse per client ratio increases the workload is reduced and hence is the propensity to call in sick also reduced.

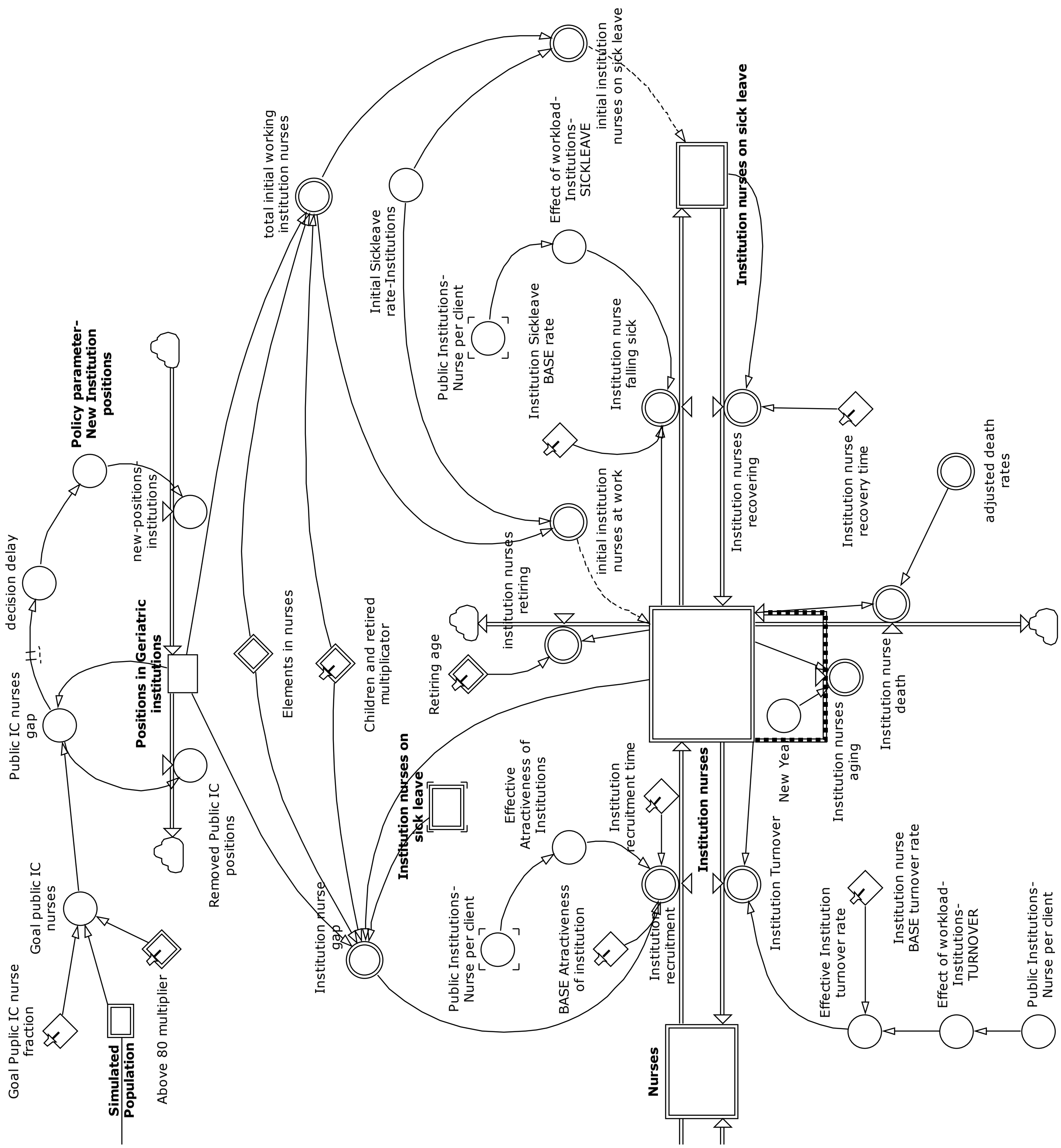


Fig 39: S&F - Geriatric Institution Nurses

The section of the Care Nurses subcomponent of the Geriatric Healthcare Projection Model covering nurses working in geriatric institutions is mirroring the model structure outlined above capturing the dynamics of homecare nurses. The essential model structure encompassing the staff dynamics of the two care categories is identical. The parameters applied are more or less equal in the two subsets. “Positions in geriatric institutions” is initialized at 1369 positions encompassing everyone with care giving jobs in public institutions in 2006(Byrådet, 2007). There is however a different definition of the goal for nurse capacity in the public institutions; the goal is defined as Institution nurses per total population above 80 years of age equal to a factor of 0.25(Byrådet, 2004). This factor governs the tedious political process of establishing new institution nurse positions.

Base rates for turnover, sickleave and attractiveness are set to match the homecare sector with consecutive values of 6, 10, and 90 percent. Recovery and recruitment adjustment times are set to approximately two weeks and three months. The relative long recruitment time is given as this is the common work contract closure period in Norway. The parameters applied in the graphical functions are not identical but the basic graph shapes are; there is no reason to suspect that nurses working in institutions are different from nurses working in homecare in the respect of responses to workload development. Nevertheless; there are subtle differences. As the number of clients are limited by the number of beds, the number of beds also restrict the nurse per client ratio and hence the workload on each nurse. As long as there is little expansion of the bed capacity and clients to fill the existing beds the workload will be more or less stable. There is still reason to assume the relative changes in the work situation will affect the willingness to work. Yet; the graphical functions affecting the staff situation in geriatric institutions are identical to the graphical functions governing homecare staff dynamics.

7.8 Private sector.

The Geriatric Healthcare Projection Model is developed to investigate the future prospects of geriatric health care in Bergen. As of 2008 geriatric healthcare is the responsibility and realm of the public sphere. However, as an elderly boom is in the making the pressure on the public healthcare system may be suffocating. Faced with potentially unsatisfactory conditions in the public healthcare sector, the political and public climate may call for private initiatives to help of the situation. Private business has the potential to move quicker then public policy; tedious political and bureaucratic processes are kept at a minimum. To investigate the possibilities embedded in allowing private care initiatives is therefore an interesting endeavour. The GHPM encompass model structure required for such investigations. This subcomponent will only be activated for the final steps of the policy analysis; the latter as a private alternative is a hypothetical scenario. It should in this respect be mentioned that there already are private geriatric care institutions in Bergen; these are however fully subcontracted on long-term leases by the city and cannot be considered as free private business pursuits.

Private sector in the GHPM includes both homecare services and institutional services. It may be that if a need for a private care sector arises the need would only arise in one of the two service categories. The Geriatric Healthcare Projection Model is open ended in the respect that the private care categories can be turned on or off at will. This opens for analysis of the effects of only allowing for private initiatives in one category. To enable both alternatives is likely to demonstrate different dynamic behaviour as the two care categories affect each other. *E.g..: A backlog or waitlist for geriatric institution beds increase the pressure on the homecare services as people awaiting a bed will receive temporary homecare services. By allowing for only private institution initiatives, the pressure on both public homecare and public institutions would be reduced. However; by allowing for only private homecare only the pressure on public homecare services would be reduced. By allowing for both private alternatives the pressure on both public services would be reduced but by different rates then if only private institutions are allowed for.*

As discussed earlier the GHPM is not considering finances. The driving engine behind private sector investment is therefore, as in the case of public sector, the need or demand for services. Private sector as it is conceived here is therefore dependant on someone paying for the services. Clients may pay for the services in full, services may be subsidised or the services may be financed by a combination of client and public spending. The GHPM is not considering this aspect. Rather, the private sector is conceived to be able to raise the funds required to meet the client demand by investment; regardless of where the funds originate. It is further assumed that private sector operates in a free market environment, experiencing great freedom to invest and make decisions unhampered by public policy processes or bureaucratic intervention. The assumption here is that the private sector has a “carte blanche” healthcare licence and that public planning offices do not inflict considerable delays in construction approvals.

The free market assumptions are not realistic; Norway has tradition and wide public acceptance for a strong and active public authorities. There is no reason to suspect that this tradition will change suddenly. It is however interesting to investigate the private sector under these assumptions; the underlying behaviour and nature of the private and public sector is different, by assuming a free market in the private sector these differences are revealed and accentuated.

The entire private sector is modelled in the Private Sector view in the GHPM. The private sector nurse model structure is by and large a replica of the public nurse model structure; the only difference lies in the policy parameters establishing new positions and the delays from when a decision is made until a position is in fact active. Parameters and structure governing sickleave, turnover, retirement and recruitment are identical in private and public sector as there is little reason to suspect that nurses employed in the private sector is any different from nurses employed in the private sector. However; as the private sector moves quicker to accommodate staff shortages is the nurse behaviour expected to be more stable in the private sector compared to the public sector.

The private homecare sector is like the public homecare sector simplified to only account for the nurses employed and clients being served; other infrastructure required to run a homecare service is not accounted for. The level of required infrastructure is highly flexible depending on housing patterns etc and does not lend itself well to meaningful formal modelling; *e.g..:* in some areas homecare nurses require no cars to serve different clients whilst in other areas each nurse require a car to commute between the different client's homes.

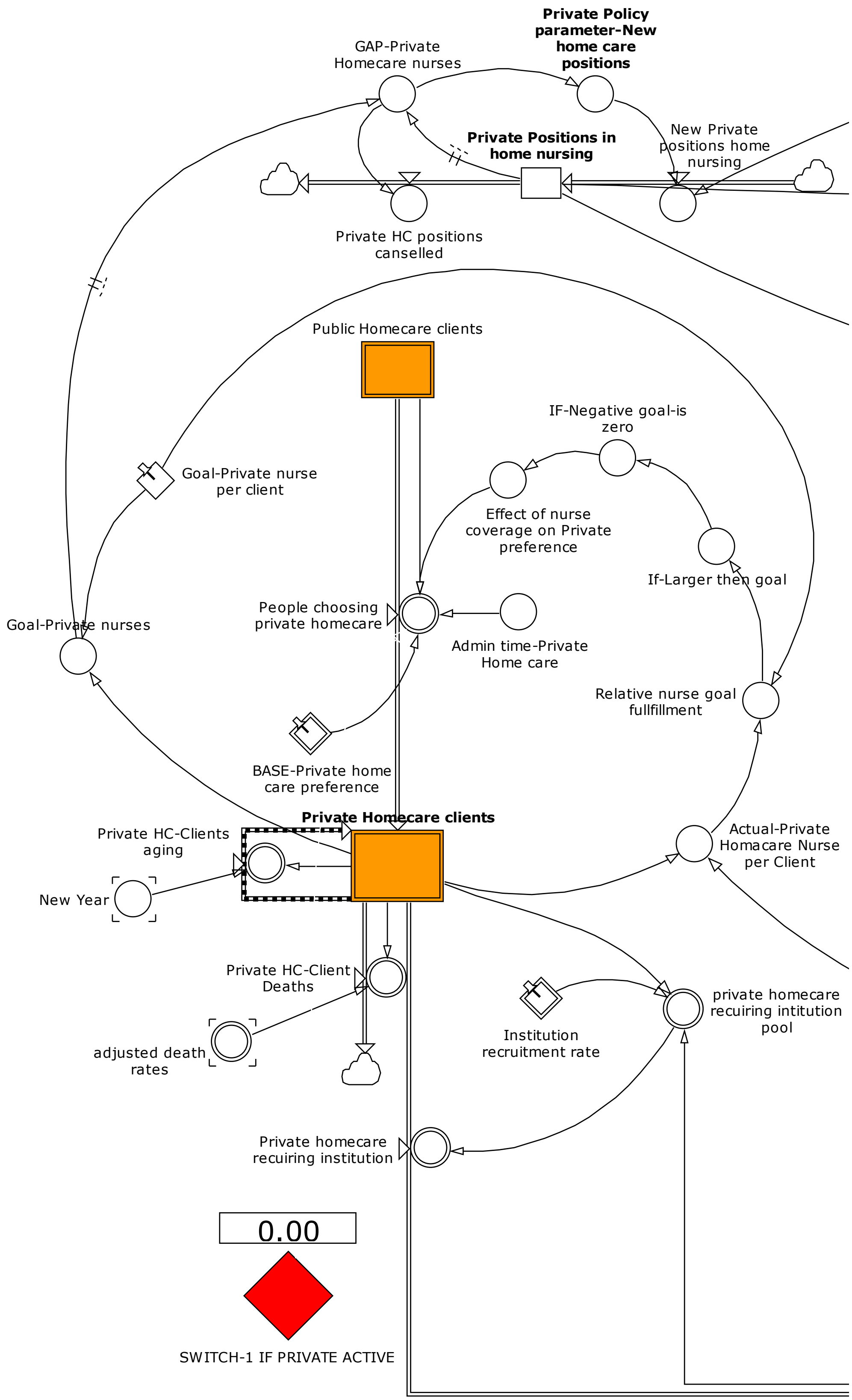


Fig 40: S&F - Private Homecare clients

The level “Private Homecare clients” accounts for the people choosing private homecare services; these people are drawn from the levels “In Homecare” and “People in need of institution bed” that are subsidiaries of the level “Public homecare clients” located in the Care Clients view of the Powersim model. When the Private sector is activated the constant “SWITCH-1 IF PRIVATE ACTIVE” must be assigned the value 1; when the private sector is to be inactive this constant must be assigned the value 0. This constant does not entirely switch of the private sector; to do that flows must be detached from the levels. The flow from “Public homecare clients” to “Private Homecare clients” is governed by the flow auxiliary “People choosing private homecare”. The level “Private Homecare clients” is subject to aging and death. People in private homecare may also acquire a need for an institution bed. “Private Homecare clients” is initialized by the auxiliary “Initial Private Homecare clients”. The initialization value is calculated based on the constant “BASE-Private homecare preference” set to 10% multiplied by the level “Public homecare clients”.

The auxiliary “People choosing private homecare” is defined as

('Public Homecare clients'* ('BASE-Private home care preference' *
'Effect of nurse coverage on Private preference'))
/'Admin time-Private Home care'

Preference is thus suggested to be the motivator for choosing private homecare and preference is assumed to be driven by the nurse coverage. Nurse coverage is a term referring to the nurse per client ratio. The constant “BASE-Private homecare preference” suggest that some people will always choose a private alternative, if such an alternative is indeed available. This base preference is affected by the nurse per client ratio in the private homecare service. The effect of nurse per client ratio is defined in the graphical function “Effect of nurse coverage on Private preference” where the input is the relative fulfilment of a goal of a nurse per client ratio set to 0.22. The graphical function suggests that the closer the private sector is to fulfilling the nurse goal the more people will choose the private alternative. The upper limit of homecare clients choosing the private alternative is set to 32 % by the graphical function;

the latter as value is chosen somewhat arbitrarily based on the assumption that it seems unlikely that more then approximately 30 % of the population can afford private homecare services.

It should further be noted that the GHPM assumes the quality of private care to be the driving force behind private preference over public; potential shortcomings of the public sector or the relative difference between the two sectors is not assumed to affect the preference of private care. The latter is assumed as some may always prefer the private alternative whilst others may prefer it but never be able to afford it; the quality of the private sector should therefore govern its attractiveness; the shortcomings of the public should be considered in this respect.

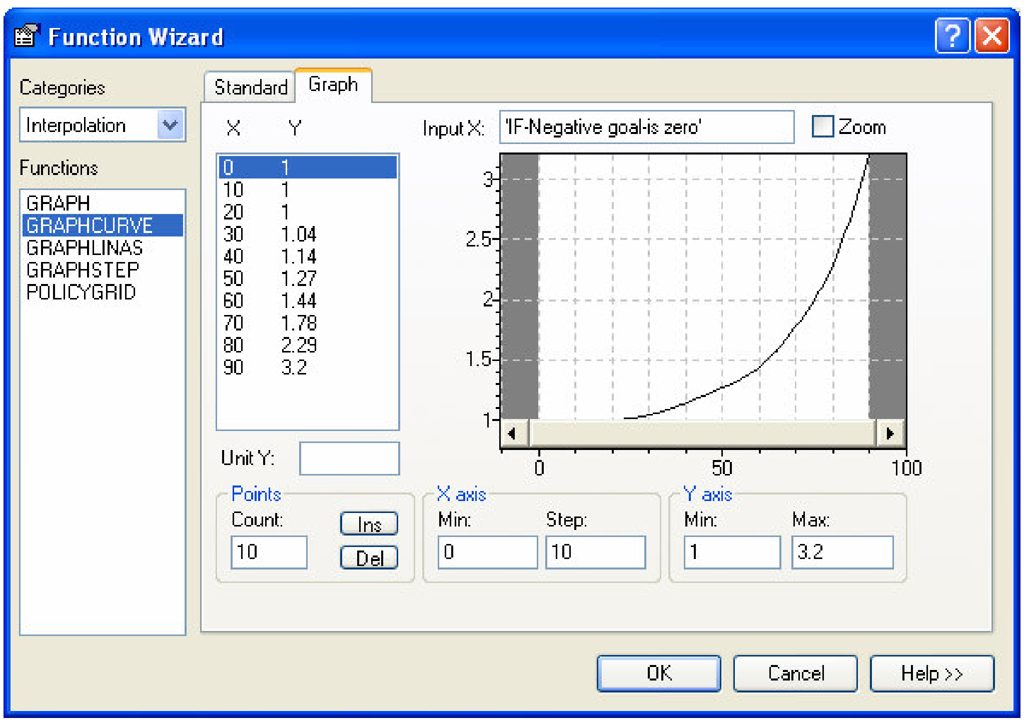


Fig 41: GRAPHCURVE function for "Effect of nurse coverage on Private preference"

There is as mentioned a set goal of a nurse per client ratio of 0.22 in the private sector; this figure is presented by the Norwegian parliament as a desirable coverage(Helseplan-2015, 2006). This goal is affecting the hiring rate of homecare nurses in the private sector. The constant "Goal-Private nurse per client" is translated into a number of required nurses in the auxiliary "Goal-Private nurses" by the equation:

ARRSUM ('Private Homecare clients')* 'Goal-Private nurse per client'

This figure is the used to calculate the gap between the desired positions and the actual positions defined in “Private Positions in home nursing”. The gap is then applied as a policy towards establishing new positions delayed only by the administrative time required to do so; defined in the constant “Admin time to establish new private nurse positions”. These new positions will then be filled by nurses through recruitment. The only difference between the private and the public Nurses components in the GHPM is the base attractiveness of the nursing positions. The private sector is assumed to enjoy a 6% higher attractiveness then the public sector; this is assumed as private sector tend to offer slightly better wages then the public sphere tend to do. Beyond this the two sectors treat the nurse dynamics equally.

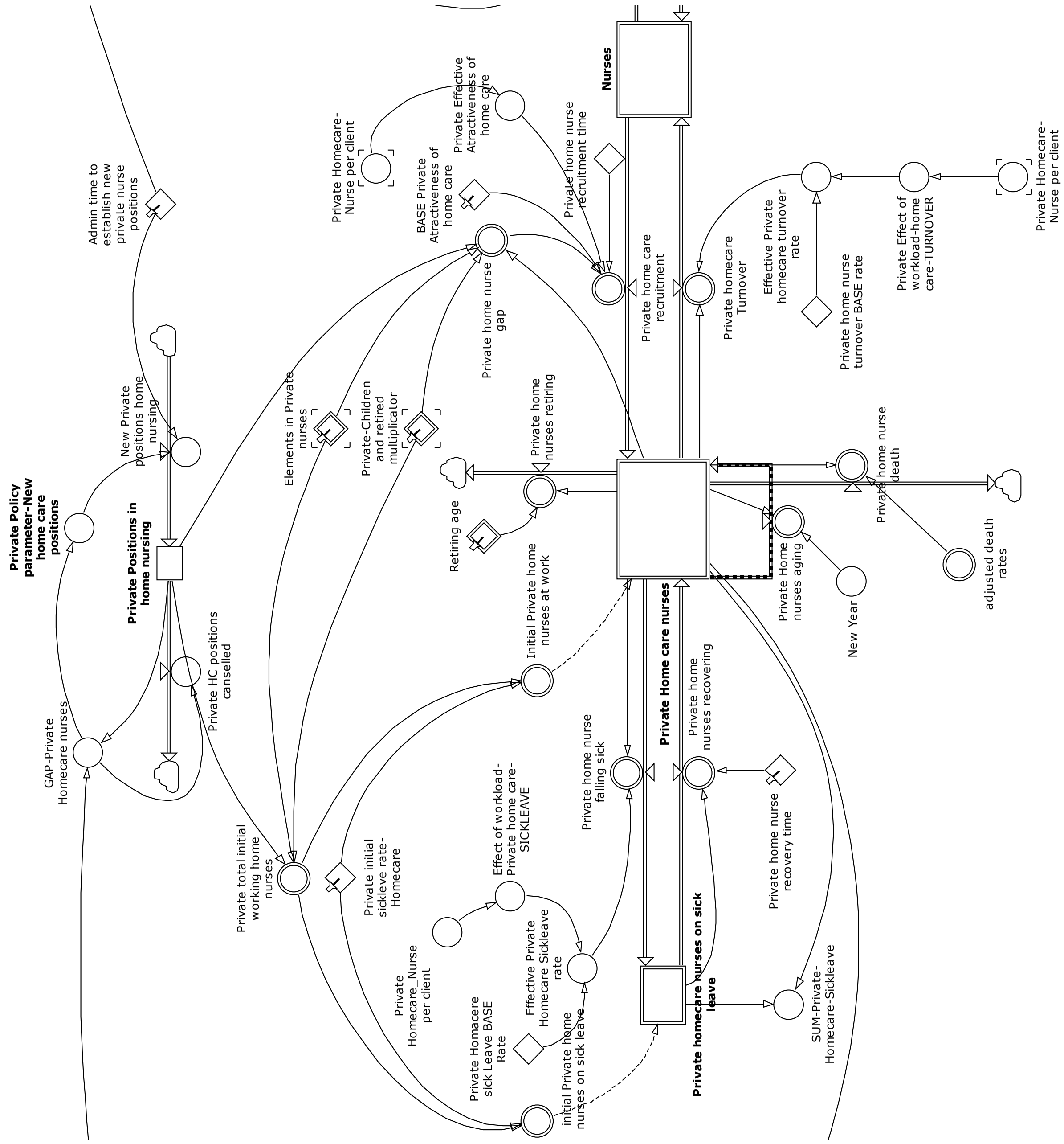


Fig 42: S&F - Private Homecare Nurses

The private institution component of the GHPM constitutes a rather simple model structure. As for private homecare the structural design of the nurse component in private institution is a mirroring of the dynamics in the public sector.

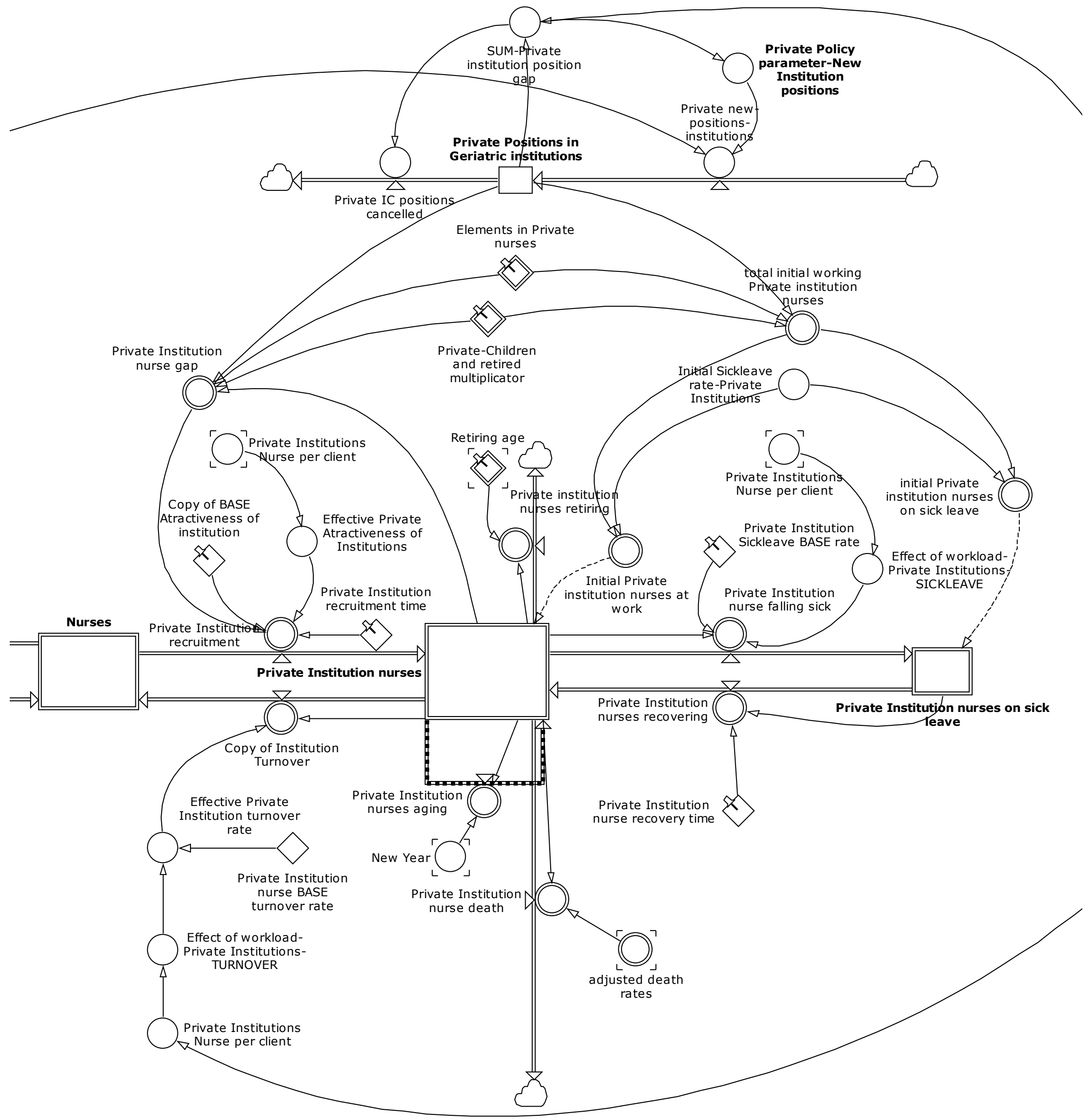


Fig 43: S&F - Private Institution Nurses

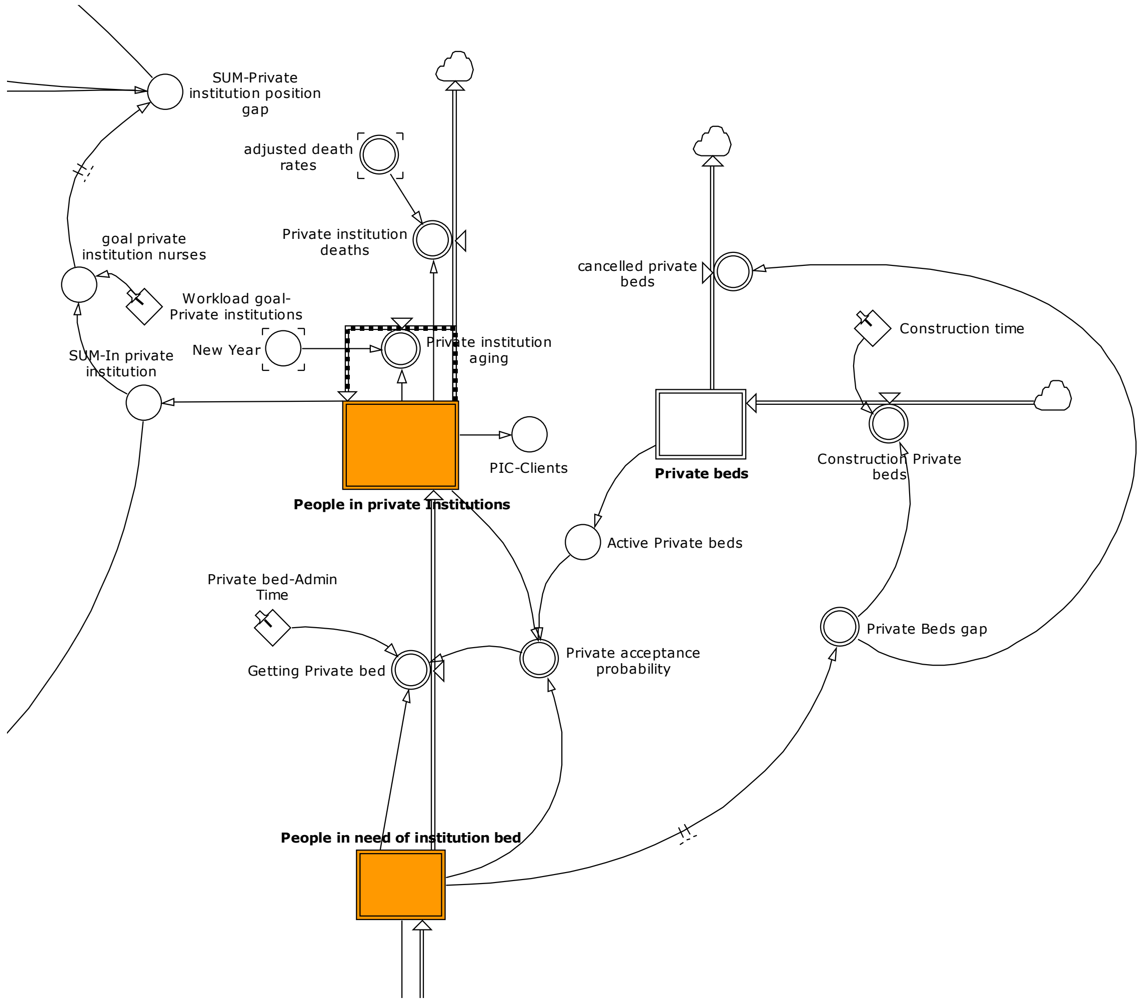


Fig 44: S&F - Private Institution beds

As the public sector nurse dynamics are thoroughly explained the above stock and flow diagram requires no further explanation. It should however be noted that the base attractiveness of becoming a private institution nurse is slightly higher then the attractiveness of becoming a public institution nurse. It should further be noted that the workload feedback in the private care sector is obviously drawn from the private nurse per client ratios.

The private sector is assumed to establish new institution beds when there is a backlog of people awaiting public institution beds. People awaiting a bed (or their families) are assumed to go far to provide the necessary institutional care. Furthermore; whilst some people cannot afford a private alternative, others can. The GHPM assumes that amongst the people awaiting beds some can afford a private bed. It is further assumed that people in public institutions may prefer a private alternative and hence enter the private sector thereby freeing a public bed. The latter dynamic is not specifically modelled partly for the sake of simplicity and partly due to problems of quantifying the private vs. public preference. Henceforth the level “People in private Institutions” only drawing people from the level “People in need of institution bed”.

As mentioned is the private sector assumed to establish new private institution beds based on the public institution bed waitlist; captured by the level “People in need of institution bed” in the Care Clients subcomponent of the GHPM. The actual number of required private institution beds is calculated in the auxiliary “Private beds gap” by the equation:

FOR (a=Age, b=Bydeler |

SLIDINGAVERAGE ('People in need of institution bed'[a, b], 3 years))

The FOR function defines the array dimensionality of the level “People in need of institution bed”. The Function SLIDINGAVERAGE calculates the average value of “People in need of institution bed” over a 3 year period. The average value is used as private business necessarily will attempt not to make investment decisions based on unrepresentative spikes in the waitlist information. New beds are established as a function of “Private beds gap”. The construction time for new beds is defined in the constant construction time and set to eighteen months. The actual construction is captured in the flow auxiliary “Construction Private beds” and private institution beds accumulate in the stock variable “Private beds”. The GHPM assumes that private beds are maintained; no decay function is applied for private institution beds. When the bed gap is negative and thus suggesting a surplus of private beds the “Private beds” level is adjusted in accordance to the surplus through the outflow variable “Cancelled private beds”. The “Private beds” accounts for the array dimensionality of the intended clients; this allows for analysis of the amount of people in each borough requiring beds at the time when the beds where constructed. Such analysis is not undertaken in this thesis; it is however the intent of the author to develop an open ended model that could be furthered at later stages. Beds are made available to anyone requiring a bed, regardless of whom a bed was “intended for” as private beds are allocated by the same probability logic employed in the public sector. The latter is reflected in the auxiliary “Private acceptance probability” where the total amount private beds summarized in the variable “Active private beds. “Private acceptance probability” is defined as:

IF ('People in need of institution bed'<=0 person, 0,

MAX (0, ('Active Private Beds'-ARRSUM ('People in private Institutions'))

/ (ARRSUM (MAX (0 people, 'People in need of institution bed')))))

The IF and MAX functions in the above equation are used to prevent the calculation from producing negative probabilities; the logic IF and MAX functions will replace negative probabilities with zero. The equation further calculates the difference between active private beds and the clients in the private institutions. This value is divided by the number of people awaiting a bed. This probability is assigned across *Age* and *Bydeler*.

People will move from the institution waitlist accumulated in the level “People in need of institution bed” to the level “People in private Institutions” based on their probability of receiving a private institution bed. The flow rate is governed by the time constant “Private bed-Admin Time” set to approximately two months.

The hiring of private institution nurses is directed by a nurse per client coverage goal defined in the constant “Workload goal-Private institutions” to 0.2. This figure is multiplied by the number of actual clients in the private institutions. The gap between the actual positions and the desired positions is then used as a policy parameter dictating the adjustment of established positions for private institution nurses. Hiring of new nurses as well as all other nurse workforce dynamics is captured in a model structure mirroring the nurse workforce dynamics in the public sector.

As the model structure for private institution reflects, the private sector is working in a more or less free market: they will establish positions and institution beds based on demand. The cost is not accounted for explicitly in the Geriatric Healthcare Projection Model. The only cost constraint introduced in the model is embedded in the preference equations in the private homecare subcomponent. Thus; the scope of the GHPM is not to model cost or economic feasibility of the private sector. The GHPM sets out to unveil future tendencies in the demand for geriatric healthcare services wherein a private alternative is a hypothetic scenario.

The private sector of the GHPM is developed as a policy alternative to be tested. The entire private sector will therefore be switched off by multiplying all flows from the public to the private sector by 0 during model testing where the private sector is indeed not an alternative, or by detaching the flow variables from the stocks they are connected to in the private and public structure.

7.9 Care Capacity

The Care Capacity view consists of a few simple variables used for calculating the nurse per client ratios for private and public home- and institutional care. Nurse per client is in this model the overarching capacity measure; along with the care bed waitlist. This view also contains a number of output graphs; the purpose of this view is simply to offer the reader a quick and easy access point for viewing the major system behaviours arising from different simulations.

The author contemplated developing a graphical user interface for the GHPM; such an interface would be located in the Care Capacity model view. This author dismissed this idea as developing an efficient user interface for the GHPM would be excessively time consuming; to develop user interfaces when complex array functionalities are applied is all but a simple process.

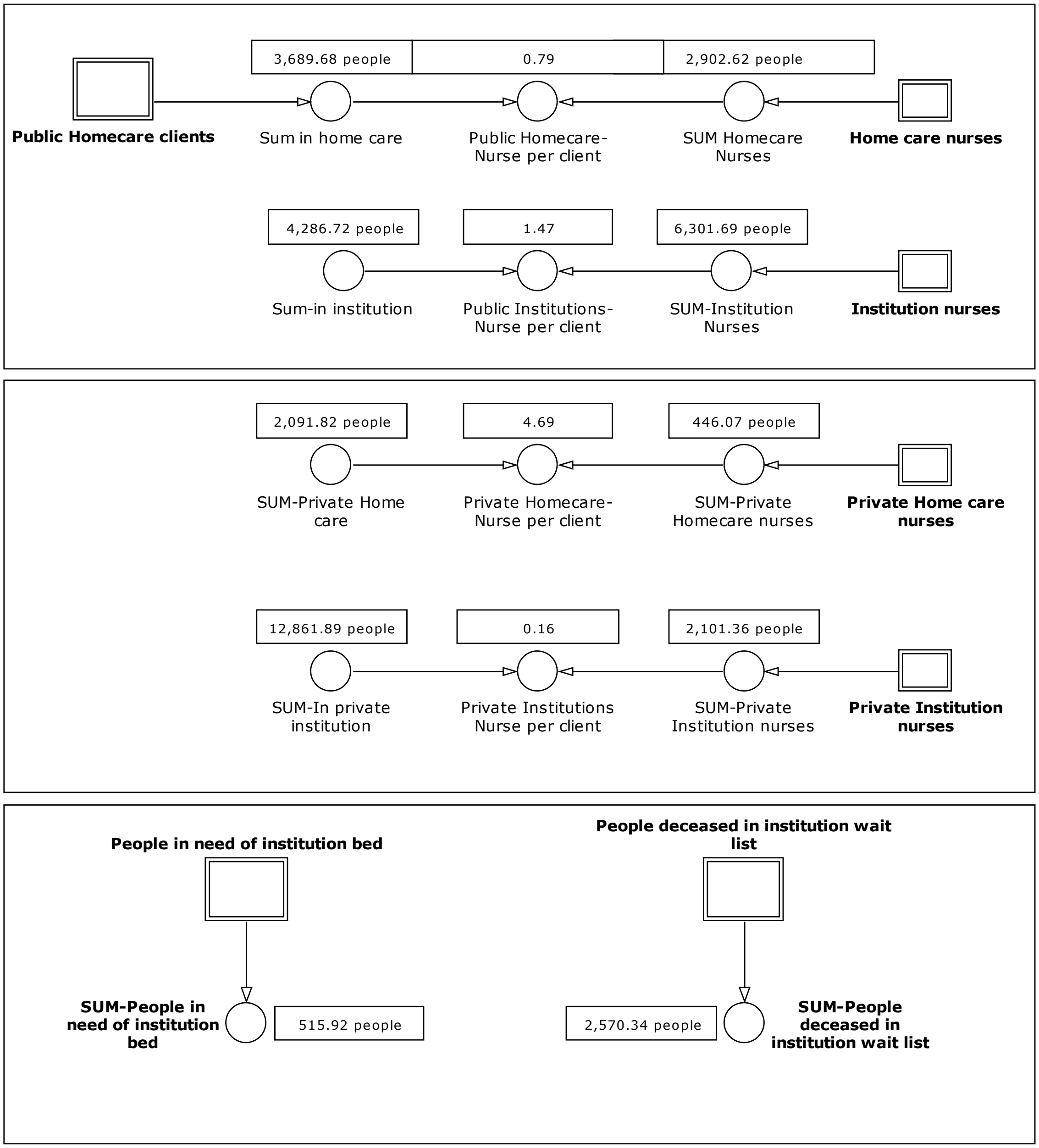


Fig 45: Care Capacity view

8. Validation

The Geriatric Health Care Projection Model is a large and multifaceted model; it covers a number of different aspects affecting the geriatric healthcare system ranging between underlying population dynamics, work conditions and qualitatively different categories of care in both public and private sectors. The model has been developed and parameterized based on data of varying lineage, resolution, uncertainty, error and accuracy. The model further employs arrays and array parameter matrices. In sum the GHPM is a vastly complex formal environment; to comprehensively validate such complexity is an exhaustive endeavour. The latter as many components of the model is derived from internal parameterisations and assumptions called for by limited access or existence of representative or meaningful reference data. The primary key towards validation of the Geriatric Healthcare Projection Model is embedded in the model structure. This is emphasised by the pronounced scope of the modelling exercise; to investigate basic behaviour and trends rather then producing accurate projection. Knowledge and understanding of the basic behaviour of the geriatric healthcare system and its proximate future dynamic challenges affords enhanced care planning. If the GHPM transcends such knowledge the modelling exercise must be deemed successful.

The first and most prominent element of validation of the GHPM is as mentioned embedded in the very model structure; if the model structure captures the important and governing stocks, flows, feedback loops and significant delays basic validity is afforded the model. As these elements are outlined and discussed in chapters 5, 6 and 7 they will not be revisited here. As a general comment it should however be added that the GHPM is a simplified representation of reality. The latter is true by default for all and any model; models are abstractions and abstractions are not reality. The latter does not infer that models are not meaningful; rather, the simplistic nature of a model is the very reason for its application. Whilst reality is infinitely complex and thereby chaotic a model may offer a manageable view on relationships blurred by the noise of the real world. The latter is well exemplified by maps; whilst a real world country is large and a utterly unconceivable to the human eye; a map of that country summarize and conceptualize its prominent features and provides the map reader with meaningful information. It is the purpose of the GHPM to provide information analogous to that of the map; it seeks not cover everything, only that of importance and significance. The simplifications applied in the GHPM thus enhance the models validity; the GHPM focus on the prominent features and attributes of the geriatric healthcare system.

This chapter of the thesis seeks to validate the model structure, parameters and derived behaviour of the GHPM through evaluation of model behaviour vs. reference modes. The

GHPM is further tested for robustness of key structures. Key parameters affecting the model behaviour is also tested for sensitivity. Given the GHPM's vast structure all parameters and components cannot be tested and documented in this thesis. Validation is therefore restricted to components deemed of dictating influence on the model's behaviour. Reference comparison, robustness and sensitivity of the various subcomponents of the GHPM is documented in the same order as the model has been outlined; the latter to ease the readers orientation and understanding. As the Powersim view Population Data does not represent any model structure but simply a data integration routine this view will is not tested for validity. Population data is however applied towards validation of the Population Simulation structure.

8.1.1 Population Simulation Reference mode.

The Population Simulation component of the GHPM is parameterized and calibrated based on the historic data embedded in the Norconsult population projection. This data ranges between the years 2000 and 2005. Validation against a reference mode must therefore be carried out for these years. As the GHPM is specific about age and boroughs these dimensions must be considered when comparing to a reference mode; to aggregate the data would infer great validation uncertainty as the model employs different parameters for different ages in different boroughs. If data was to be aggregated the sum of people at different ages could be right yet completely wrong in each respective borough. To demonstrate the similarity between the reference mode and the "Simulated Population" five sets of graphs are presented; these are snapshots of all ages in all boroughs at the turning of each year between 2000 and 2005. Each borough is represented by two graphs; the red trajectory identifying the simulated population and the green trajectory representing the historic data. As documenting eight boroughs and each with 100 age cohorts over a period of five years simulated with a timestep of 0.06 years is a space consuming endeavour one snap shot per year is deemed sufficient for reference mode qualification. The very short timestep of 0.06 years is only applied when documenting the validity of the population component; the timestep used for all other purposes is defined to 0.1 years. The reader is urged to consult the GHPM for further inquiries. The following figures start in year 2000 and ends in year 2005.

In the following population graphs age is defined along the X axis and people along the Y axis. The red trajectory identifies the simulated population whilst the green trajectory identifies the Norconsult population projection. The graphs are snapshots of a given moment in time; these graphs are not time graphs.

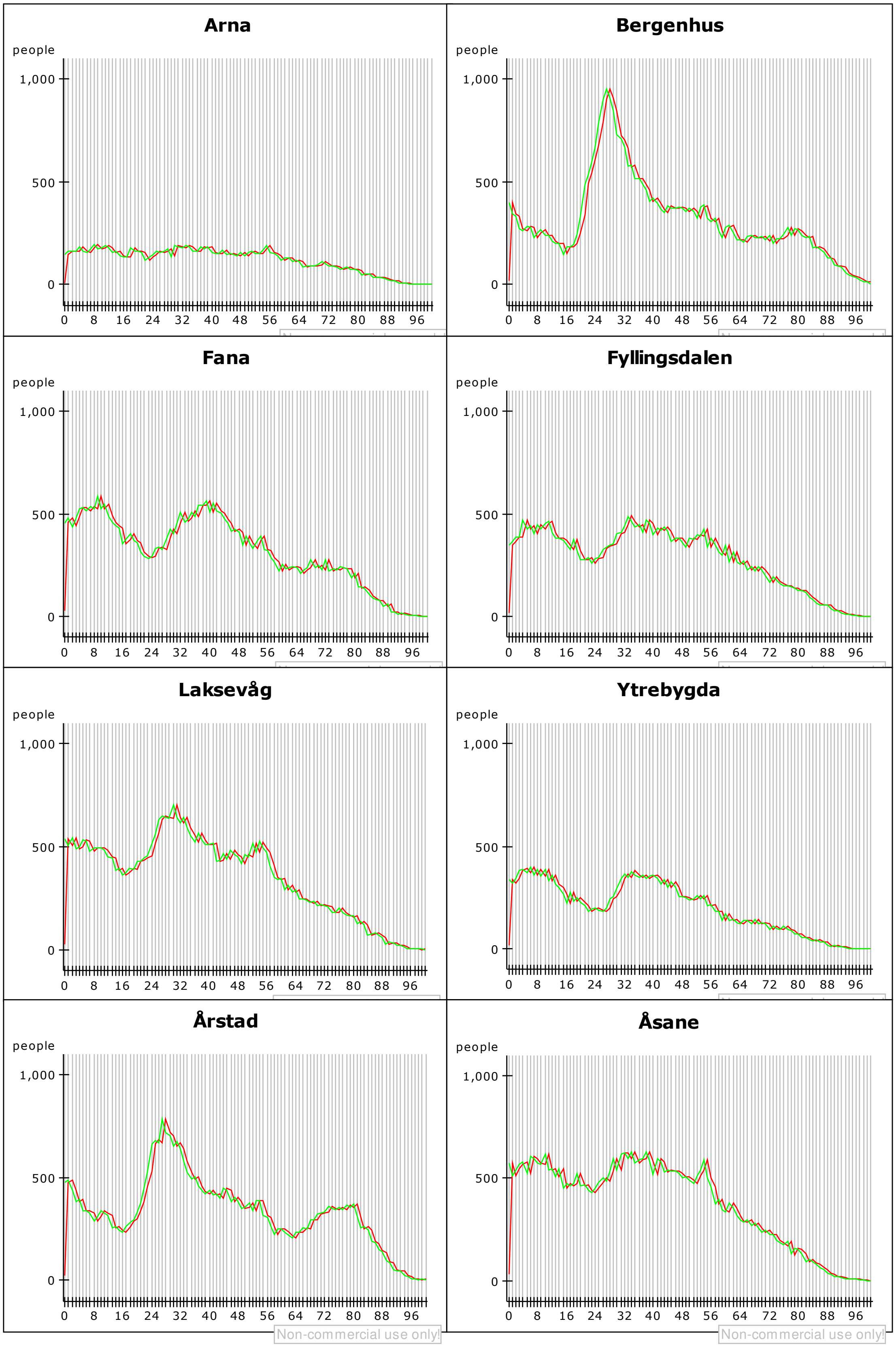


Fig 46: Reference mode and Simulated Population in 2000

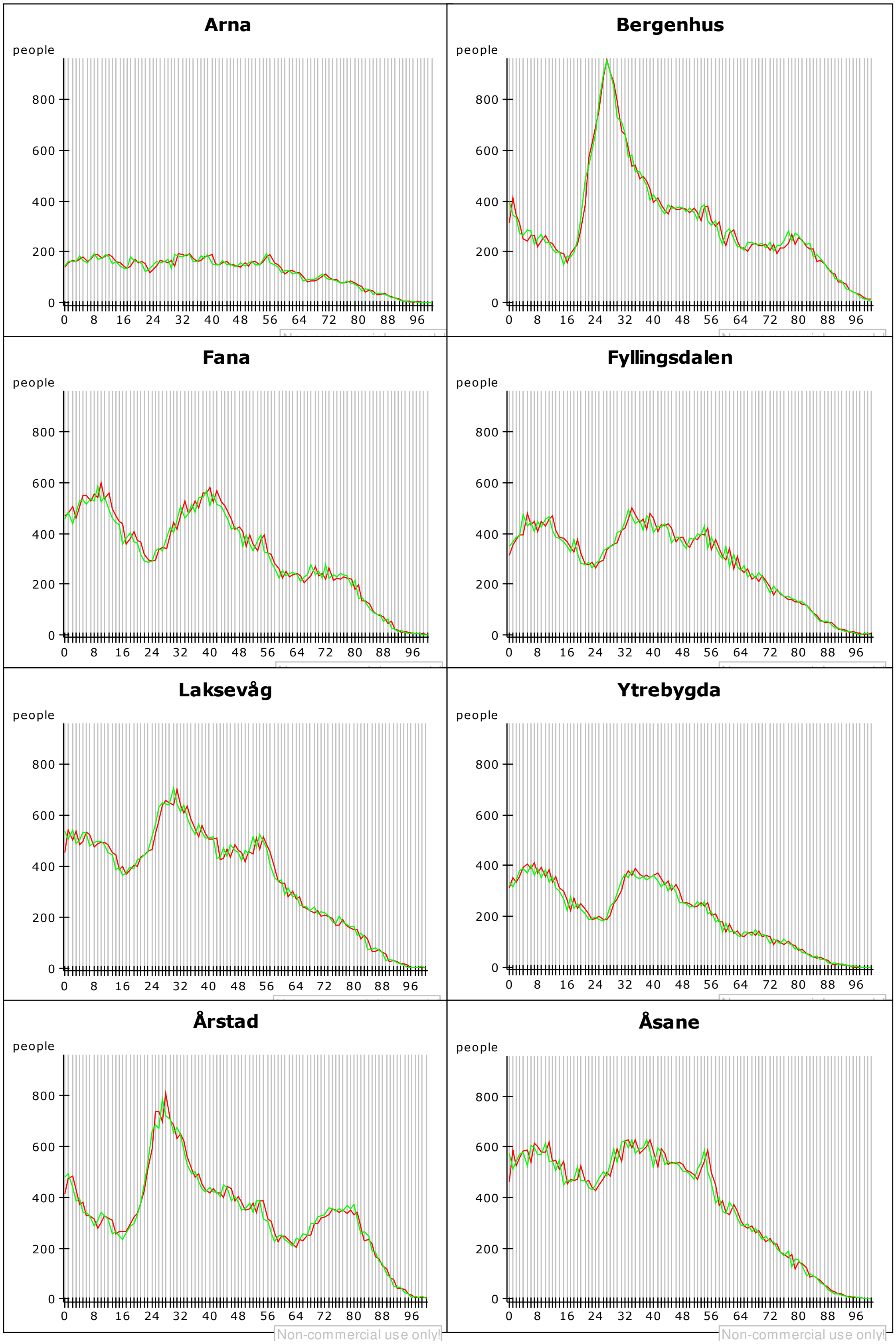


Fig 47: Reference mode and Simulated Population in 2001

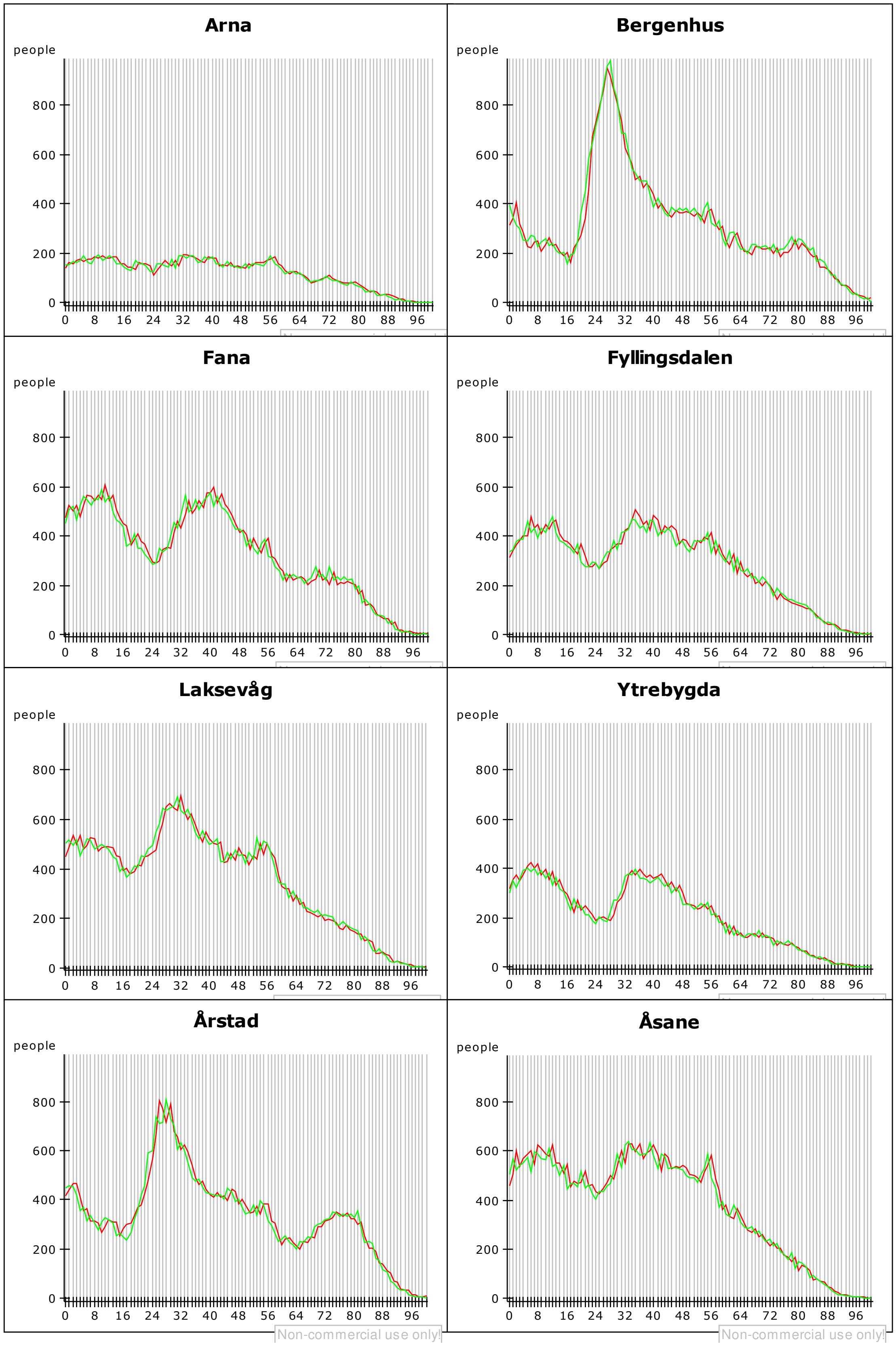


Fig 48: Reference mode and Simulated Population in 2002

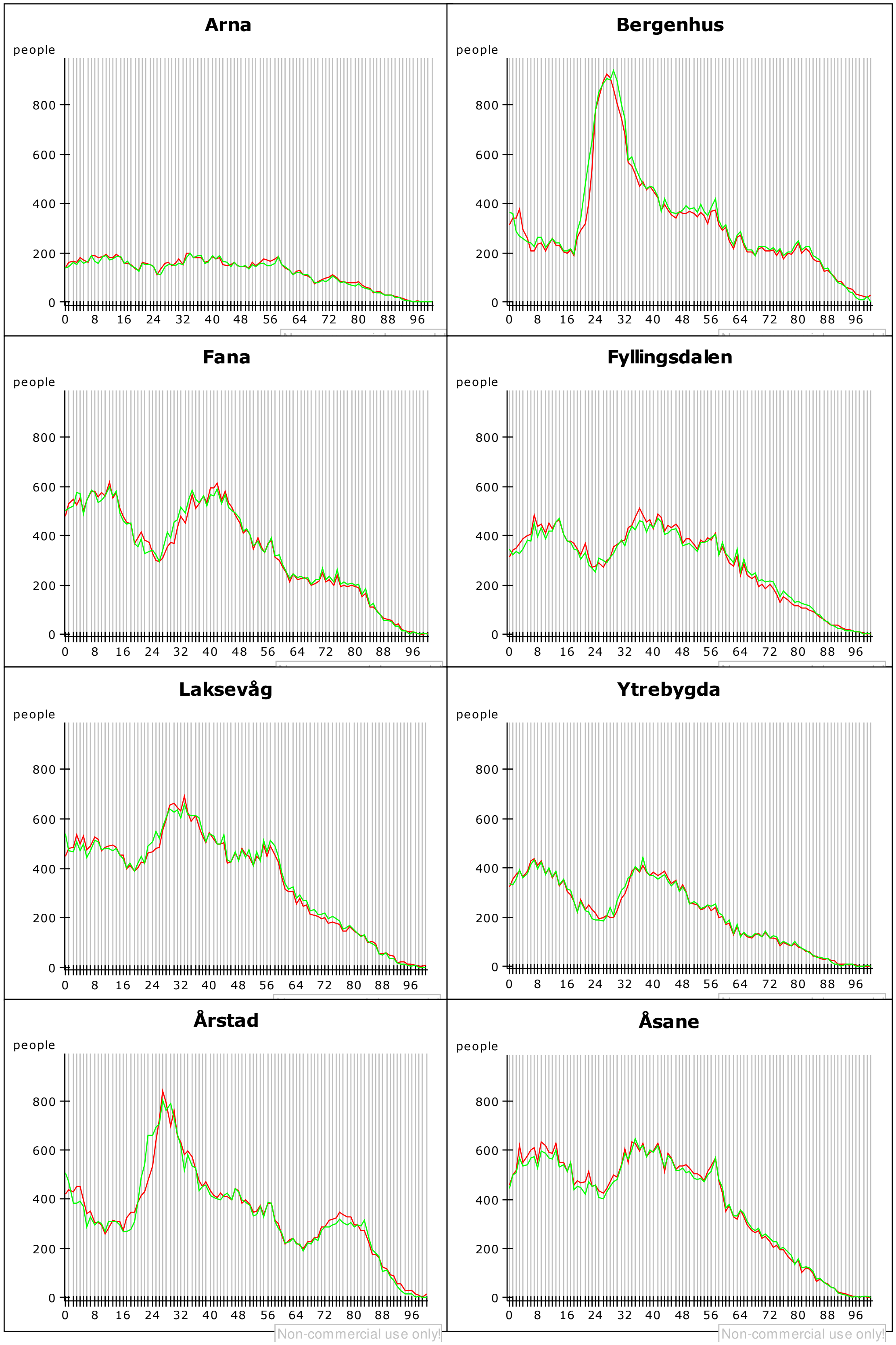


Fig 49: Reference mode and Simulated Population in 2003

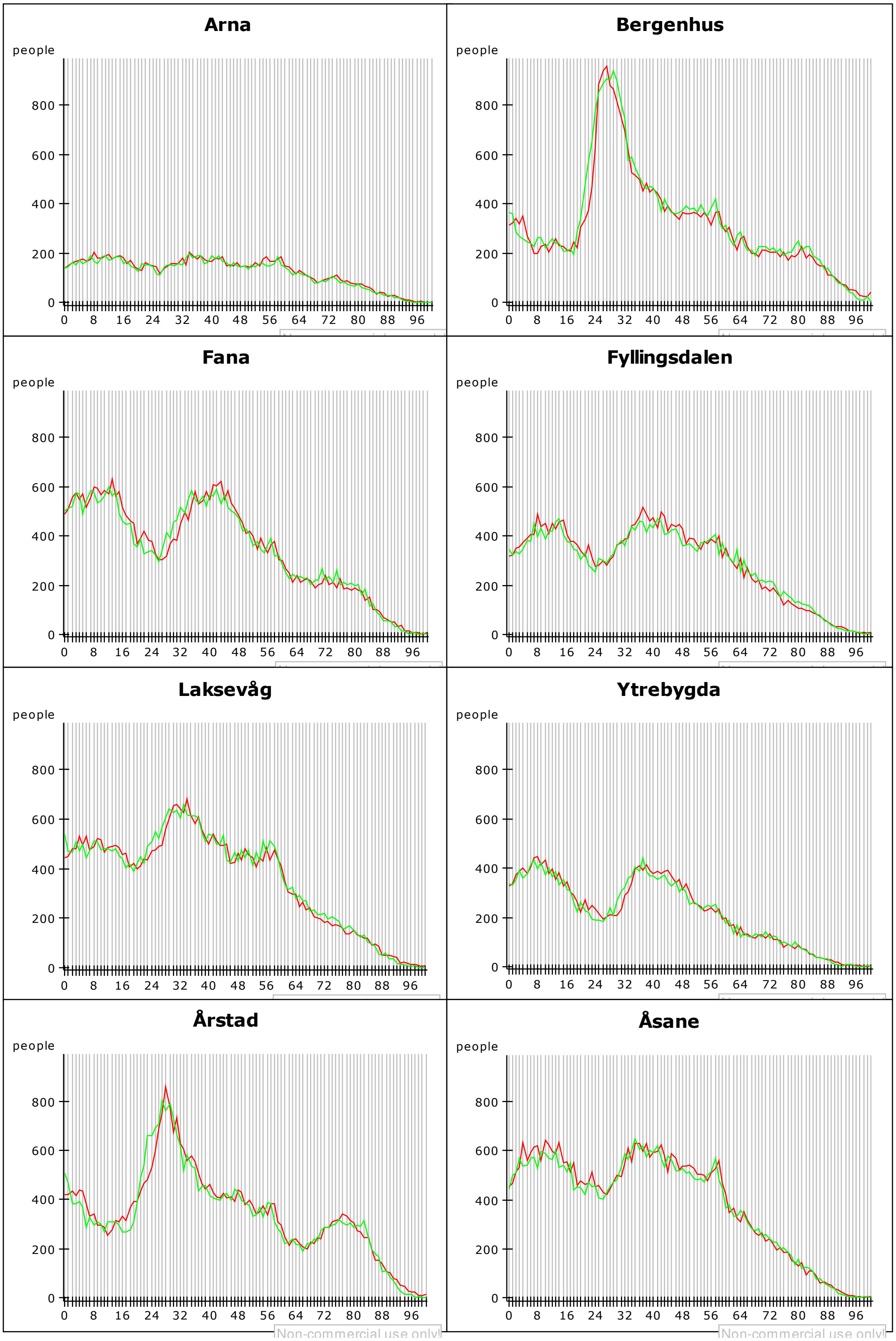


Fig 50: Reference mode and Simulated Population in 2004

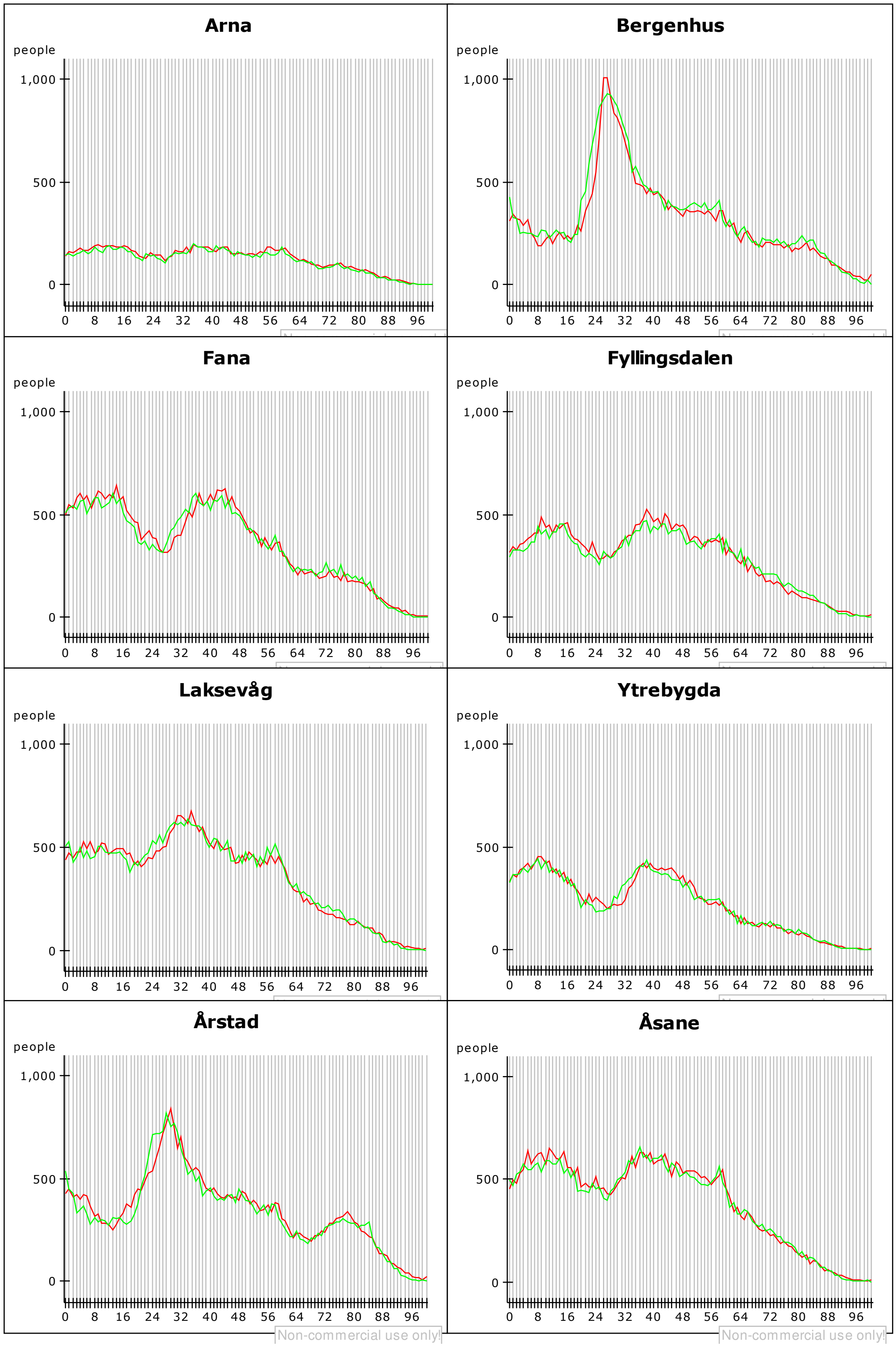


Fig 51: Reference mode and Simulated Population in 2005

Evidently the simulation is mimicking the reference data rather well; some discrepancies are to be expected as the model employs arithmetic constants whilst reality is subject to natural and random variance, fluctuation and coincidence. The goal of the population model is to reproduce the basic behaviour of the historic data; if successful in doing so this offers validity to the model. More historic data for comparison may be desirable; for the purpose of the GHPM this is considered superfluous. After all the GHPM targets behaviour of the geriatric health care system as an effect of population; modelling population dynamics is not the overarching scope of this project. To retrieve historic data at the resolution required for further reference has also proven expensive.

The population component of the GHPM assumes a very different approach then employed by the city of Bergen and Norconsult; whilst the Norconsult projection is rather static and arithmetic the GHPM is dynamic in its nature. It is to be expected that the GHPM produce a rather different population projection then what Norconsult has put forth. This is also the case and is evident when comparing the two population projections for year 2020. It is not the purpose of this thesis to challenge the work done by Norconsult or the city of Bergen. The GHPM may be applied towards other population projections. As no other projections reach beyond 2024 the latter is impossible and thus is the GHPM employing its internal population model for all purposes. The population component could be replaced by other projections at will; the model behaviour should still be robust. The latter will be revisited in the following section.

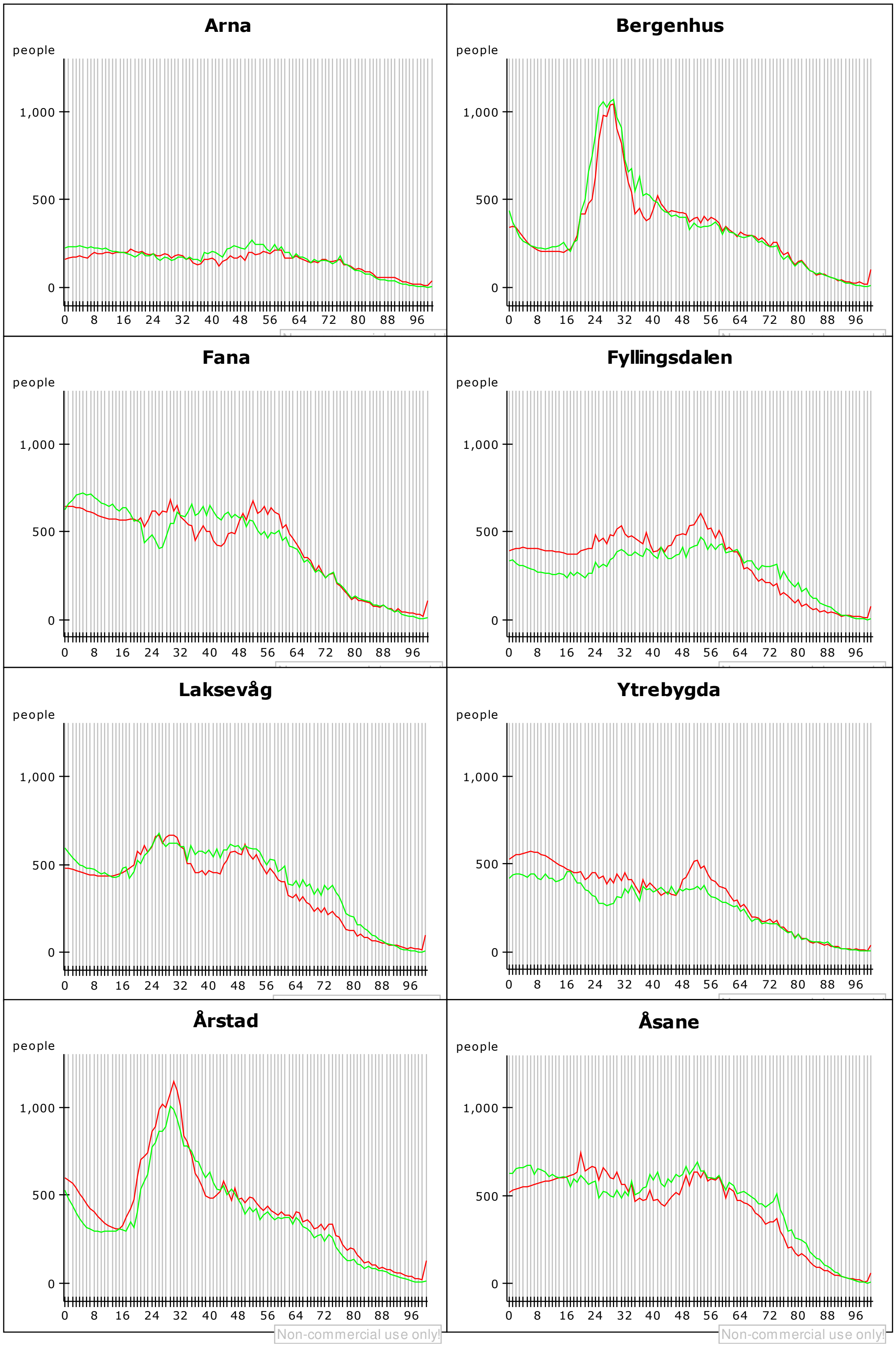


Fig 52: Reference mode and Simulated Population in 2020

The graphs above show different behaviour between the Simulated Population and the population projected by the city of Bergen and Norconsult. Different behaviour arises from different modelling approaches. Notable is it still that there still is resemblance between the two different projections. This lends validity to the GHPM as a completely different projection is produced by the simulation. The author is not suggesting that the Norconsult projection is completely wrong but rather that the GHPM assumes a different approach to demographic modelling.

8.1.2 Population Simulation Robustness testing

To test the Population Simulation component of the GHPM for robustness extreme conditions testing is undertaken. The first step of this is to test the model behaviour under the assumption that there is no addition of people to the population. By cutting births and immigration whilst keeping deaths active it is expected that the population will be dramatically reduced. This is also evident in *Fig. 53*; by removing births and immigration from the population simulation the population of the various communities is decaying towards distinction.

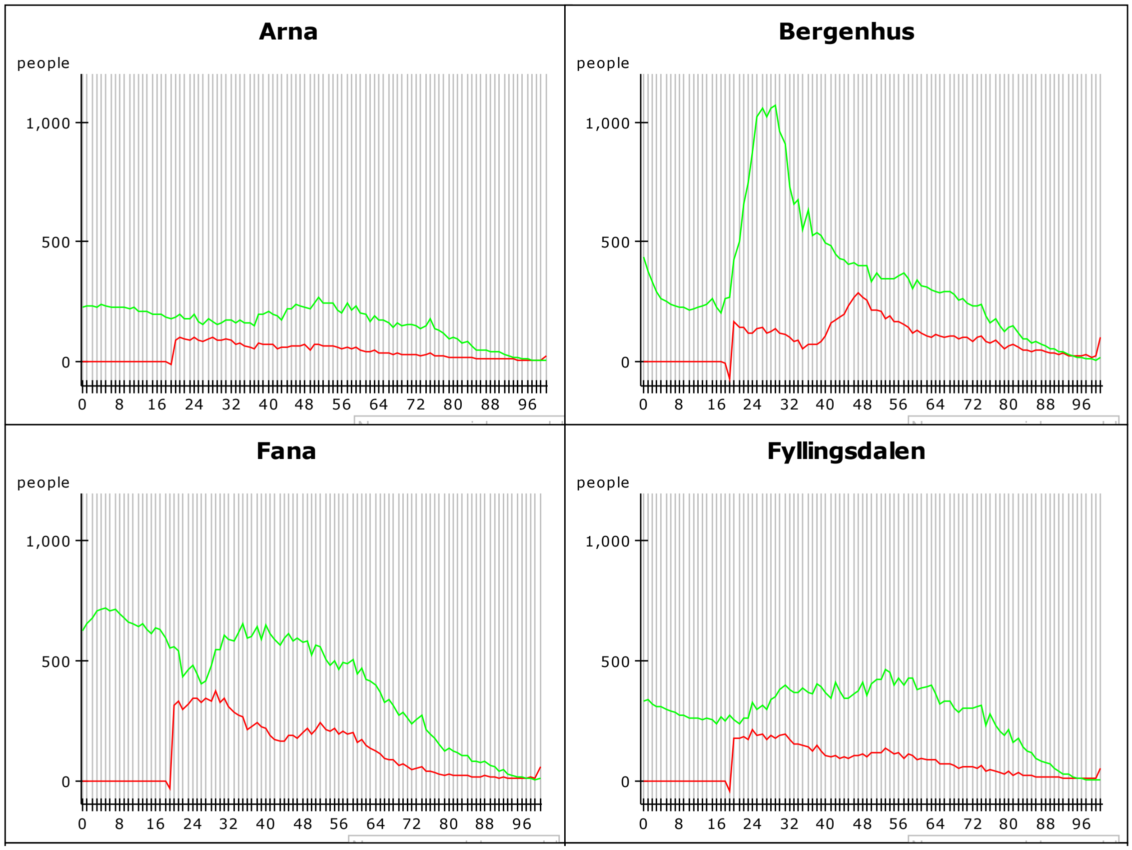


Fig 53: No Births or immigration-2020.

The snapshots above are taken in year 2020; the green trajectories (reference data) is left in to underline the difference between the two projections under these conditions where the GHPM simulation is not adding any people to the population.

The second extreme conditions test assumes that no one leaves the population stock through death or migration. It is in this case expected to be horizontal shifts of the age cohorts and an accumulation of people in the oldest age cohort.

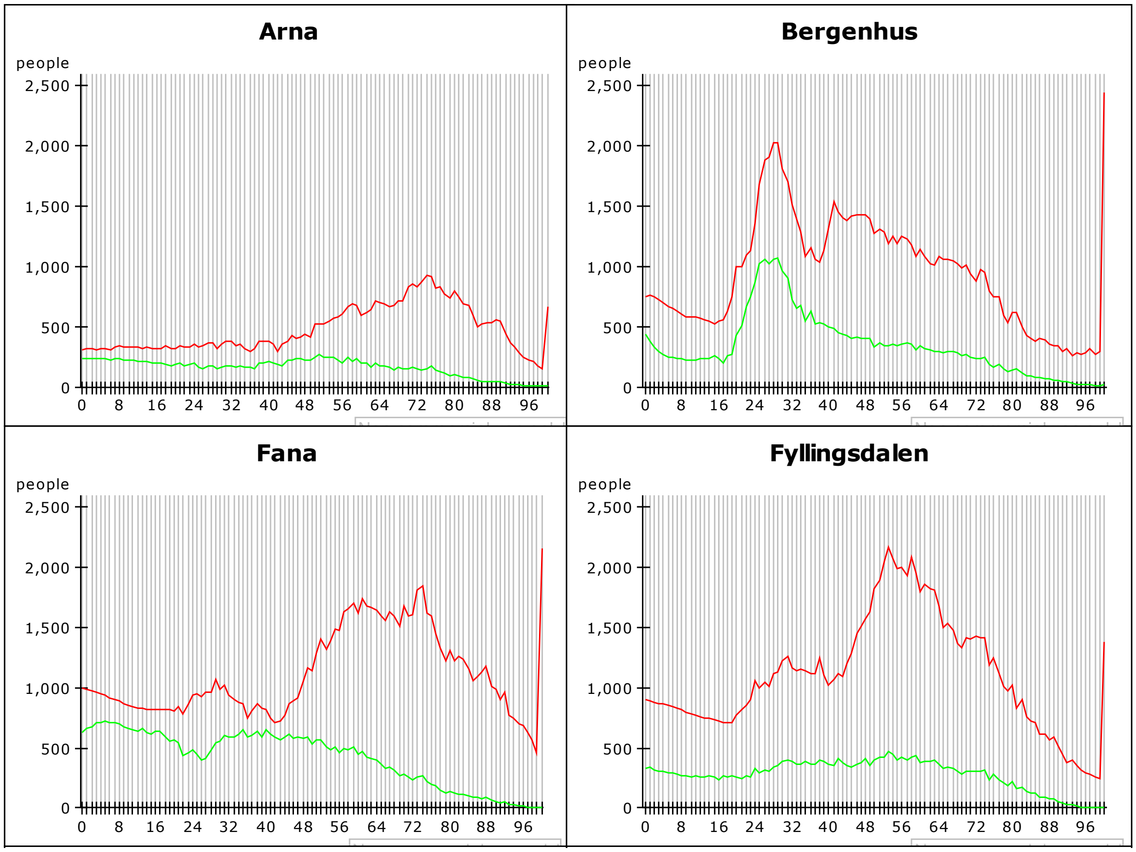


Fig 54: Selected Boroughs – No deaths or emmigration-2020

The above graphs demonstrate the expected behaviour; as nobody leaves the various levels through emigration or death, there is considerable accumulation of people in all boroughs. The accumulation in the oldest age cohorts is also evident.

8.1.3 Population Simulation Sensitivity Testing.

The population component of the GHPM is assuming that life expectancy will increase over the next 40 odd years. The GHPM assumes that in 2050 life expectancy will have increased by 15 %. This figure is based on the development of life expectancy between 1950 and 2000. The population simulation's sensitivity to this figure is obviously interesting as the population projection employed by the city of Bergen does not account for such a dynamic development. The sensitivity to this parameter is tested in four scenarios. The base-run employed is the 15 % increase of life expectancy during the 50 year simulation period; as outlined earlier increased life expectancy is modelled by a linear graphical function affecting the mortality rates.

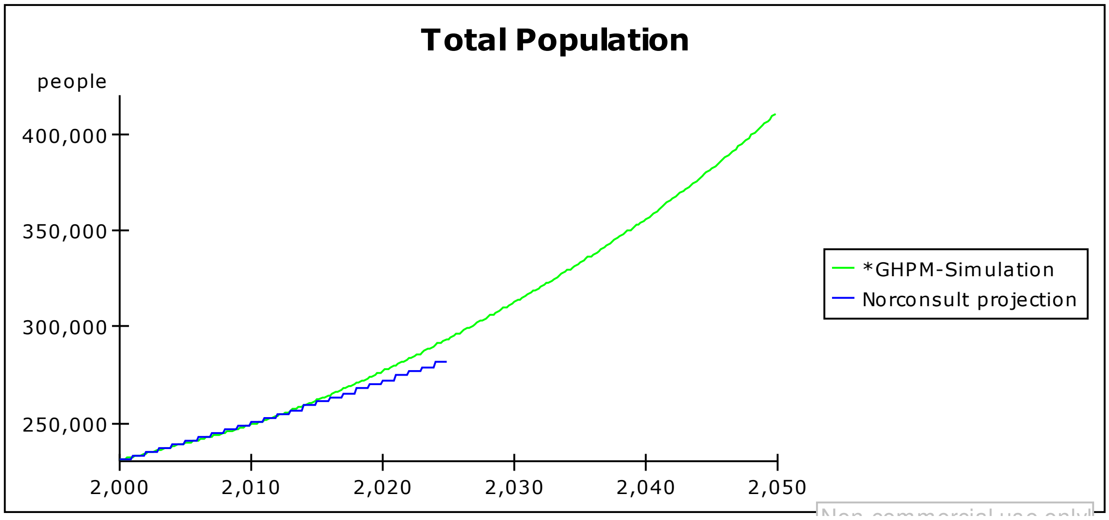


Fig 55: 15 % increase of life expectancy through 50 years

Fig. 55 demonstrates the baserun of the validity testing of the dynamic life expectancy parameter; the baserun is here and will in succeeding graphs be denoted by the "*" symbol. The Total Population graphs identify the simulation year along the X axis. The graph denotes the simulated year along the X-axis and the total population of the city of Bergen along the Y-axis. The Norconsult/City of Bergen projection is also visible in the above graph. As the latter projection only is calculated until 2024 the trajectory of this projection obviously also ends at this point in time. It's evident in Fig. 55 that the increased life expectancy is affecting the population development; the trajectory departs from the linear Norconsult projection around 2015 and demonstrates a slight exponential behaviour. From this it can be ascertained that the graphical function employed to capture mortality changes is indeed introducing dynamic behaviour to the population simulation. It further emphasizes the shortcomings of omitting such important dynamics in population projections. When simulating without the dynamic graphical function altering life expectancy the following behaviour is evident.

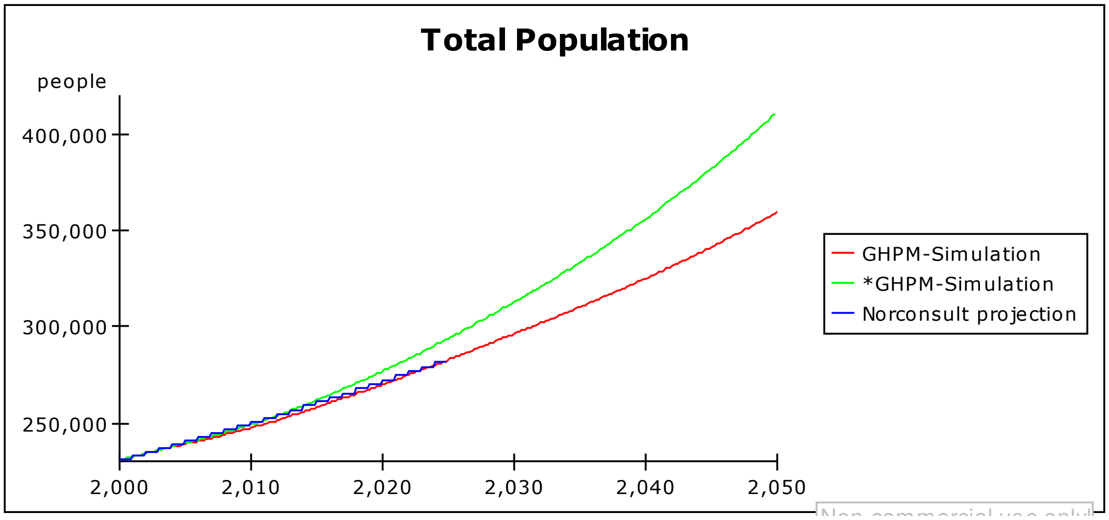


Fig 56: No change in life expectancy

The above graph demonstrates the effect of omitting a gradual increase of life expectancy. The green trajectory denotes the baserun of 15 % increase in life expectancy whilst the red trajectory identifies the population development if mortality rates are kept constant; evidently is this nonlinearity important and henceforth is henceforth enhancing the validity of the population simulation. It should be noted as this above graph also draws validity to the population simulation as the simulation run is closely correlated to the Norconsult projection as far as this projection can be regarded a representative reference mode. This again draws further validity as the population simulation of the GHPM is able to reproduce another qualified projection as well as enhancing it by incorporating known and expected tendencies in life expectancy development.

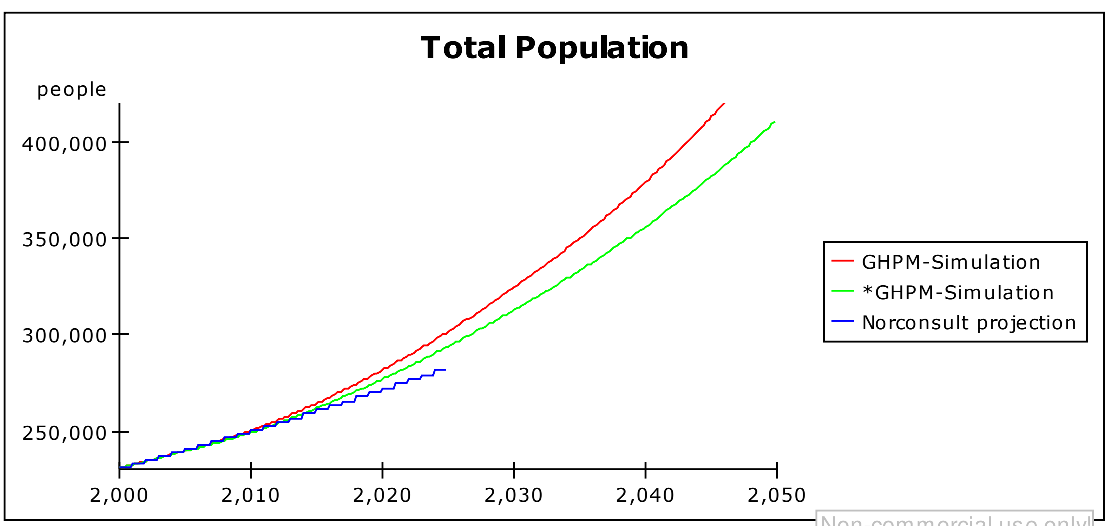


Fig 57: 25 % increase of life expectancy

Fig 56 shows, along with the Norconsult projection and the baserun, a 25 percent increase of life expectancy. Evidently a 10 percent shift of this parameter is significant; much steeper tangent slopes are evident when the life expectancy is increased by 10 percent relative to the base run.

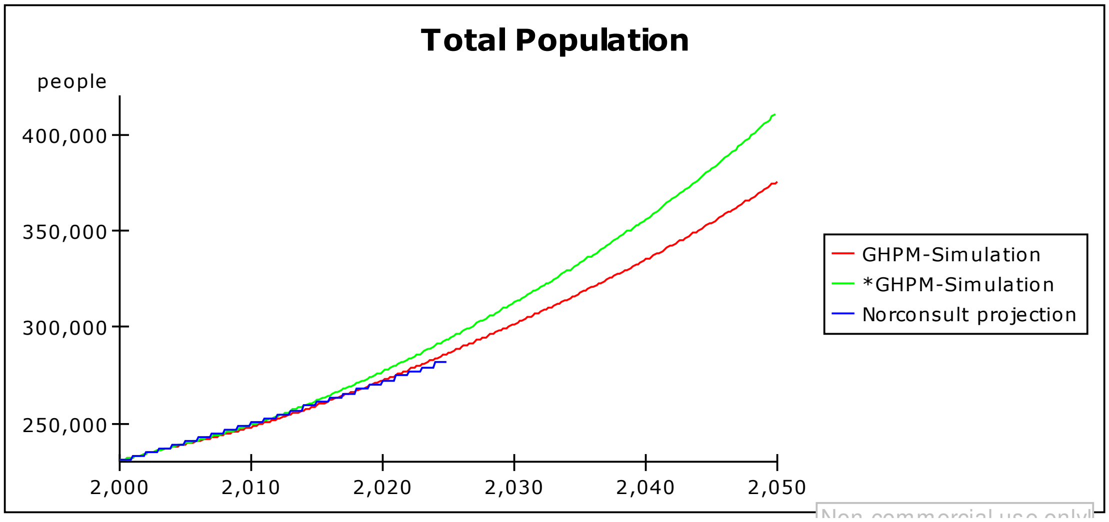


Fig 58: 5 % increase of life expectancy

The above graph shows the simulated population behaviour when life expectancy is increased with 10 percent less then the base run. With a total increase of life expectancy of 5 % the simulated population exhibits a slower rate of growth.

It appears to be safe to consider the population simulation to be sensitive to the rate of change of life expectancy. When no change of life expectancy is simulated the simulation is by and large reproducing and furthering the Norconsult projection. With a dramatic 25 % increase of life expectancy the simulated population appears to be growing rapidly; the growth rate is lesser when the life expectancy is subject to less change. All further validation and policy testing employs the change of mortality here denoted as the 15 percent baserun.

8.2 Nurse Pool - Validation.

As mentioned earlier there is no data or statistics on educated nurses available on the city level; Statistics Norway only offers statistics on the aggregated statistical unit of educate health and care personnel and this is thus of no use to the GHPM. The author has consulted a number of databases as well as the nurse labour union but has not been successful in retrieving data at the desired resolution. Statistics Norway will release data at this resolution in fall 2008; the GHPM may then be further parameterized. Thus; a data reference mode is therefore not available. The internal consistency of the Nurse Pool component of the GHPM may be tested for extreme conditions. As this component is a modelled mainly to provide an open end for further development as well as providing a recruitment pool for geriatric care workers expected never to be depleted this component will not be tested for sensitivity.

By cutting all outflows from the "Nurse" level it is expected to see an accumulation of nurses.

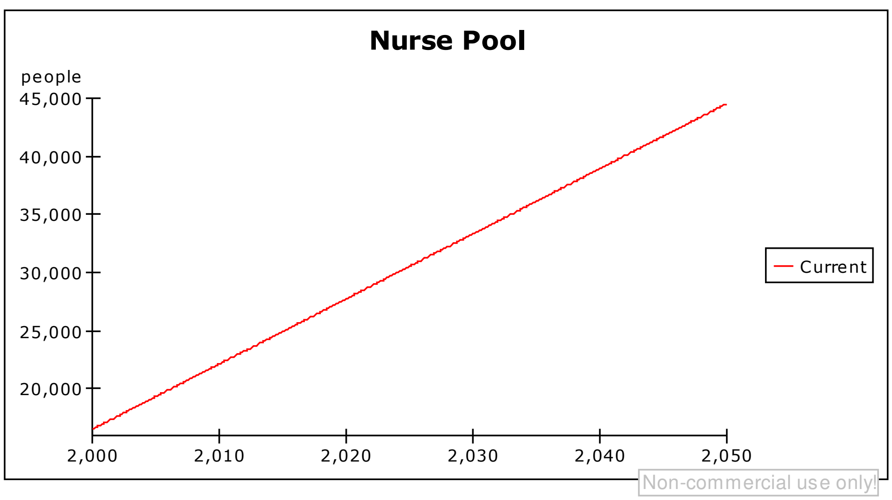


Fig 59: "Nurses" - accumulation as all outflows are cut of.

As the above graph demonstrates the expected behaviour is evident. When cutting of the inflow to the nurse pool the opposite behaviour is expected; in this scenario the nurse pool is expected to diminish; this is also the result as shown in the graph below.

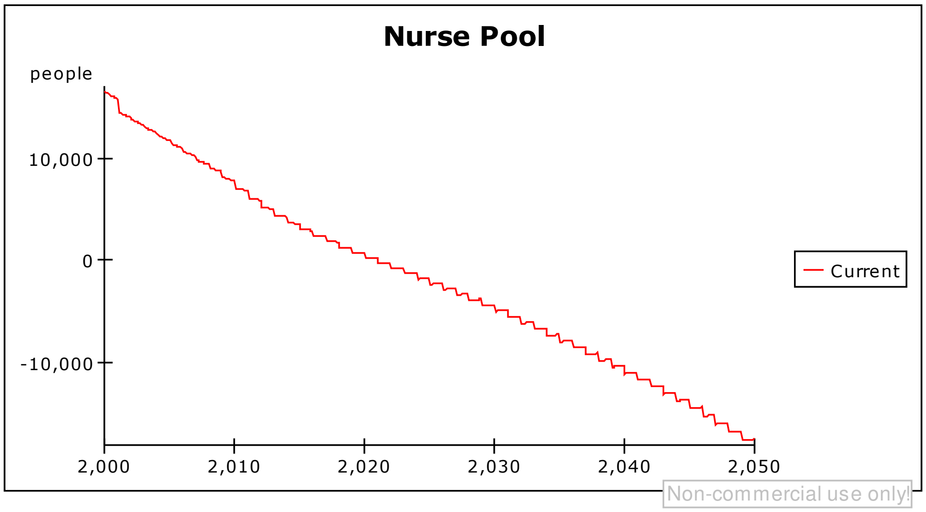


Fig 60: *Depletion of nurse pool*

The above graph shows that negative values of the nurse pool results from no inflow. Negative values are not illogical in this respect; they identify and enumerate a shortage of labour.

The GHPM is tested both with and without a private sector active; these two different scenarios are as expected taking different tolls on the nurse pool. This is expected as the addition of a health care sector obviously calls for more nurses

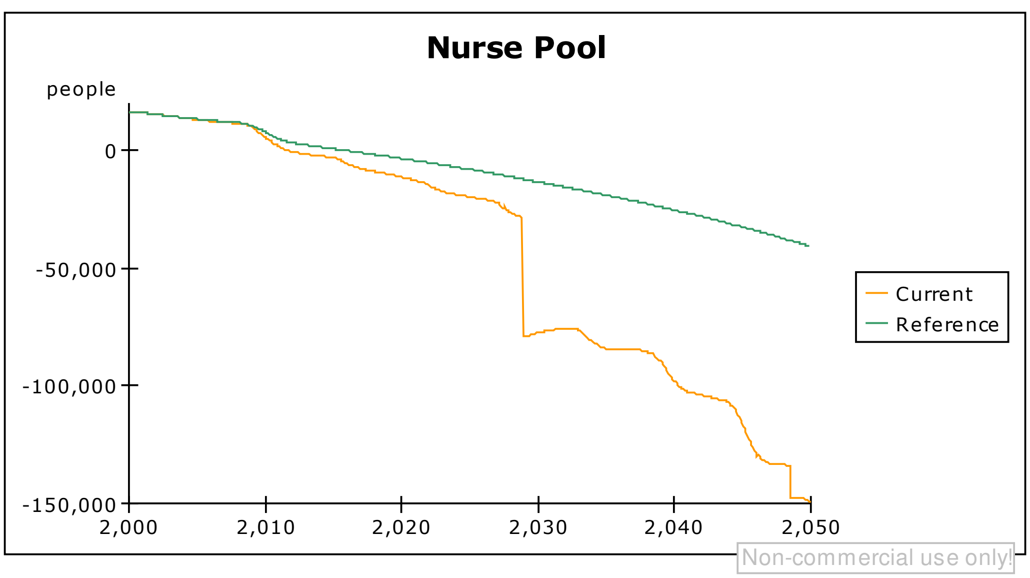


Fig 61: *Nurse pool behaviour with and without Private sector*

In the above graph the “Reference” trajectory identifies system behaviour whit only a public care sector, the trajectory labelled “Current” identifies the system behaviour with both private and public sectors activated. The above graph shows that the nurse pool is sensitive to the employment of nurses. The graph can however not be used to outline a general nurse capacity problem; the nurse pool is not parameterized to allow for such conclusions. However; the graph is suggesting that many more nurses may be required in the future considering that geriatric nurses only account for a limited number of the total nurse pool. It should also me underlined that the behaviour of the nurse pool is not realistic; the figures are way off. This problem is accredited to problems related to the integration errors due the array functionality in Powersim. The problems may be solved but this has not been considered important to the author; the purpose of the model is to model the geriatric health care sector and not the overall nurse situation. From the behaviour of the Nurse Pool it may however be asserted that when a public sector is active more nurses are required and that there is a general trend towards rising demand for nurses. The Nurse Pool is brought into the model to raise awareness about the notion of labour supply as well as facilitating an open end for further model development.

8.3 Care Beds Validation

The GHPM projects future events; providing reference modes for comparison is henceforth a problem as any data necessarily also would be projections. It can however be deduced that as the elderly population is expected to increase, the number of geriatric institution beds must also increase, granted that the political environment does not change dramatically. The graph below demonstrates the model behaviour for public geriatric institution beds when the private sector is deactivated. The behaviour is as expected showing an increasing number of beds through time.

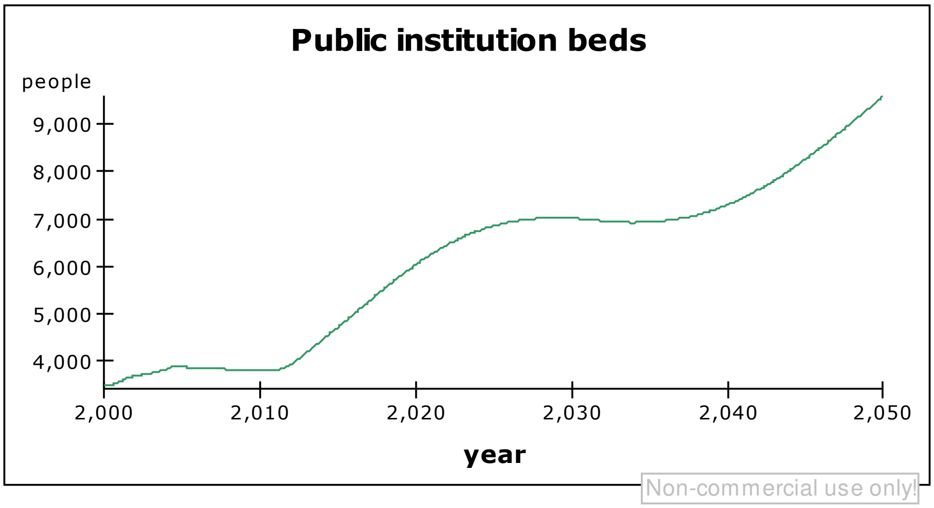


Fig 62: Public institution beds base projection.

The GHPM assumes that the number of public beds is adjusted according to the demand for institution beds. If this assumption is annulled it is expected that no beds will be added after 2011; prior to 2011 bed acquisitions are governed by external data.

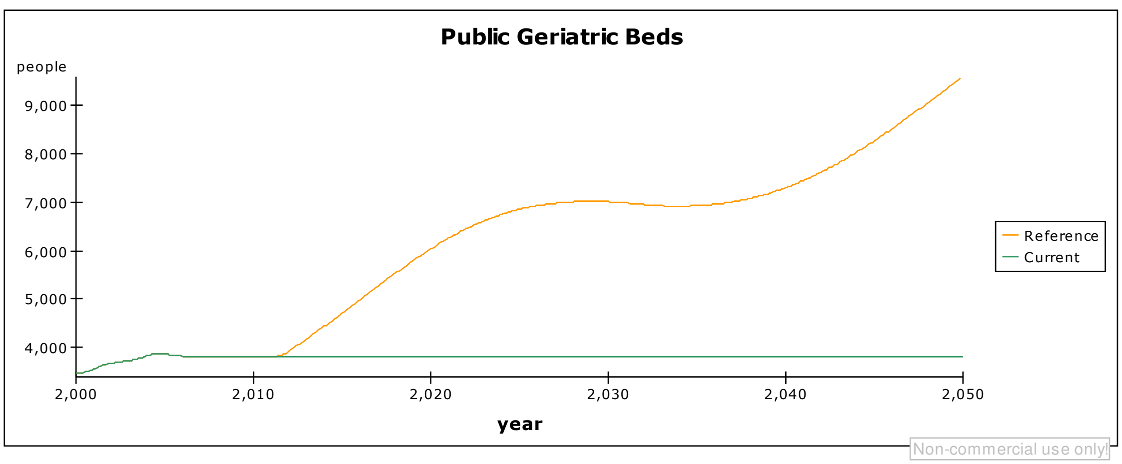


Fig 63: Public beds not adjusted according to demand

The above graph shows that when the demand is not allowed to govern bed adjustment there are no beds acquired. The trajectory labelled "reference" reflects the base run behaviour where beds are adjusted according to demand changes. The Care beds component of the GHPM appears to be robust.

Delays in public policy have been suggested as an important behavioural influence. It is therefore interesting to consider the sensitivity of the Care Beds component towards delay times. The graph below shows the development of public geriatric beds when the construction delay is reduced by 50 percent.

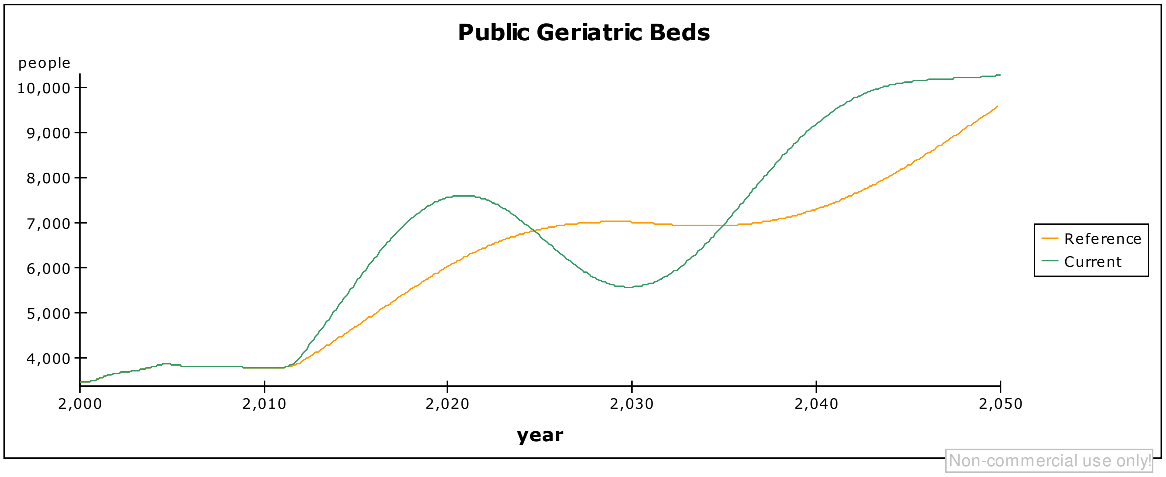


Fig 64: Public geriatric beds - Sensitivity towards reduced construction delays

The graph above suggests that the number of geriatric beds is sensitive to changes in construction time. When testing with a 50 percent increase of construction time the following behaviour is exhibited:

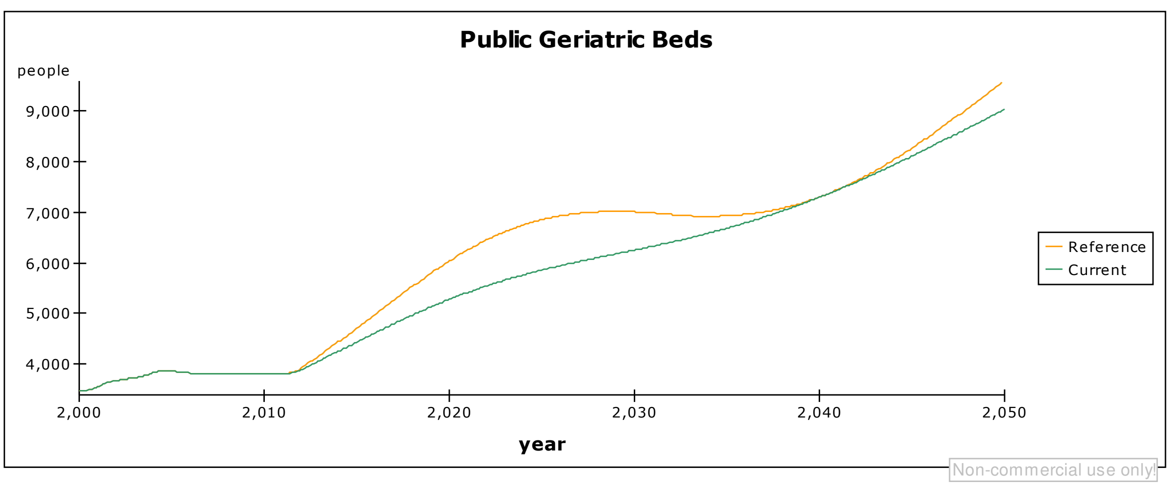


Fig 65: Public geriatric beds - Sensitivity towards reduced construction delays

Evidently increased delays in bed construction dictate a slower rate of bed construction. The latter is expected and intuitive; it is however an important notion as this sensitivity may provide insights into the impact of public policy efficiency.

The above sensitivity analysis assumes no private sector. The public geriatric beds development is expected to be sensitive to an introduction of a private sector as a private alternative would alter the need for public geriatric beds. This indeed also the case:

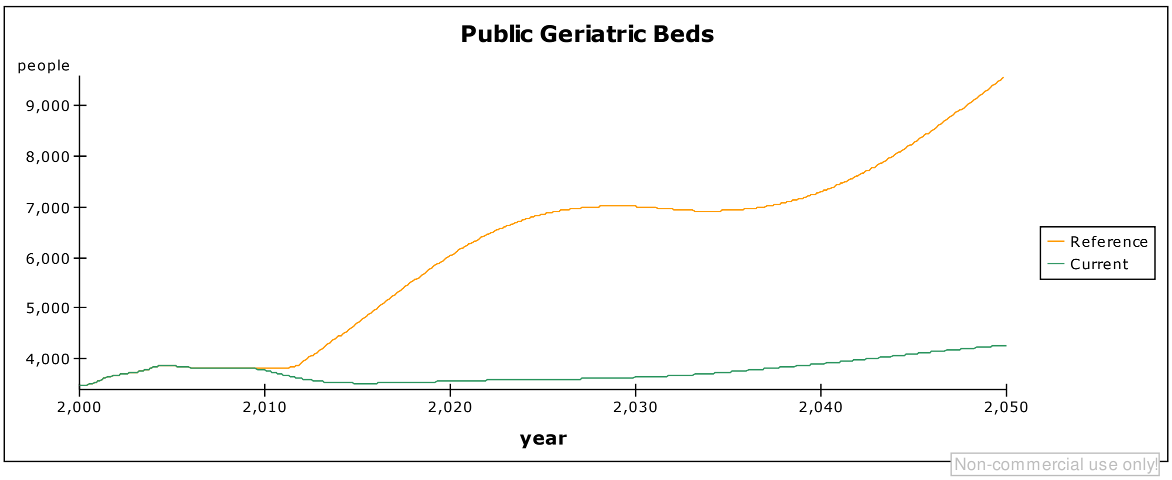


Fig 66: Public geriatric beds – Sensitivity towards the introduction of a private sector

Evidently a private sector, simulated at base run settings as outlined in the previous chapter is causing radical changes in the development of the public institution bed capacity. As the GHPM assumes that private alternatives will be paid for regardless of the cost people on a public institution waitlist is assumed to enter the private institutional alternative and thus relieving the demand for public institution beds. This is obviously a simplification; it is designed to investigate possibilities of a private sector. Nevertheless; the public institution capacity is highly sensitive to the GHPM's private alternative.

8.4 Care Clients Validation

The number of people requiring some level of geriatric health care is expected to rise in the future as the proportion of elderly in the population is rising. The GHPM conceives a population's demand for geriatric health care as a function of the amount of elderly; the

GHPM assumes constant recruitment rates to the geriatric health care services. The reference mode for the number of care clients may simply be described as "growth". A base run where no private alternative is activated confirms this assumption.

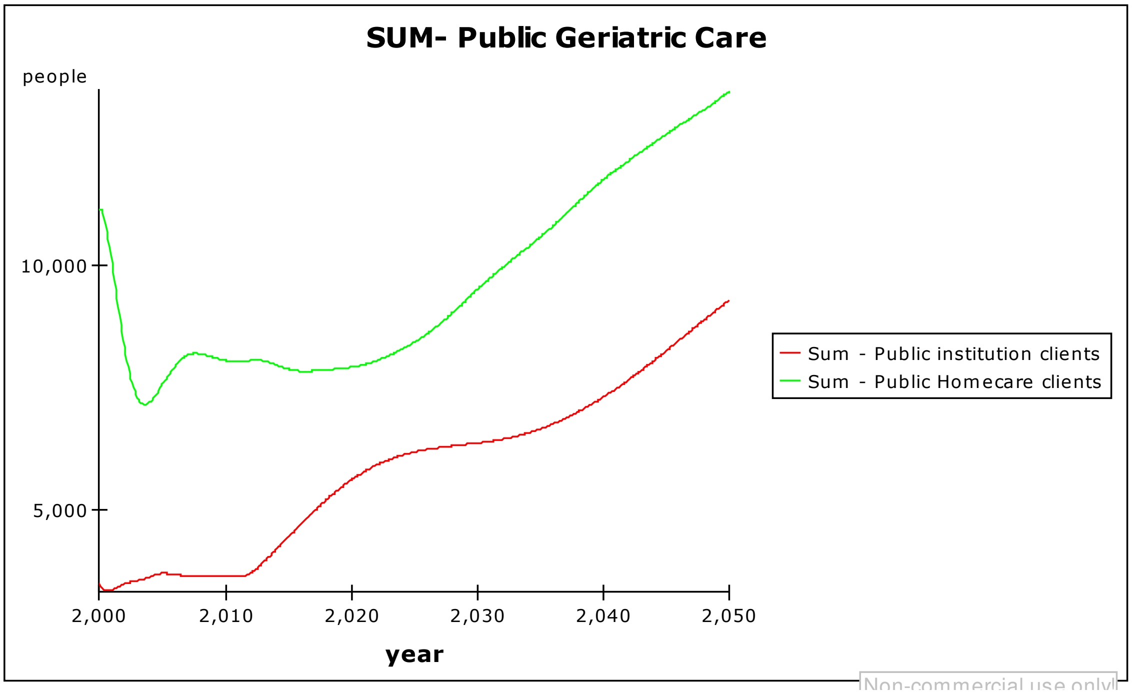


Fig 67: Baserun Public care clients

Evidently the basic trend is one of growth. The homecare clients' trajectory exhibits an initial drop in clients. This behaviour is suspected to be the result of an initialization problem arising from the way initial values are calculated as probabilities not accounting for "Initial death". Before public care can be administered new clients must expect certain delays. The amount of people on wait lists is also a function of the amount of people requiring care and is henceforth expected to show growth behaviour. For homecare clients it is expected that the growth will be rather steady as the waiting is only caused by administrative delays. For institution clients the waitlist is expected to show more complex behaviour as the acquisition of new institutional beds is subject to considerable delays. As new institution beds are made available the wait list is expected to be reduced.

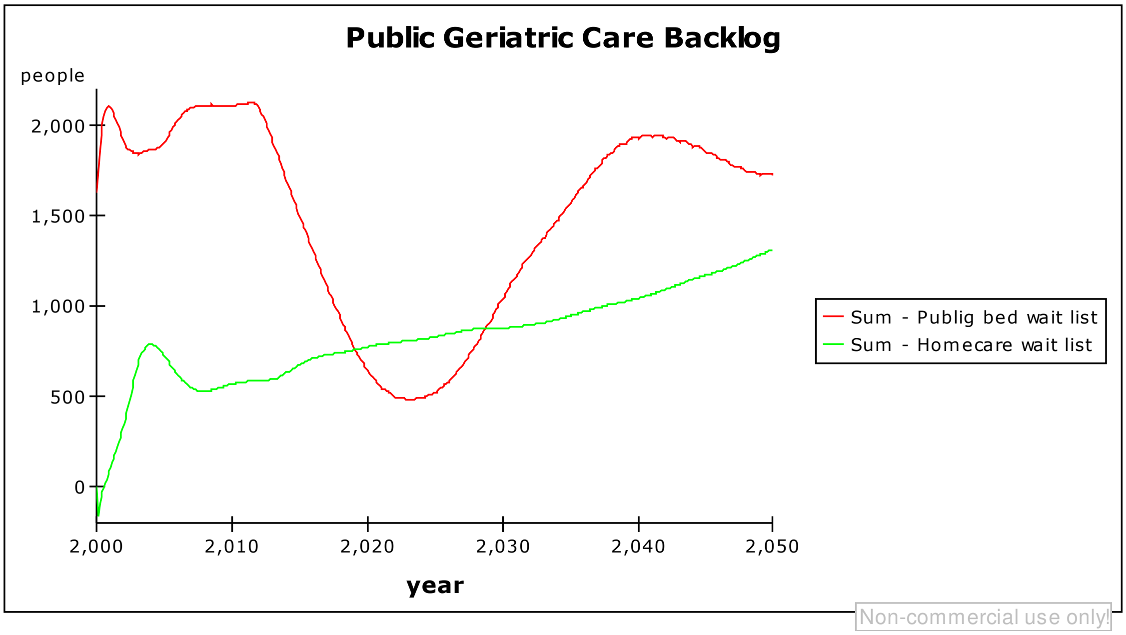
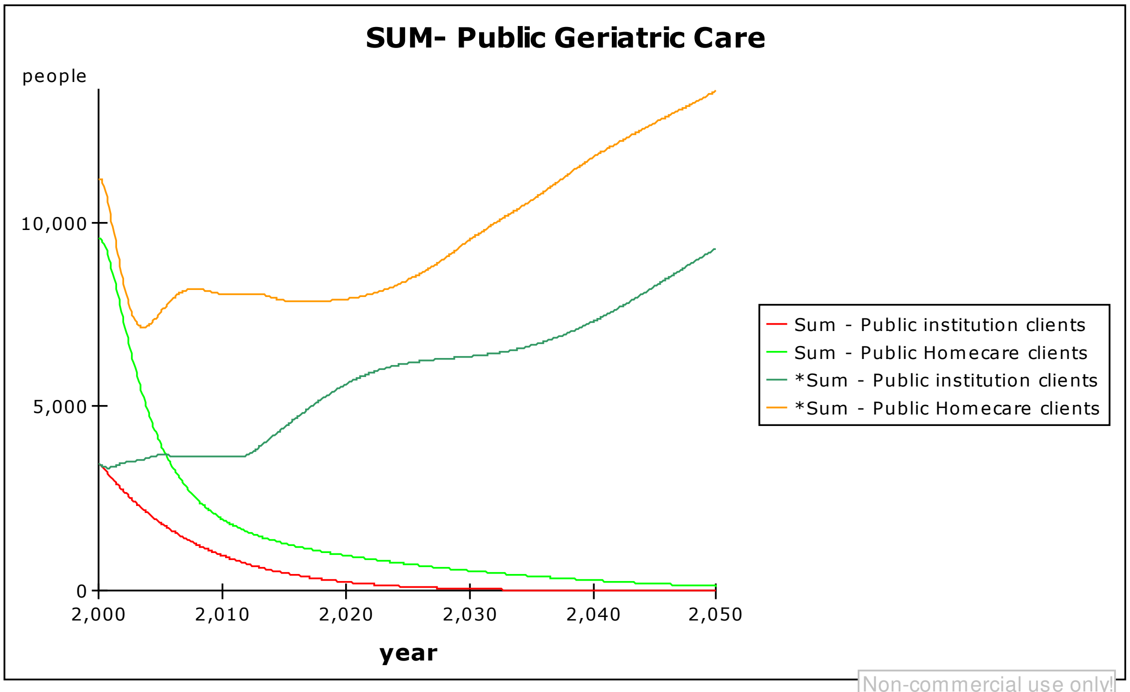


Fig 68: Baserun Public waiting lists

The expected behaviour is evident also in this case; different delays are causing different behaviour.

An interesting extreme conditions test revealing the robustness of the Care Clients is to cut of all outflows from the waiting list levels. In this scenario it is expected that there will be accumulation of people in the waitlists whilst the levels accounting for people receiving care will diminish. The graphs below demonstrate these dynamics.



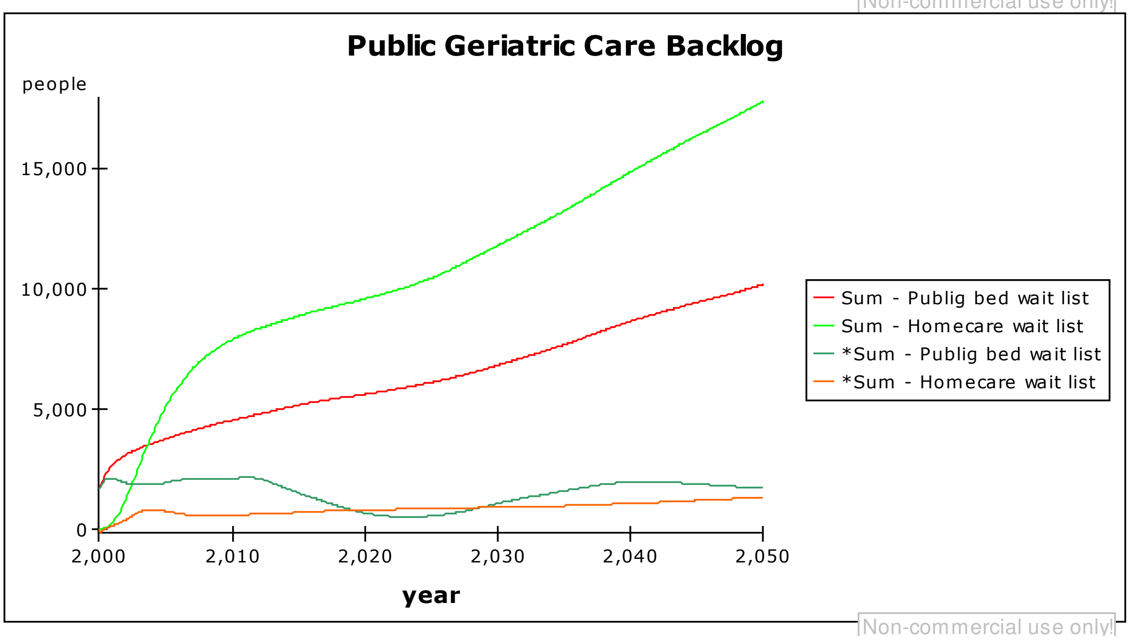
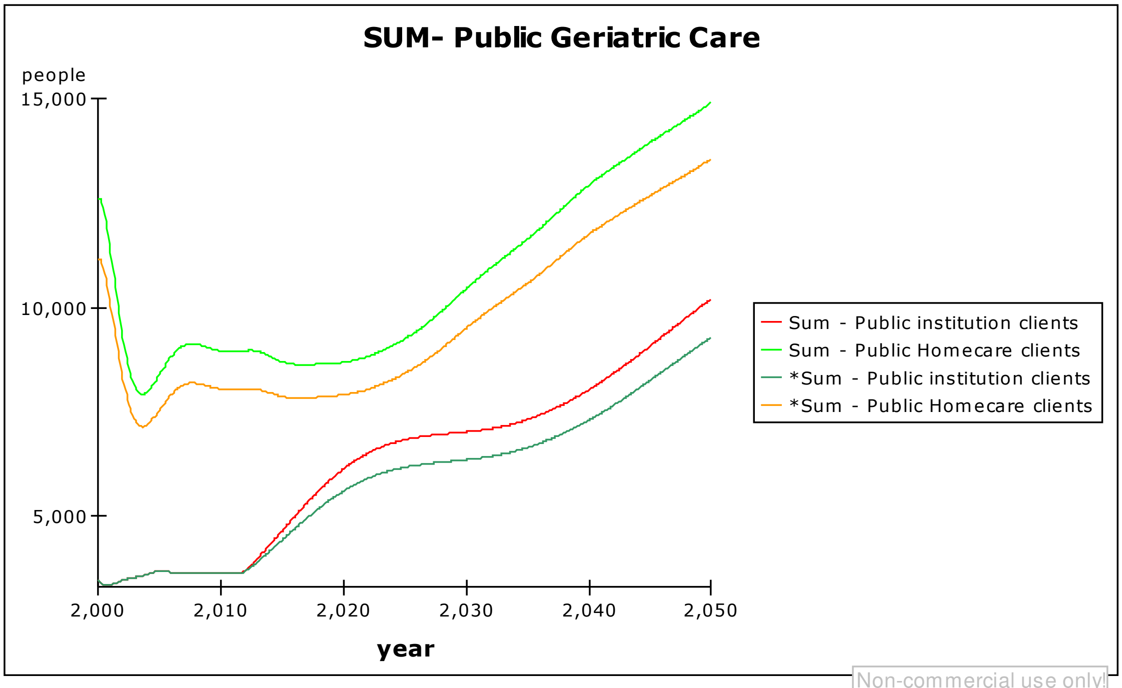


Fig 69: No outflow from waiting lists

In terms of sensitivity it is interesting to test the influence of the constant recruitment rates. If the model is sensitive to the recruitment rates one should expect the number of clients and people awaiting care to be higher at higher rates and lower at lower recruitment rates. The graphs below display behaviour when recruitment rates are increased by 10 percent. The graphs display expected behaviour and the model appears to be sensitive to the recruitment rates.



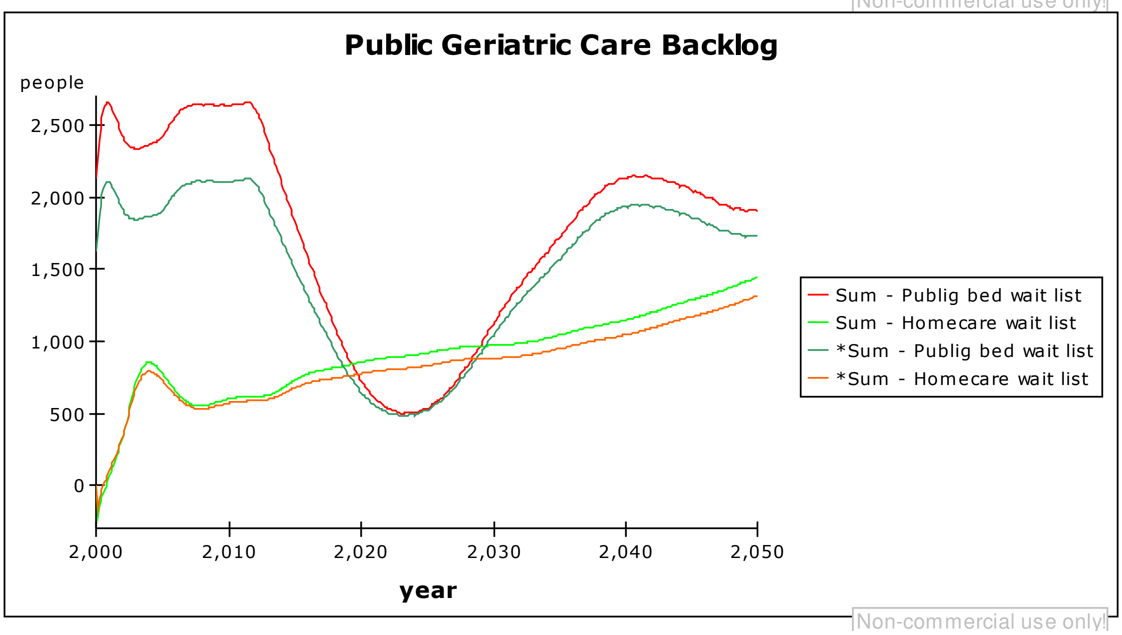


Fig 70: Care clients - Sensitivity to recruitment rates

Finally the Care Clients subcomponent of the GHPM is tested for sensitivity towards the introduction of a private care sector. it is by activating the private sector in the model expected to see radical changes in the development of care clients.

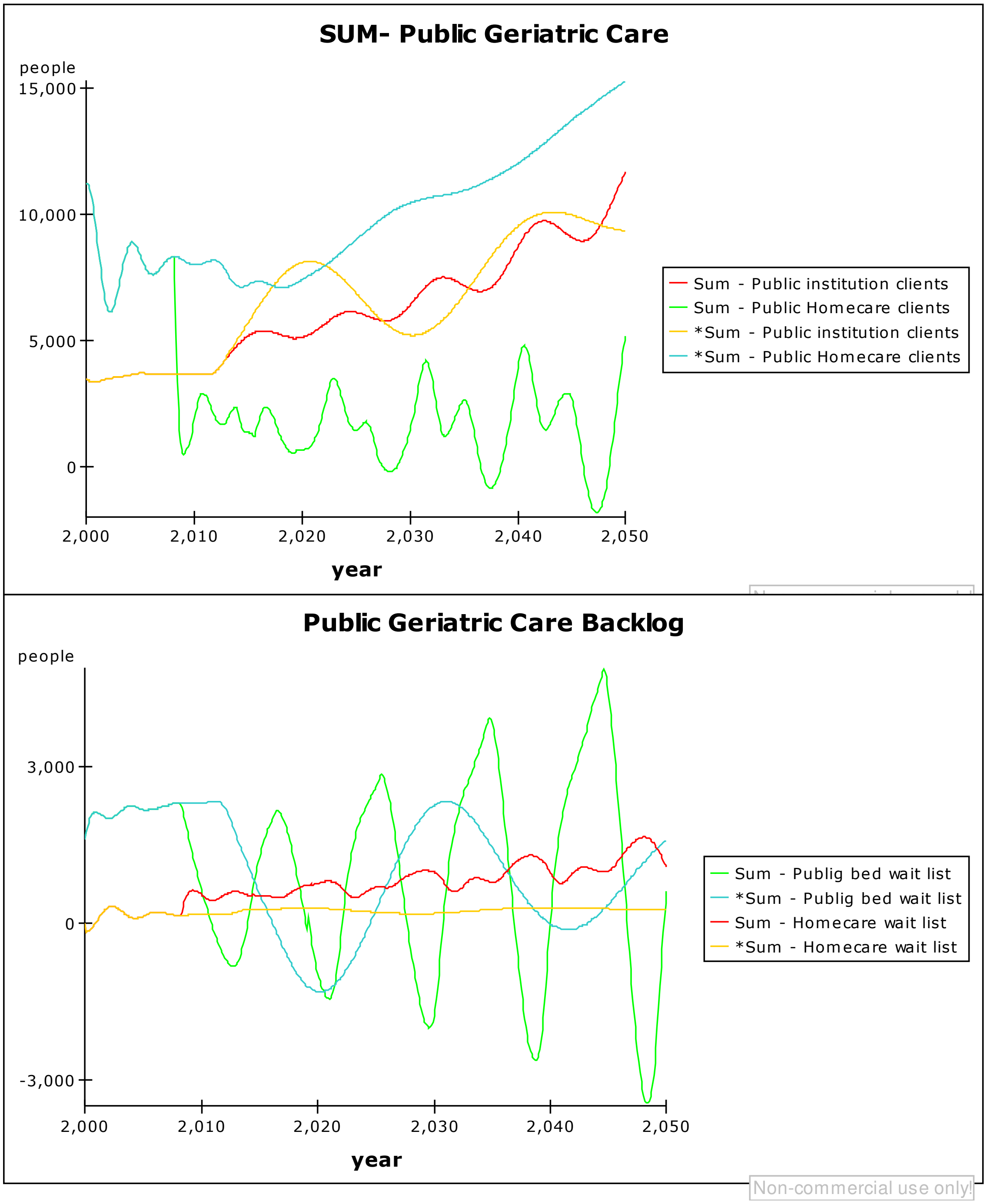


Fig 71: Care Clients – Sensitivity towards a Private Sector

The above graphs show that the Care Clients subcomponent is highly sensitive to the introduction of a private sector. In the above graphs the baserun constitutes the reference trajectories and the current trajectories represent the behaviour when the private sector is activated. The behaviour exhibited is as expected; a significant decline in the pressure on the public care sector. Private sector also introduces oscillations to the public sector; these effects will be discussed in chapter nine. It should also be noted that negative values in the backlogs suggest a surplus of capacity.

8.5 Care Nurses Validation

The Care Nurses segment of the Geriatric Health Care Projection Model captures the dynamics of nurses in the public care sector. The reference mode for this segment is as for the preceding sectors a general tendency towards growth; more elderly suggest more geriatric care clients and more clients call for more nurses both in the homecare and the institutional care categories. The model reproduces this reference mode; the baserun shows a tendency of growth.

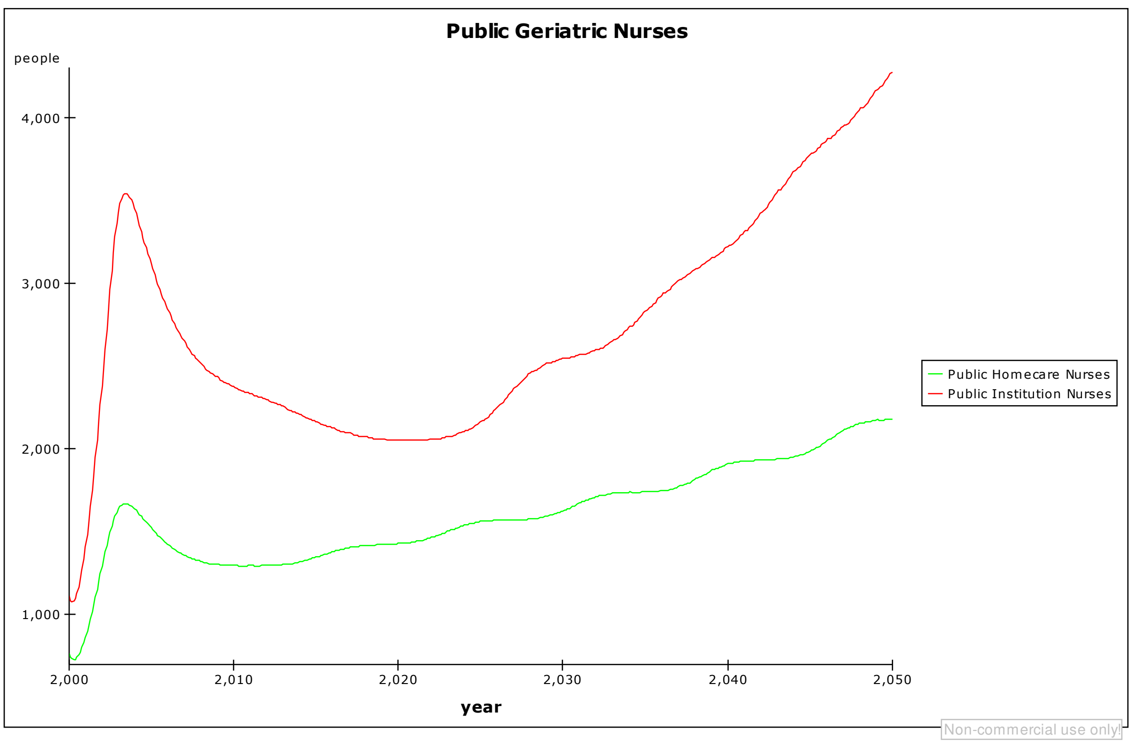


Fig 72: Baserun – Public Geriatric Nurses

As much as the reference mode suggesting general growth over the simulation period is evident the baserun reveals certain dynamics that must be addressed; for both homecare and institution nurses there appear to be a distinct overshoot during the first years of the simulation. Overshoots are most commonly due to delay processes. This is certainly the case in the baserun. Furthermore; the overshoot is induced by underestimated initialisation values. The city of Bergen claims in the 2007 document to be close to their own target nurse capacity (Byrådet, 2007). When examining the figures in the same report it is evident that this is a truth subject to modifications. The total staff of the geriatric services is close to targets; this figure does however include a number of non-care giving staff such as administrators and janitors. As the GHPM is initialized with the number of actual care providers the model is initially below target. As the model attempts to compensate for this and delays are present in the process of decision-making significant overshoots are generated. The model is therefore sensitive to the delays in the decision-making process. By reducing the delay, the overshoot is reduced:

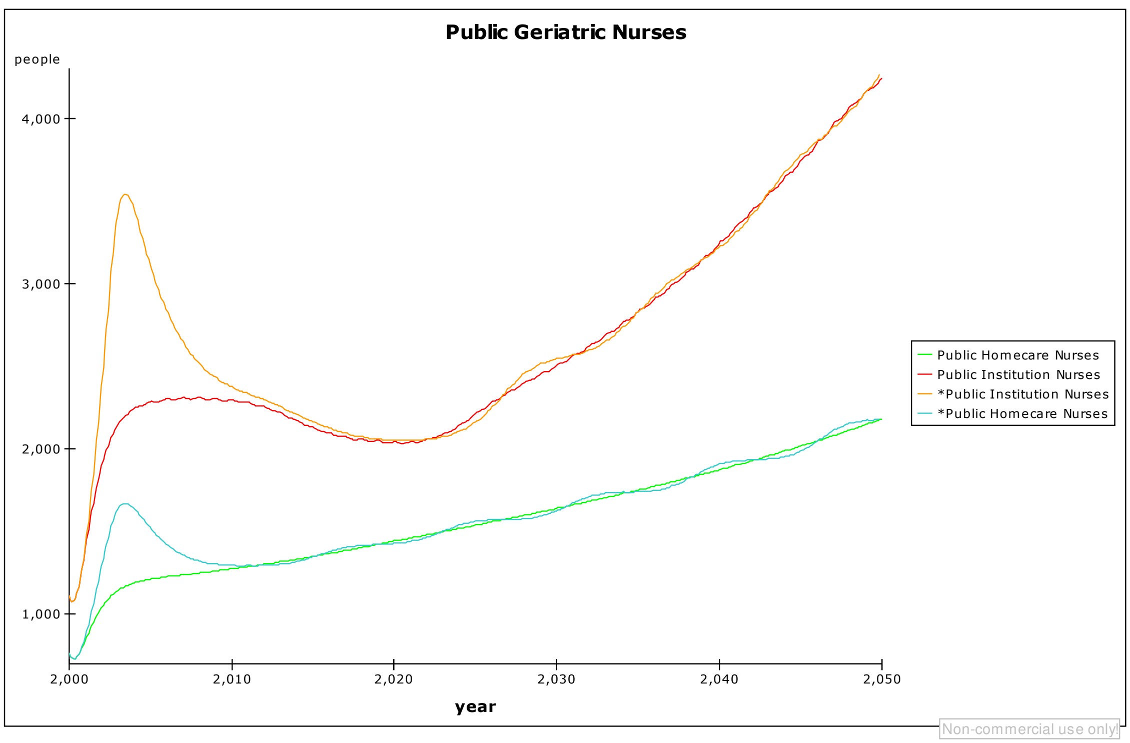


Fig 73: Care Nurses – Sensitivity to delays.

As the delays are reduced the initial overshoots are reduced. This is an important point for the further analysis; delays in the public decision making process are directly affecting the quality of care provided.

To test the Care Nurses component for robustness the flows from the Nurse Pool to the active nurses levels are cut of. In this scenario it is expected that the number of working nurse will decline rapidly. The rapid decline will be produced by retirement and death as well as the ever increasing workload on remaining nurse which will produce a reinforcing effect sending ever more nurse on sickleave or completely out of the ranks of geriatric care staff.

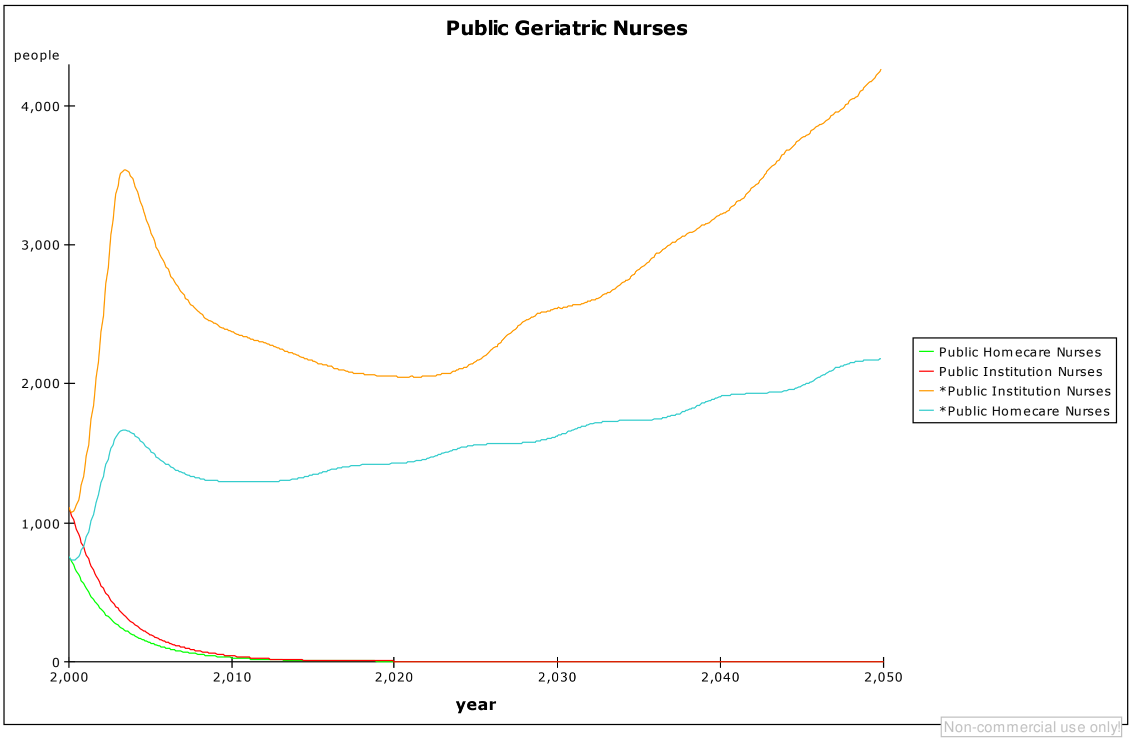


Fig 74: Care Nurses – No recruitment

Evidently the model is robust in the scenario of no recruitment. It is also interesting to investigate the model behaviour in the event where nobody leaves the nurse staff, by cancelling the turnover flow directing nurses back to the nurse pool. In this scenario it is expected that the behaviour will be similar to the baserun, as recruited nurses will not quit, and hence need no replacement.

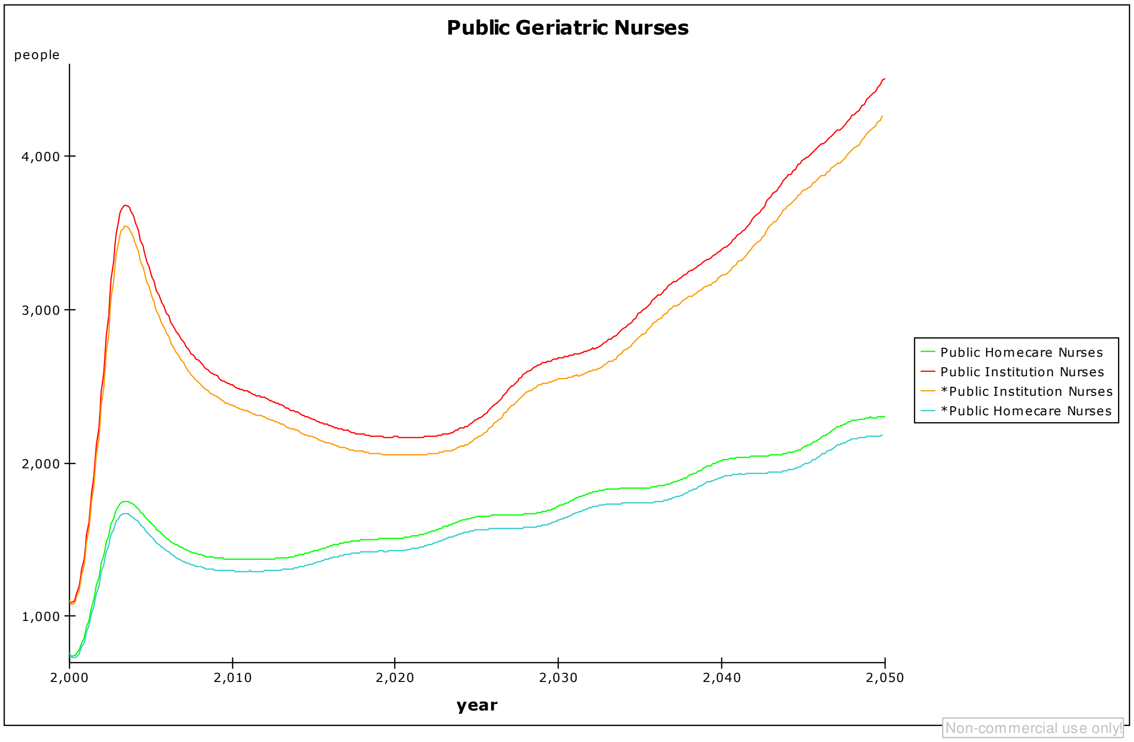


Fig 75: Care Nurses – No quitting

The above graph demonstrates the expected behaviour and must be deemed robust in this respect. As no one quits their job the accumulated staff is slightly higher then in the base run scenario.

Workload, in the GHPM conceived as the nurse per client ratio, is influencing the rate at which nurses quit, call in sick and are attracted to positions in the geriatric services. To test the sensitivity of this the workload is forcibly reduced by 40 percent. The sensitivity test reveals that the labour dynamics are affected by this reduction but not to alarming degrees.

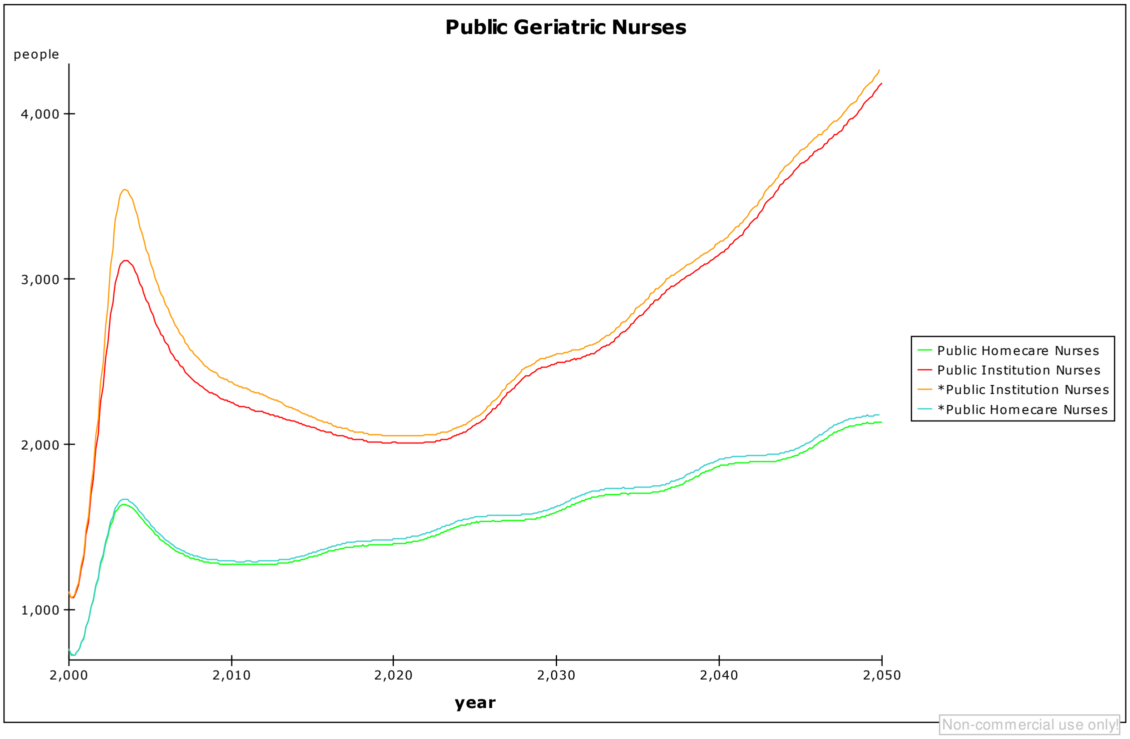


Fig 76: Care Nurses – Sensitivity towards workload

This suggests that the dynamics introduced by the graph functions are important; workload does affect the staff. A constant shift of workload does not identify the sensitivity towards the actual magnitude of the nonlinearities arising from the graphical functions. By employing different graphical functions, different trajectory shape is expected. For the purpose of sensitivity testing the following two graphical functions were applied.

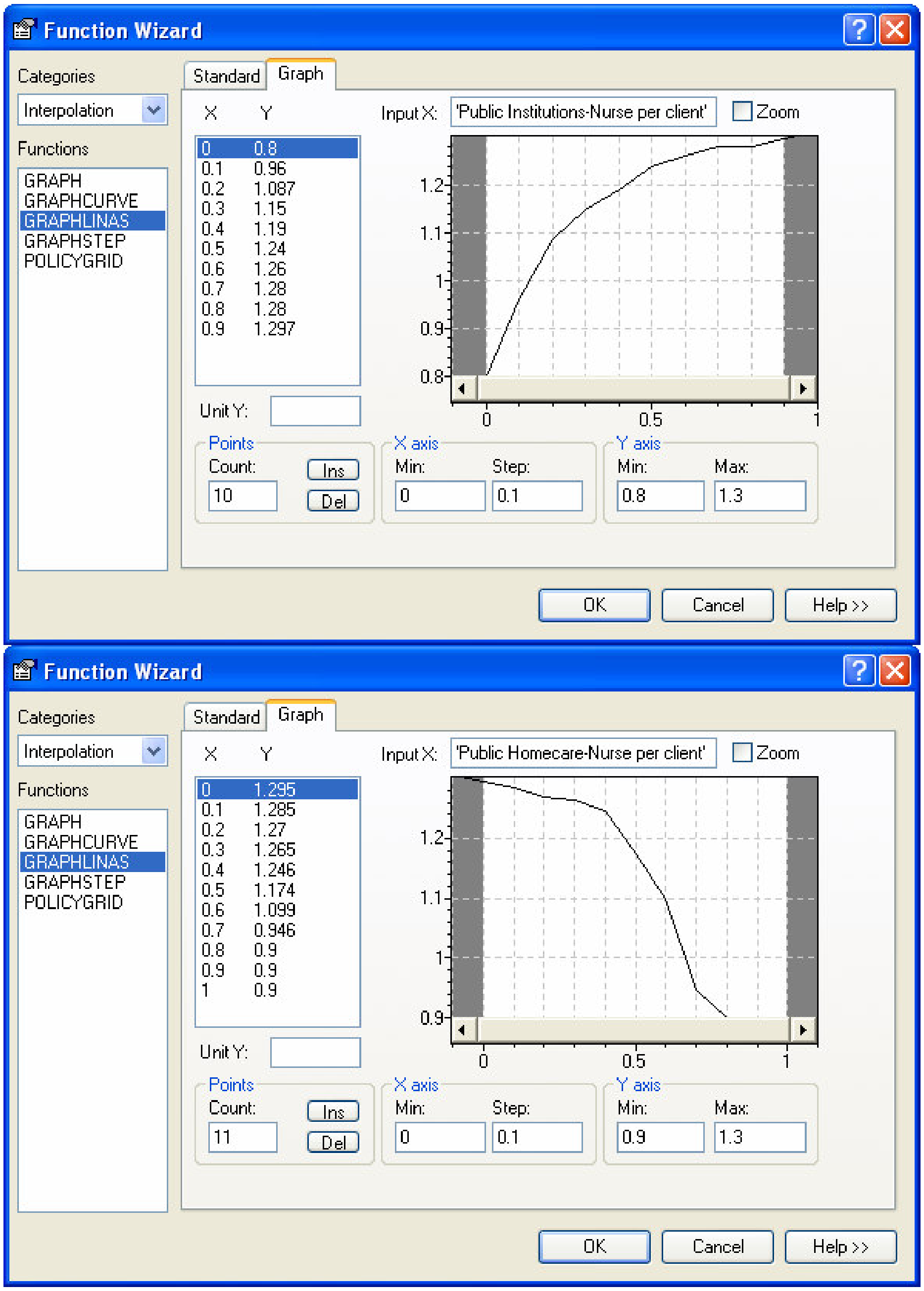


Fig 77: Graph functions for sensitivity testing

The graphs above are defined with more aggressive trajectories. Simulating with these graphical functions will render different trajectories then simulations with the baserun graph functions if the model is sensitive to the nonlinearities introduced by the graph functions. The figure below reveals that the staff dynamics are indeed sensitive to the graphical functions.

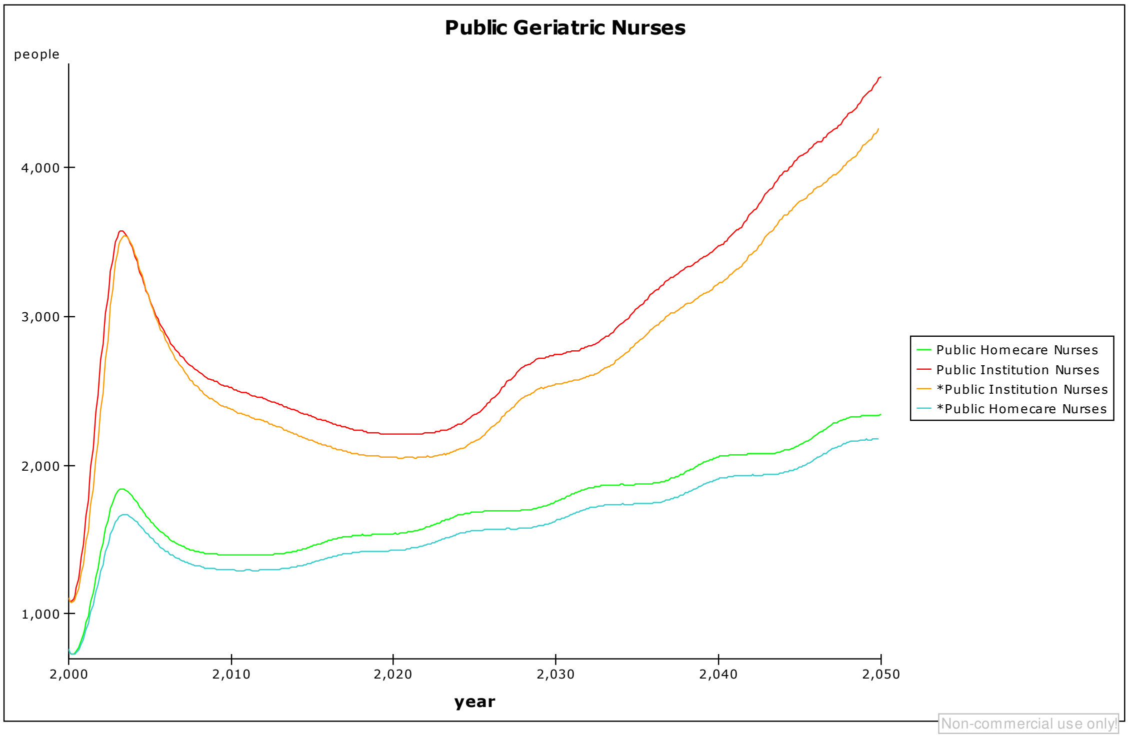


Fig 78: Care Nurses – Sensitivity to workload graph functions

Although there are traceable differences between the baserun and the test run the differences are not large. This suggest that the GHPM is sensitive to workload effects but not greatly so. Should the opposite be the case questions would have to be raised as to whether the graph functions were correctly conceived. If not the validity of the model would also necessarily have to be questioned. By employing modest estimates of the effect of workload the model is not generating unreasonable behaviour due to erroneous conception of labour psychology.

Finally the Care Nurses component must be tested for sensitivity against the introduction of a private sector in geriatric health care. The result of this test may appear counterintuitive:

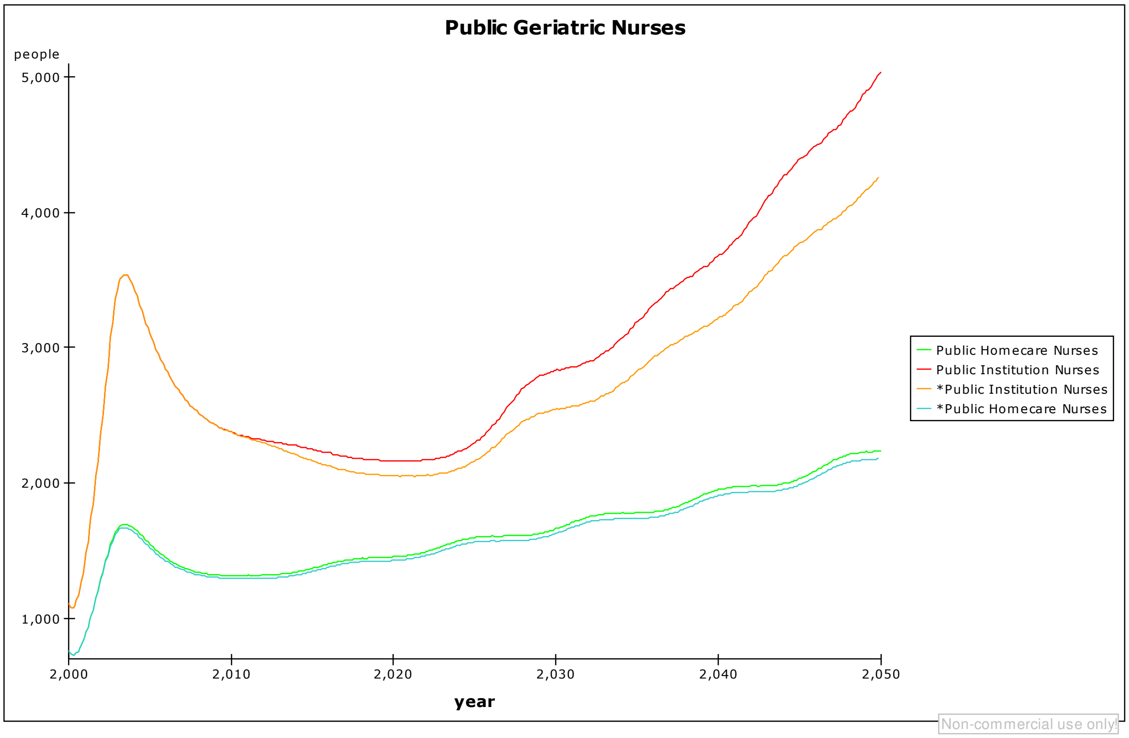


Fig 79: Care Nurses – Sensitivity towards the introduction of a private sector

As the private sector is activated the number of both institution and homecare nurses rises. One should imagine that as there are fewer clients, there would also be a need for fewer nurses and in reality this would also be the case. However; the need for nurses in the private sector is defined to target a goal defined as nurse per population factor and not as a nurse per client factor. The amount of clients is therefore not affecting the recruitment of nurses. Instead of reducing the number of nurses in the event of fewer clients the model shows that the staff magnitude increases. This behaviour is an effect of the workload being reduced by the reduction of the number of clients; an enhanced nurse per client ratio reduces the sickleave and turnover whilst enhance the attractiveness of being a publicly employed nurse. The recruitment goals are defined for an environment wherein there is no private alternative. This suggests that the recruitment policy for public nurses should be revisited when analyzing the hypothetical scenario of a private care alternative; this will be discussed in the following chapter. Nevertheless; the GHPM is indeed sensitive to the introduction of a private care sector, although in a different manner then dictated by intuition.

8.6 Private Sector Validation

A substantial subset of the Private Sector component captures staff dynamics. This subset is a mere replica of the Care Nurses component of the GHPM. As Care Nurses is already validated the private account of these dynamics need no further testing. It should however be noted that the establishment of new nurse positions is slightly different in the private sector; the positions goal is dictated internally in the subcomponent structure. The nature of the model structure capturing these dynamics is basic and intuitive. The author sees no need to further validate these structural elements as they are explained in chapter 7.

The Private Sector component of the GHPM is a model subset developed to analyze a hypothetic scenario. There is henceforth no data or grounds for comparison against a relevant real world reference mode. However; given the assumption of the private sector being a near-perfect market, that cost is no constraint, and that the demand for a private sector is driven by shortcomings in the public sector it is possible to deduce a simple reference mode for the private sector. As waitlists for public institution develops, the private sector will invest and clients will choose a private alternative over a public waitlist. For private homecare it can be assumed that the level of clients will be rather stable; granted that clients will choose the private alternative based on the private nurse per client ratio, a ratio that in turn will be held stable due to the manner in which private institutions recruit staff. A stable behaviour is also expected to arise as a significant proportion of the public homecare clients are in fact people waiting for an institution bed. As the private sector depletes the public institution waitlist by providing beds the growth in public homecare arising from public bed shortage is removed. The latter dynamic further suggest that there will be an initial rapid growth in private homecare as potential private institution clients are awaiting the new institution beds to be realized. Stabilization of growth in public homecare will furthermore stabilize growth in private homecare.

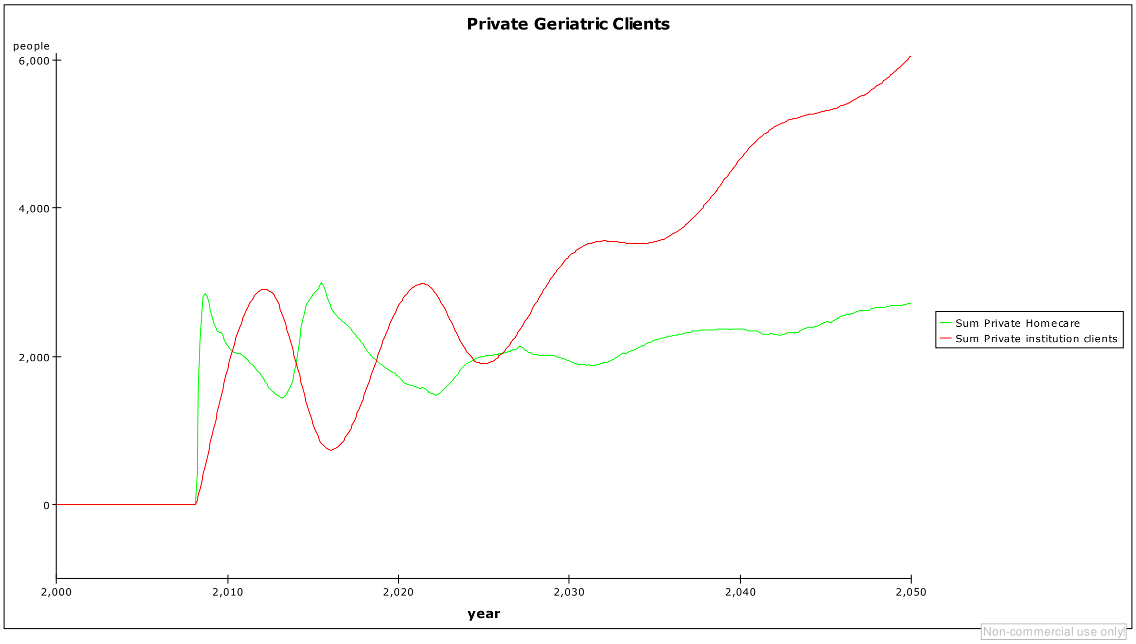


Fig 80: Private Sector – Baserun

The Private Sector baserun shows the expected behaviour. The initial temporal offset in private institution clients is accredited to the time delays governing public investment and construction. The initial surge in private home care is a result of people awaiting private beds to come in place. The initial oscillating behaviour arise from overshoots generated by the construction delays.

To test the robustness of the Private Sector the inflows from public sector is cut off. In this scenario it is expected that there will neither be clients in private institutions nor in private home care

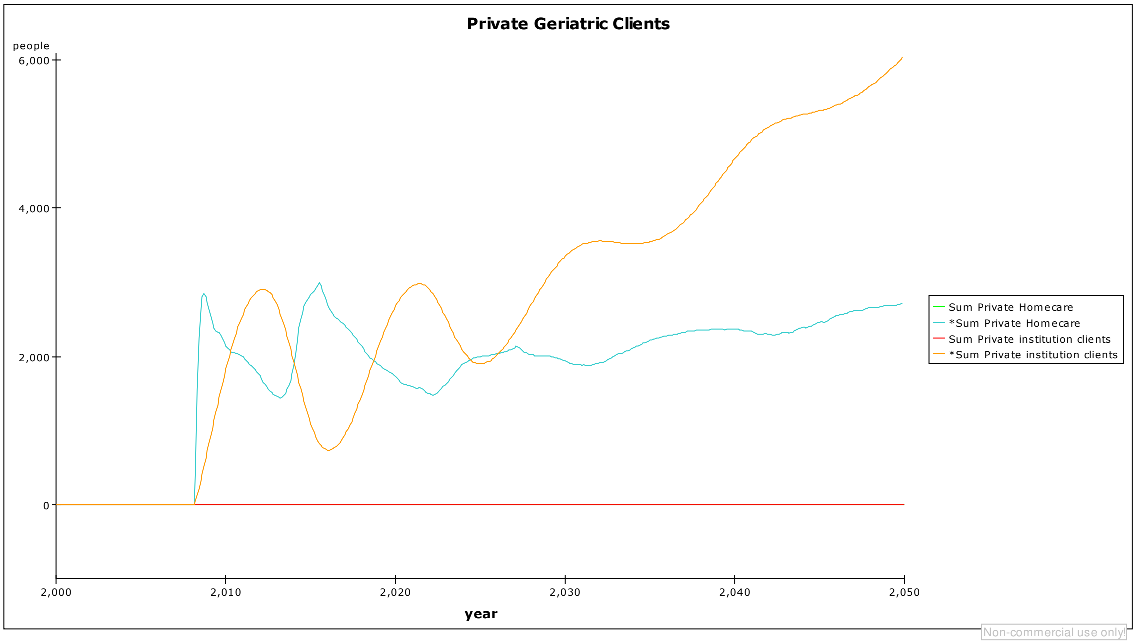


Fig 81: Private Sector – No Inflow from public sector

Evidently the Private sector is robust in the event of getting no input from the public sector. Secondly the Private Sector may be tested for robustness in the scenario where there is only a private homecare alternative active and no private institutions are providing for people awaiting institution beds. In this case a vastly larger wait list would be evident in the public sector. The graph below shows that the baserun produces a significantly lesser number of people awaiting beds:

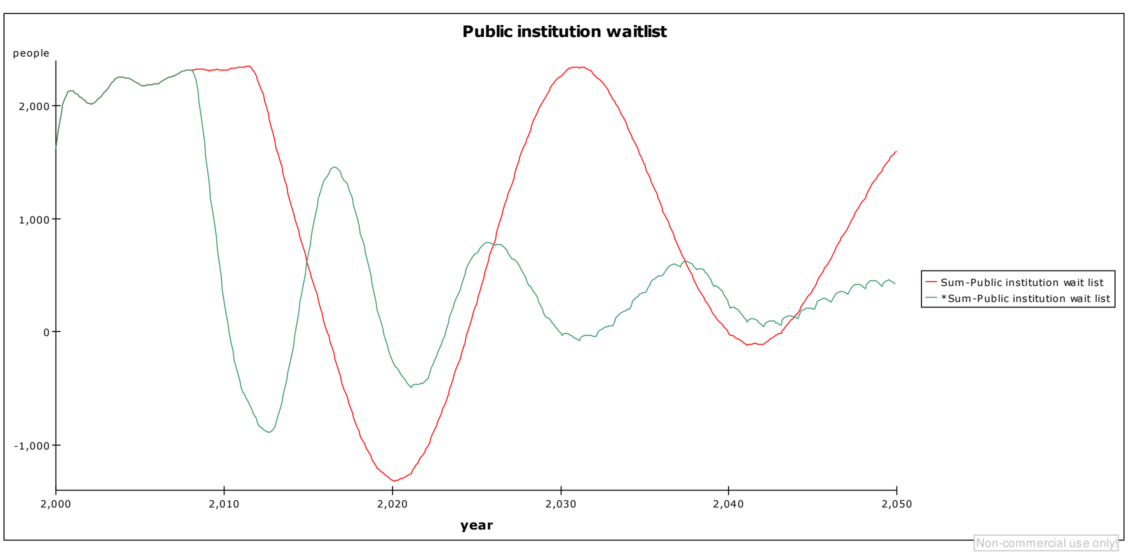


Fig 82: Private Sector – No Private Institutions

In terms of sensitivity the time delays of private investment and construction as well as the propensity to choose private homecare is tested. By increasing the delay time of private investment and construction by 50 percent the following behaviour is exhibited:

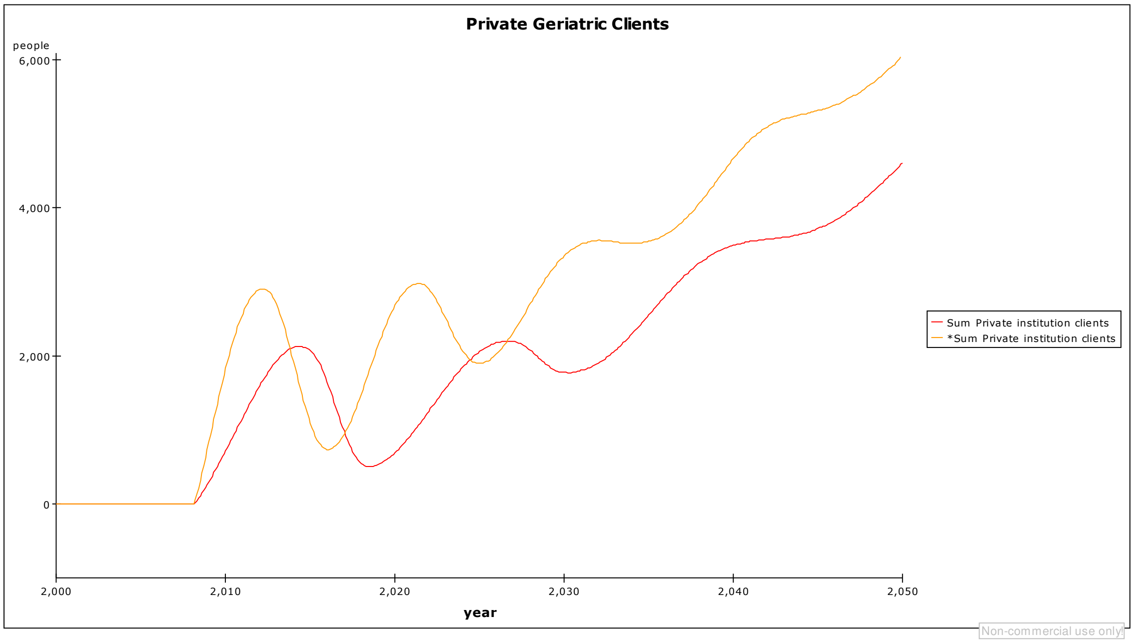


Fig 83: Private sector – Increased private investment and construction time

The graph above suggest that the Private Sector is sensitive to construction time as elongated delays lead to a lesser growth of private institution clients. This further lends validity to the note of delays being a major influence on the public sector; delays have again caused lesser growth.

By increasing the base rate of private homecare preference it is expected that a larger number of people will choose the private alternative if the model is indeed sensitive to this parameter.

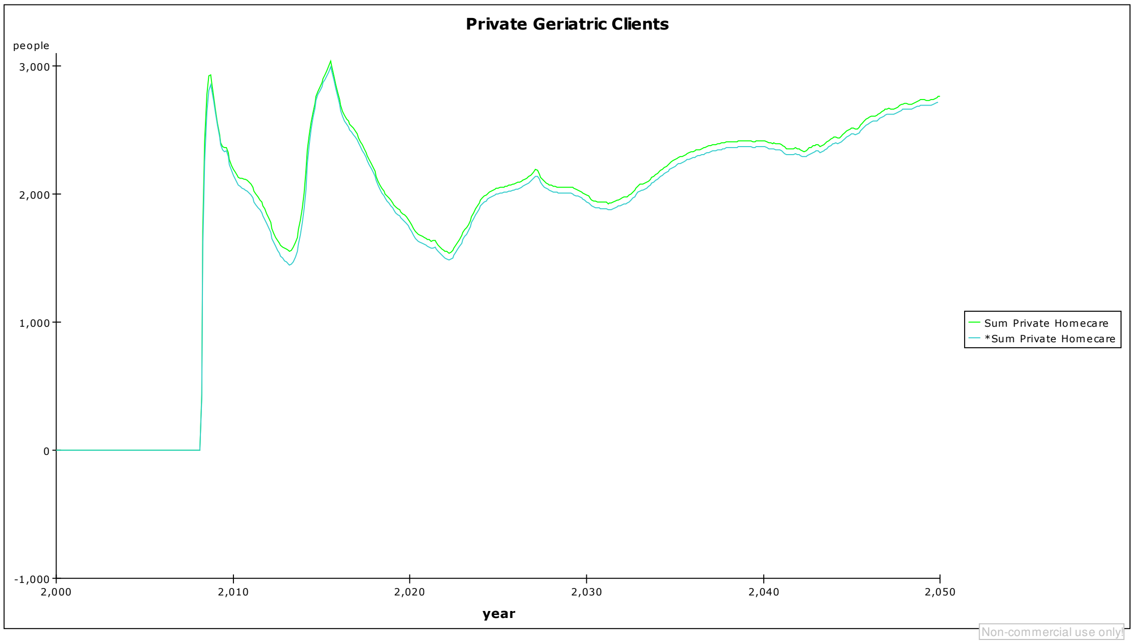


Fig 84: Private Care – Increased Private homecare preference

The above figure suggests that a 10 percent increase in private preference leads to slight differences in the simulation result. That the two trajectories are closely tied in the simulation run us; the private homecare sector is henceforth sensitive to changes in the preference and a constant shift of preference suggests a constant shift of clients. The sensitivity in this respect cannot be considered as highly important.

9. Policy testing and Discussion

To analyze the future prospects of the geriatric healthcare services in the city of Bergen seven different simulation runs are conducted. The different simulation runs are differentiated by different policies, thus is the different runs allowing for a comparative discussion of different policies.

9.1 The baserun Scenario

The baserun forming the grounds of analysis is the same baserun as was applied in the validation chapter; no private sector is activated in the baserun and the public sector will always move towards a 100 percent fulfilment of care goals although delayed by tedious public policy processes. The baserun commence on simulated construction and recruitment policies in 2008.

The initial baserun suggest that delays are strongly affecting the quality of care and fulfilment of care needs. Whilst the public care sector moves slowly clients are subjected to what can only be assumed to be stressful situations of waiting and insufficient care.

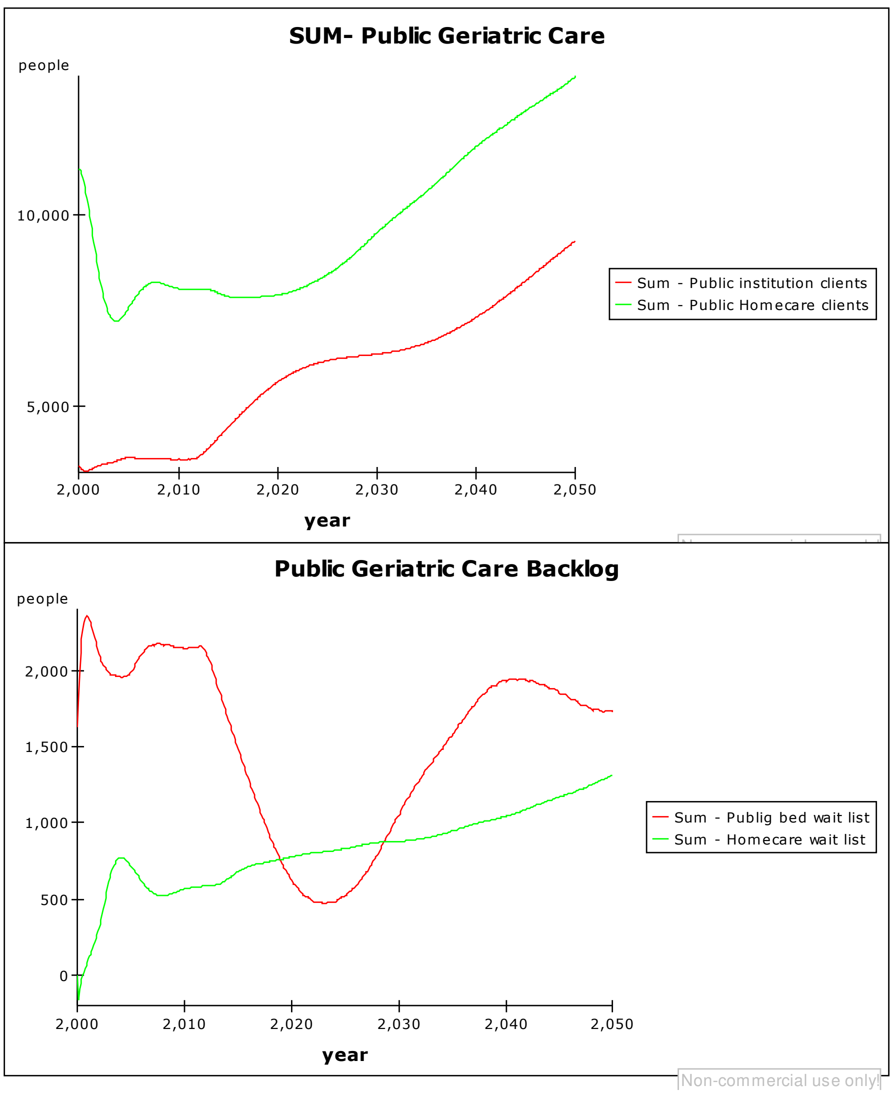


Fig 85:   Public Care Clients and Care backlog – Baserun

The baserun indicates that with respect to the clients the situation is not satisfactory. The amount of people awaiting an institution bed is extensive. To these people and their families such a situation cannot be satisfactory. Remembering that people in need of an institution bed in fact are not able to take care of themselves a situation like this is strongly affecting the needing people's quality of life. It further suggests that families and friends must dedicate considerable time and energy on providing care. This in itself raise a number of questions as to whether this has socio-economic costs beyond the geriatric health care spending as people may need to reduce their own work effort in order to provide care for loved ones. It further raises questions as to whether the needing clients are receiving the proper level of care. The City of Bergen is stressing that more and heavier care tasks are to be shifted from institutions to the homecare services. However, with growing pressure on the homecare services the reliance on other informal care givers must increase. People without the skills and training of educated nurses are by definition not necessarily fit to provide the required level of care for any given client. The care capacity indicated by the nurse per client ratios suggests that the City of Bergen is not currently fulfilling their own goals for geriatric care. It further suggests that more nurses are required in the geriatric sector.

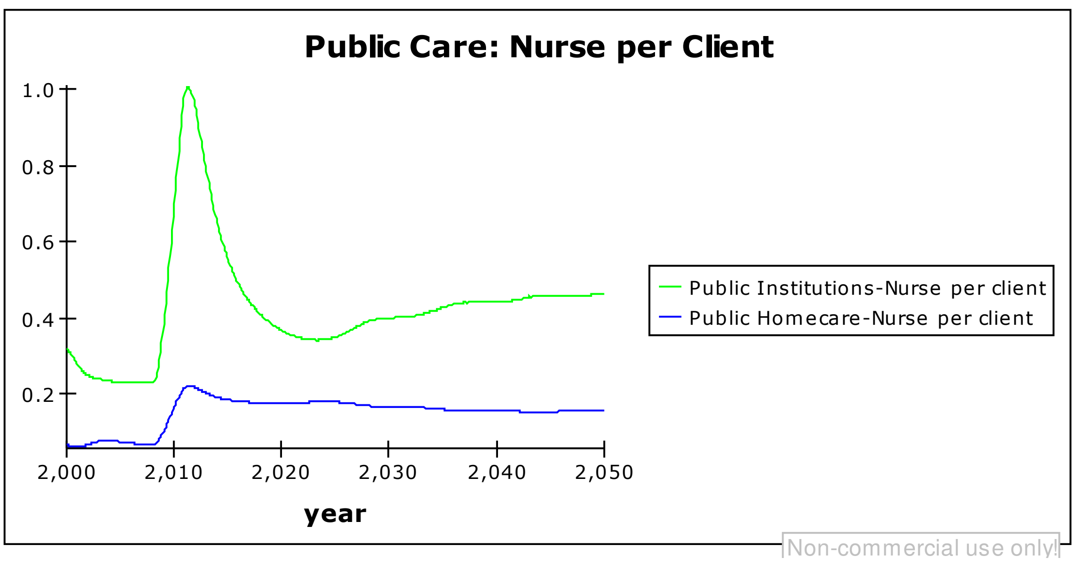


Fig 86: Nurse per Client – Baserun

The baserun suggest that there is an initial mismatch between the stated goals and reality in geriatric care capacity. For institution nurses a distinct overshoot arise due to this issue, in lesser extent the same behaviour is evident for homecare. As the simulated recruitment policy does commence before 2008 a backlog of nurses in terms of the nurse coverage goal is produced. Delays in the hiring process lead to an overshoot. This behaviour is foremost an inevitable result of simulation technicalities but important knowledge could still be drawn from this; delays in information and implementation may come at a large cost. One may find that too many nurses at some point are hired; reckless hiring cost money. It should further be noted that whilst institution nurse care capacity appears to be steadily after the initial overshoot is equilibrated, the opposite is the case in the homecare services. A steady increase or at least a stable behaviour is expected in the institution services as the number of clients is limited by the number of bed. For the homecare services clients are increasing as the institution capacity falls short this suggest that the homecare nurse coverage goals are estimated based to the expected number of people needing home care only and not accounting for additional homecare clients receiving temporary homecare services whilst awaiting an institution bed.

Another and perturbing issue is the number of people deceasing while awaiting institutional care. This figure is rather large and will probably always be large as the mortality amongst people in the age qualifying for institutional care is high. Still, it is a matter of concern for the city of Bergen as the city is obligated to provide an acceptable quality of lify for the seniors. If a high number of people is dying while awaiting the proper care this should suggest considerable grounds for critique.

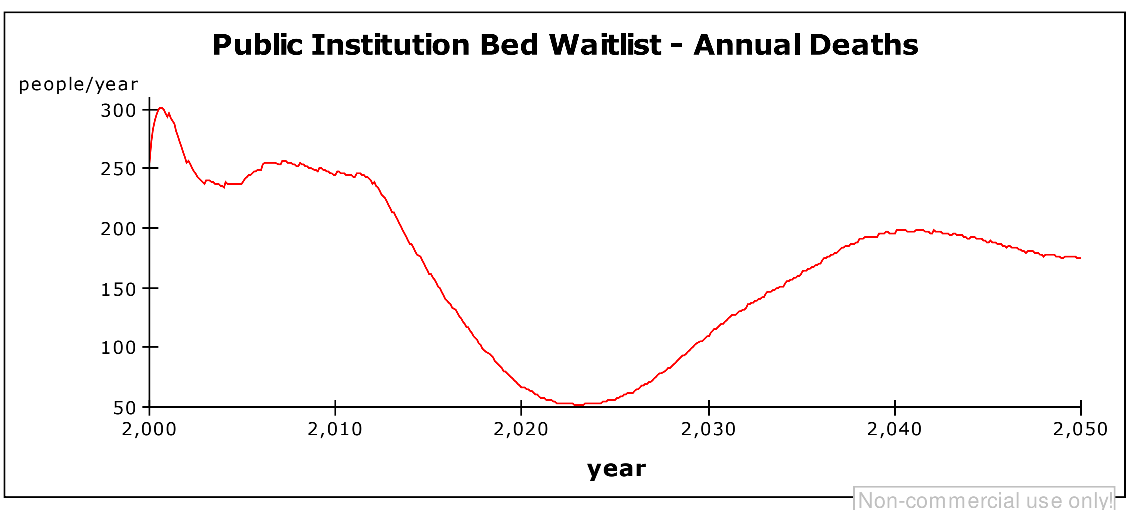


Fig 87: Public Institution bed waiting list – Annual Deaths

The above graph suggests that when the public institutions are “up to speed” the number of deaths in the waiting lists is also reduced. The latter is obvious but it is still worth mentioning as a high number of people dying while awaiting proper care may lead to massive disgruntle with the public policy makers amongst the clients and their friends and families. This again suggest that it is in the policy makers own interest to ensure efficient and sufficient institutional care. Health and thereby health care is at the base of the well known hierarchy of needs; shortcomings in this respect would dictate harsh reactions against the responsible authorities.

9.2 The less the 100 percent coverage scenario.

As much as one might expect the public policy makers to seek 100 percent goal fulfilment in the geriatric health care sector, this is probably not the full truth in real politics. Geriatric health care is one of many responsibilities of the city health authorities. Furthermore, health is one of many responsibilities for the general city authorities. As long as there is a de factor limit to spending the different arenas of public responsibility will always find itself in a situation where priorities must be made and different interest’s calls for compromises. To test the baserun against a scenario where the goals in geriatric health care can only be partially fulfilled is therefore of great interest. By only allowing an 80 percent goal fulfilment the consequence of the squabble for resources is highlighted.

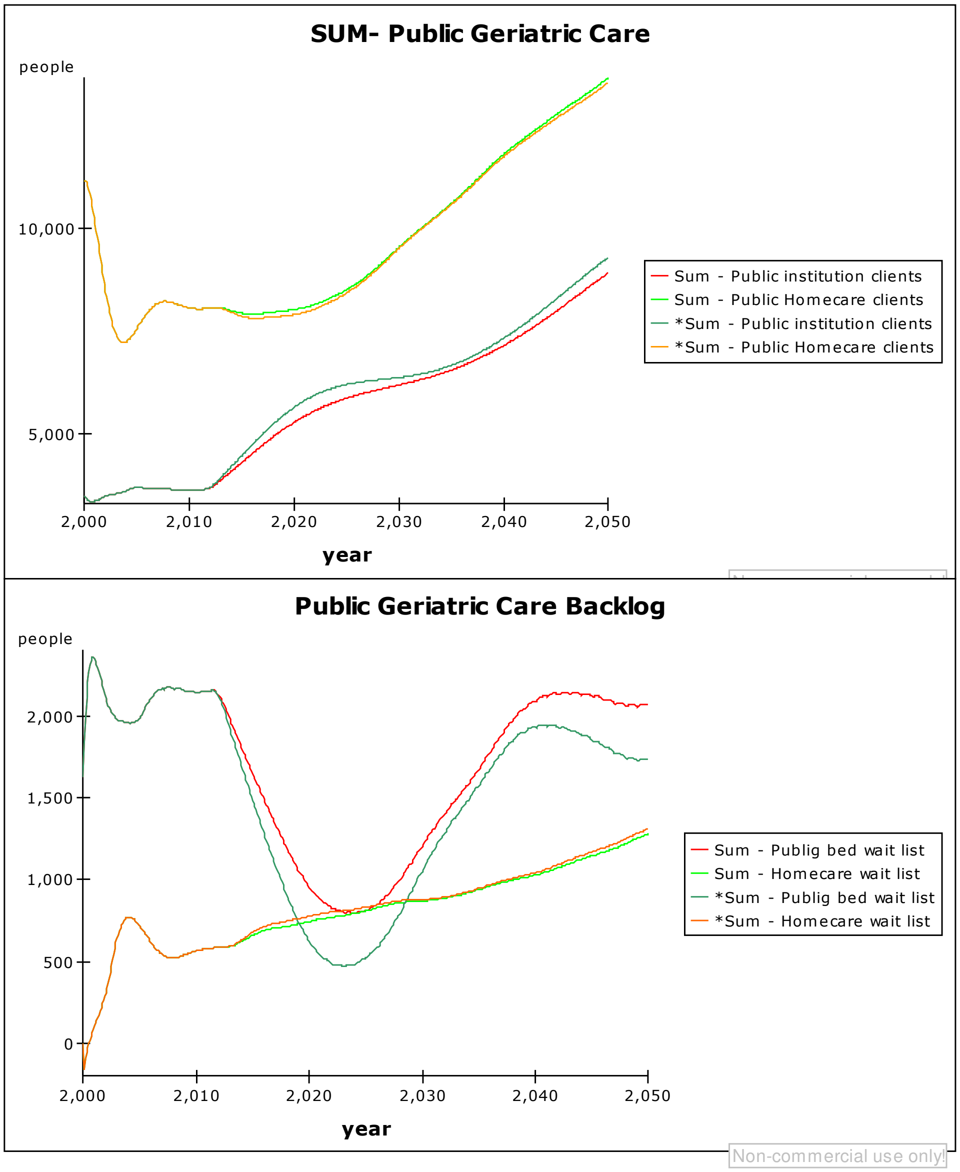


Fig 88: Public Care Clients – 80 percent goal fulfilment

Evidently the 80 percent goal fulfilment affects the institution clients backlog more significantly then what is traceable in homecare; this as fewer beds are provided more people must wait and the time required to provide a new bed is much longer then the time required to provide homecare. It should further be mentioned that this policy and derived dynamics increase the pressure on the homecare services as fewer people receive the required institutional care and therefore must receive homecare.

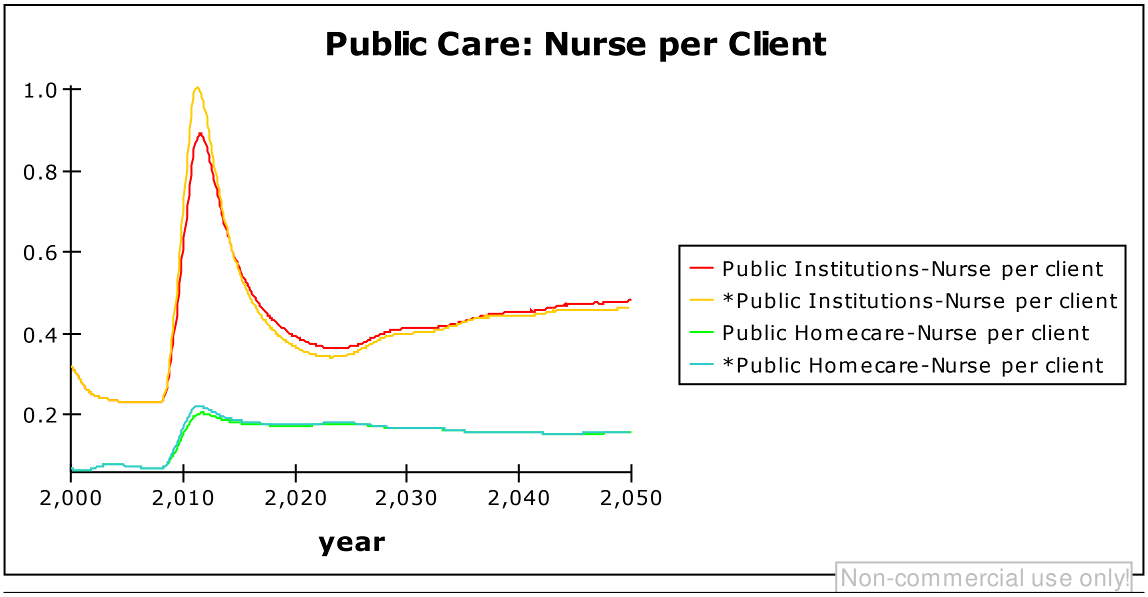


Fig 89: Public Nurse per Client – 80 percent scenario.

The above graph shows that the 80 percent goal fulfilment policy reduce the nurse per client ratio in the public sector. Notably the initial overshoots are also reduced. This again is actually causing a slight enhancement of care capacity in institutions. The latter dynamic arise as a consequence of reduced a reduced overshoot also leading to a reduced undershoot in the next turn. This behaviour is henceforth to be considered somewhat ambiguous as an actual overshoot of the magnitude here presented is unlikely. It can however be concluded that 80 percent goal fulfilment induce a reduced nurse per client ratio. Nurse per client is a cold and faceless figure. In real life a reduction of this ratio means less time in each clients home or institution room for the responsible nurses. Less time suggest that fewer symptoms of various sorts are spotted, that clients feel more loneliness or abandonment that the meals served are of poorer quality that the nurses can exert less sympathy and in a lesser way relate to the client.

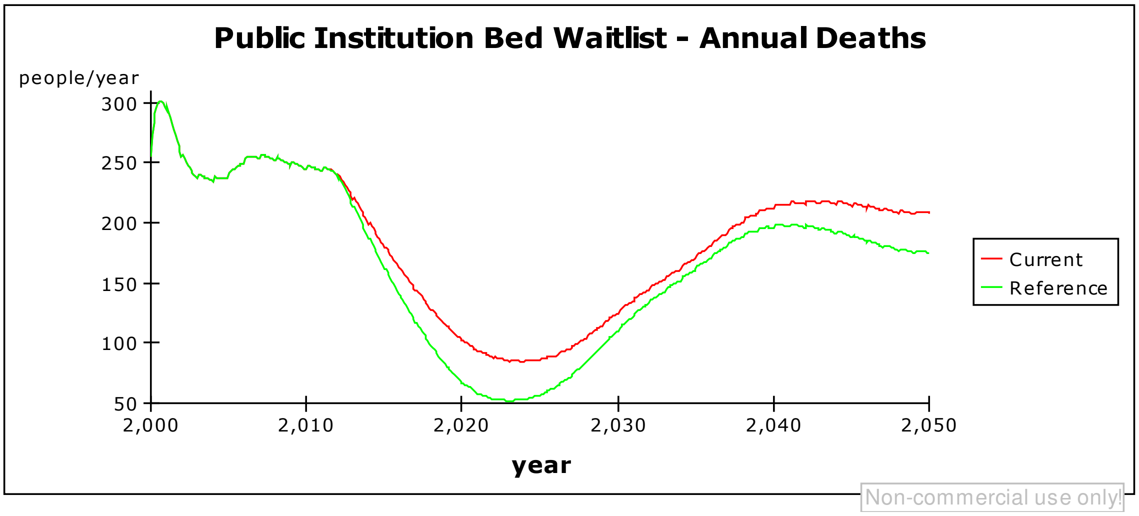


Fig 90: Annual Deaths in Waiting lists – 80 percent scenario

The number deaths amongst people awaiting institutional care are significantly higher in the 80 percent scenario. This is a disturbing dynamic expressing how some of the weakest and most vulnerable members of society are paying the price of recourse limitation. Alas, this dynamic is probably not something that can easily be cancelled. The scarcity of resources is very real and although shortage in the health sector may be an appalling reality it is probably also an inevitable fact. Should the health care sector always be provided with every resource required other sectors would probably be severely hem strung. That could in turn have a major influence on the overall productivity or efficiency of the community and thereby reduce the tax incomes affording the health sector.

9.3 Shortened delays; the enhanced efficiency scenario.

Throughout this thesis the importance of the delays present in public policy planning and implementation has be highlighted as a major governing phenomenon. It is therefore interesting to investigate the effects of reducing the delays in the public care sector. In real life it may be a considerable challenge to reduce policy delays. Public policy is a fluid and shifting environment; there are different political parties with different political agendas; the political process is tedious as disagreeing opinions must find a middle ground of compromise. It is a further challenge to reduce the bureaucratic process. Employees in the public sector are not exposed and rewarded along the same lines as employees in private business; as the public sector traditionally cannot compete with private enterprises in respect of salaries they tend to compete for labour based on work hours and vacation time. There are also commonly restrictions on overtime budgets. Altogether the public sphere tends to move at a somewhat slow pace.

Not considering the actual measures taken to enhance efficiency in the public sector the GHPM is able to test a scenario where such enhancements are made. If such enhancements are indeed bettering the future prospects of the geriatric health care services then the measures needed to afford these enhancements should be thoroughly investigated. In the following scenario the investment and construction time of institution beds have been reduced to a total delay time of four years. The delay time for establishing new nurse positions have been reduced to about one year.

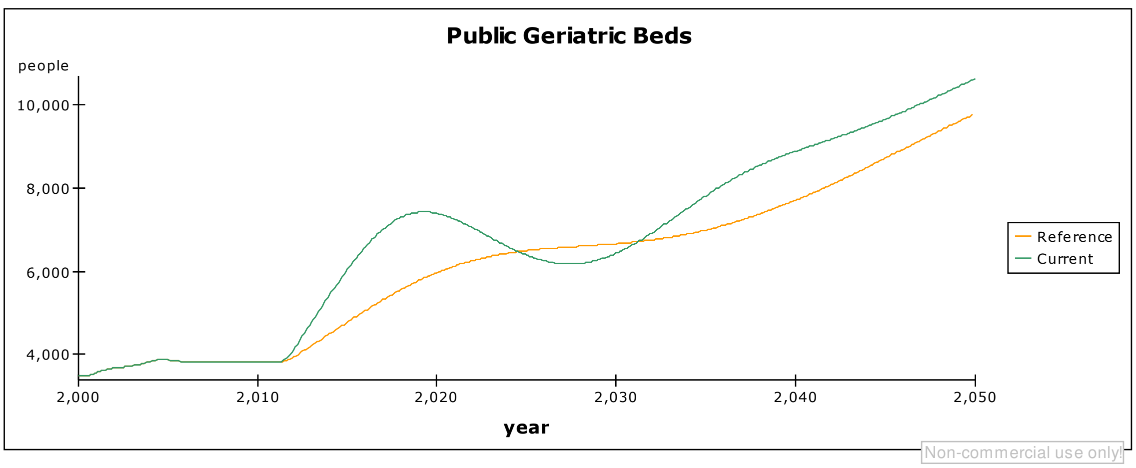


Fig 91: Shorter delay time scenario – Public Geriatric Beds

The shortened delay time shows that altogether more beds facilitated. It is further shown a tendency towards more oscillation. This suggests that the delays present in establishing new bed posts are serving a purpose of avoiding overshoots. Whether this is an argument for maintaining relatively high delays in the policy process is an ethical question; there are people waiting for beds who are the *de facto* cost bearers of the delay. For the community as a whole it may be desirable to avoid overshoots and the cost introduced by these. However, with longer delay times there are more people not receiving the level and category of care they require.

In terms of clients served the shortened delay time scenario reveals an enhanced service offered.

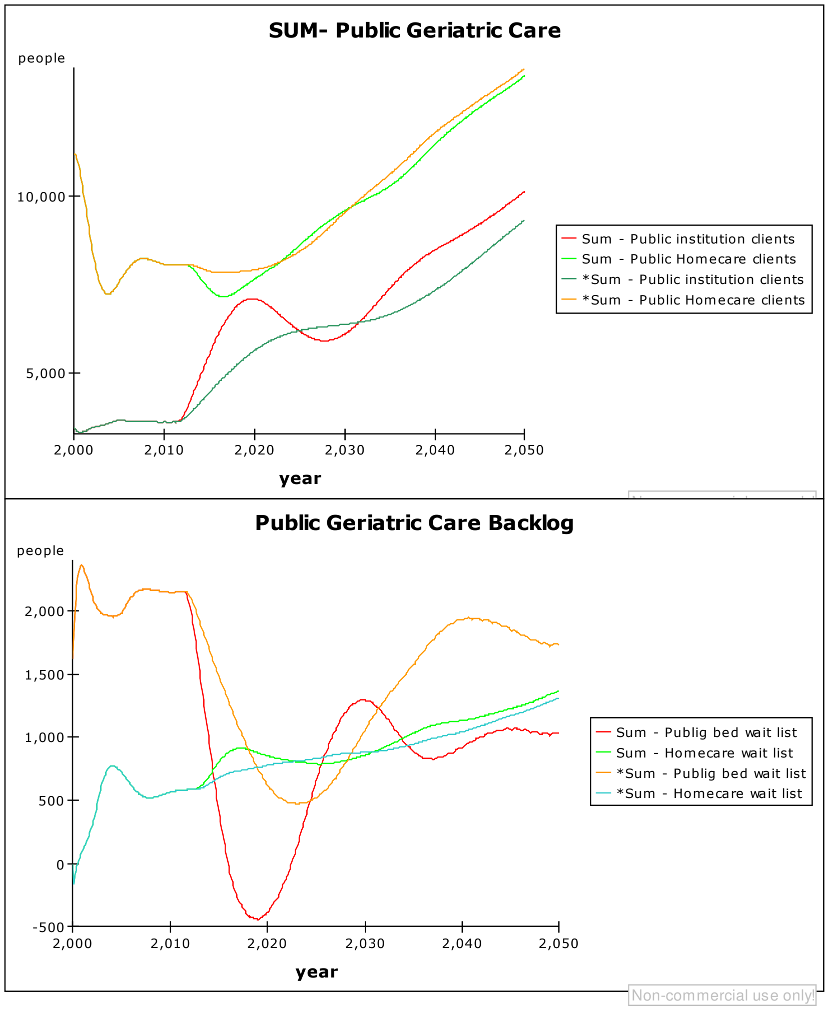


Fig 92: Reduced delay time – Care Clients

Evidently the reduced delay time is bettering the situation for the care clients; more people get the institutional care they require and the amount of people in homecare is reduced. The backlog graphs show interesting behaviour. The institution backlog is significantly reduced; the backlog actually goes negative. This partly suggests a shortcoming of GHPM and partly indicates an important dynamic. Levels of people should intuitively not have the potential of going negative. This is a modelling problem introduced by limitations when working with arrays; the author has not been able to model array defined levels as reservoirs that cannot be depleted beyond zero. Nevertheless; this dynamic is important as it indicates that there is actually a surplus of capacity opening up in institutional services. This infers both a bettered level of service as well as an enhanced potential for choice on the clients end. If there is free capacity flows between different institutions would be made easier; many clients and clients' families would greatly appreciate such freedom of choice.

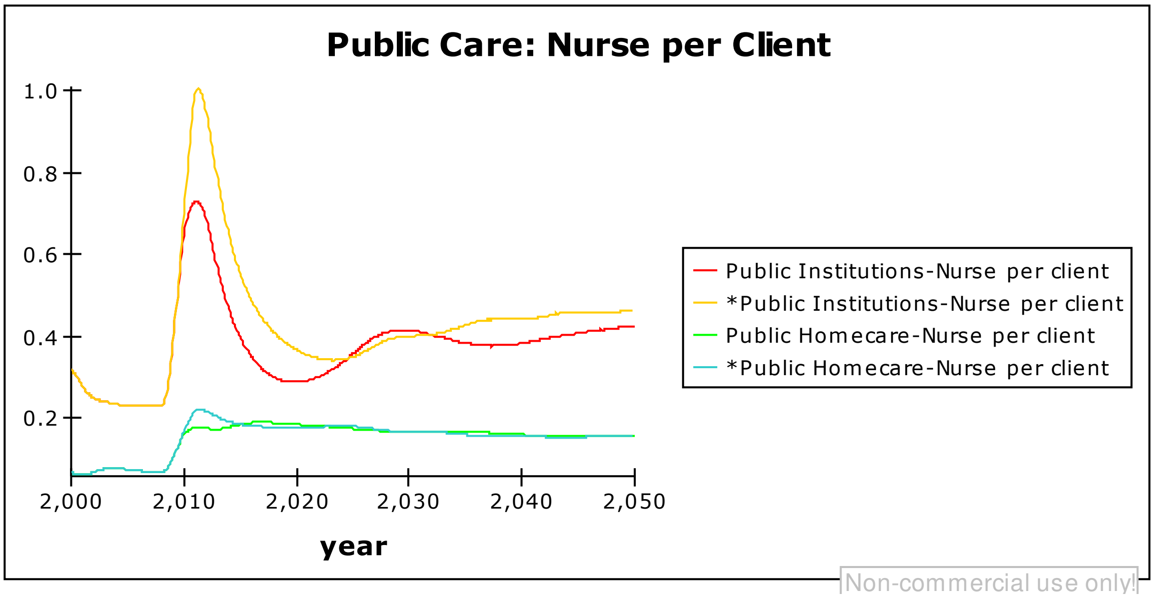


Fig 93: Nurses per client – Reduced Delays.

The reduced delay time is reducing the initial overshoot of nurse positions. In terms of homecare this is appears to stabilize the levels of nurses quickly at the required level. With respect to the institutional capacity the image is more complex. As the initial overshoot is reduced the nurse per client ratio is reduced throughout the simulation run. The reduced client per nurse ratio is also lower then the baserun as more clients are afforded an institution bed.

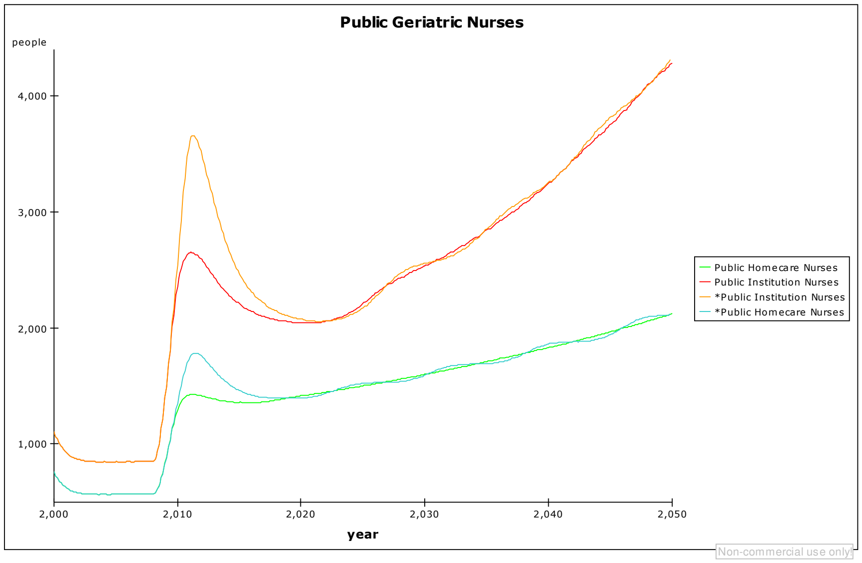


Fig 94: Care Nurses – Reduced delay time

The above graph demonstrates how the reduced delay time in the hiring process is reducing the overshoot in the nurse recruitment.

9.4 Enhanced Efficiency and a Squabble for Resources

The reduced delay policy proved to be an efficient policy. More people where getting the care they needed, the costly problem of overshoots was reduced and the nurse per client ratio was kept stable. The latter scenario is however ignoring the squabble for resources that are omnipresent in public policy making. It is therefore interesting to test the scenario where delays are reduced yet the geriatric health care services are only allowed 80 percent of their goals. To fully capture the difference between this scenario and the utopian scenario of 100 percent goal fulfilment the comparison should be made not against the baserun but against the 100 percent goal fulfilment scenario.

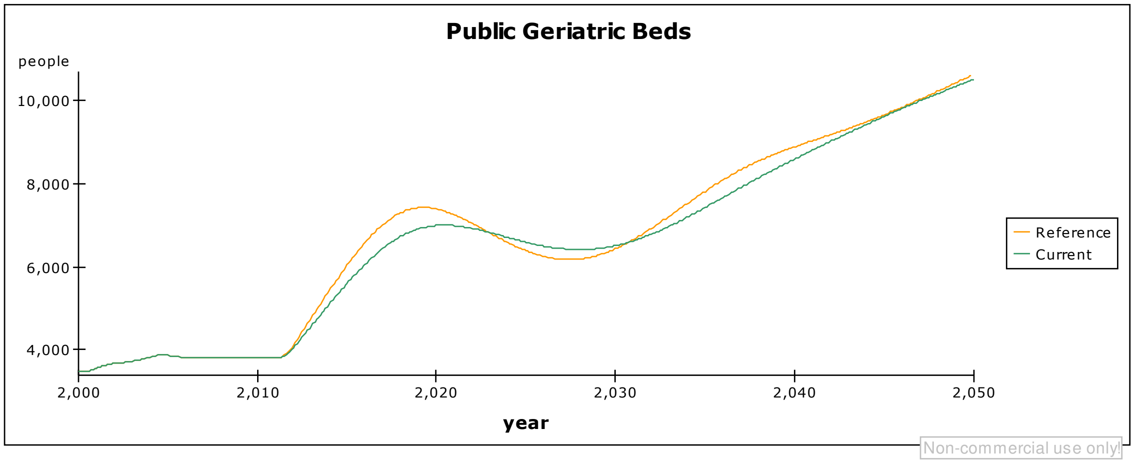


Fig 95: 80 percent fulfilment at reduced delays – Geriatric Care Beds

As expected the more realistic scenario of reduced goal fulfilment renders a dampened oscillation in the development of geriatric care beds. Another and obvious effect is that there are fewer beds provided in total. The reduced oscillation suggests reduced cost to the community but more people will have to wait longer for required institutional care.

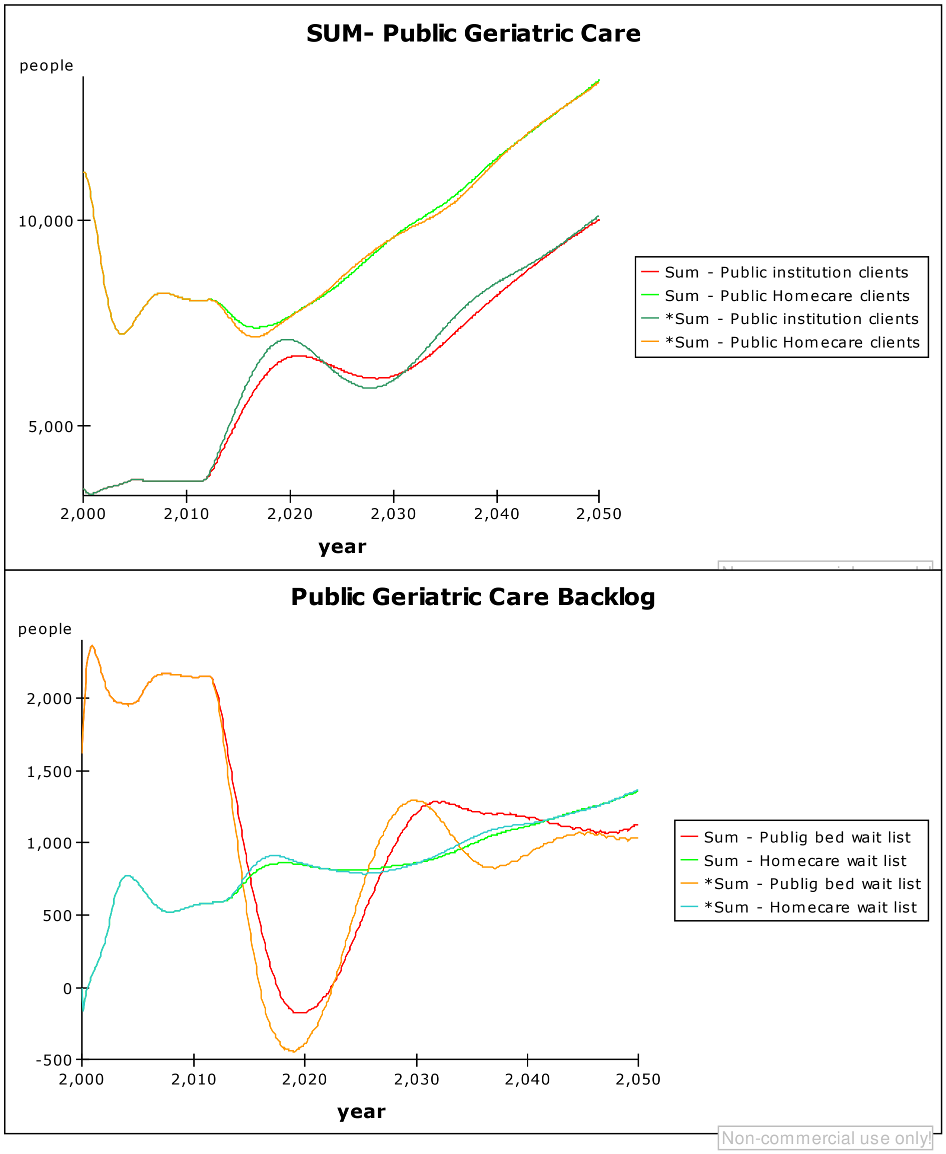


Fig 96: 80 percent goal fulfilment at reduced delays – Care Clients

The same trend as described for institution beds is traceable in the clients account. Oscillation is dampened but the backlogs are larger and fewer people are receiving the care they require. Also the client per nurse ratio reflects this difference.

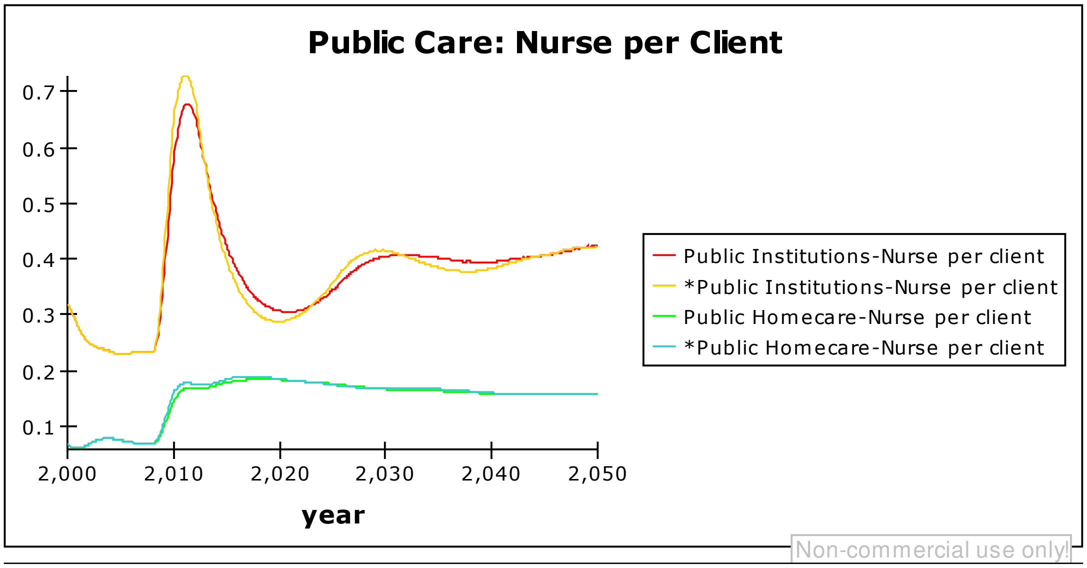


Fig 97: 80 percent goal fulfilment at reduced delays - Nurse per client

The nurse per client ratio exhibits dampened oscillation and a somewhat lower capacity of nurses. The latter indicates that the more realistic scenario of a less then complete goal fulfilment is generating a situation where the care provided has a lesser quality then what would be the case if the health sector was to be equipped with all desired resources.

9.5 The private alternative vs. an inefficient public care sector

A private alternative to the public health care system is in all respects a highly hypothetical scenario. As of 2008 geriatric care is considered a public responsibility. Considering the challenges ahead in the geriatric health care services a private alternative may still be an option worth to address. The GHPM assumes an approach to private business that is unlikely to emerge in Norway; the private sector is here conceived as more or less detached from economic and political reality as it assumes a near perfect market with near limitless resources. Clearly a private sector in geriatric care would not be coined in this manner. The scenario is still an interesting and revealing object of analysis as it may unearth underlying or potential effects of the establishment of a private alternative. How a real world private alternative could or would be designed or developed is not within the scope of the work here presented; the GHPM merely seeks to investigate the behaviour a private geriatric health care sector could induce.

Private business is assumed react to changes in demand significantly quicker then the public sector affords. The private sector is further conceived to consider the public institution waiting lists as the market potential for new clients. Private home care is conceived as attracting clients from the public homecare services as a function of own achievements with respect to nurse per client ratio. As the private sector is activated the pressure on the public sector will be relieved and in turn will this affect the dynamics playing out in the public sphere.

Two scenarios with a private alternative are tested. Firstly the private alternative is introduced in an environment where the public sector is limited to accessing 80 percent of the target capacity and is hampered by long delay times. Secondly the private alternative is introduced in an environment where the public sector is limited to 80 percent goal fulfilment but operates with shorter delays. One could potentially also test a number of other scenarios where only one of the two categories of private care was active or scenarios where the public sector was able to fulfil their goal to greater or lesser extents. As the private alternative is a hypothetic scenario and as it virtually impossible to predict with any accuracy what level of spending the public care can expect in the future the policy testing of private alternatives is limited to the described two scenarios.

One important note must be made with respect to public capacity goals; as the private alternative is launched no change is made to the public target capacity model structure. This is not a probable scenario; if a private alternative is in place one would expect the public policy makers to modify the goal definition to account for this effect. The author wishes not to speculate how such modification may be carried out and leaves the public target definitions unchanged in the event of private emergence. The reader is urged to keep this in mind when considering development on public nurse dynamics that are largely governed by effects of workload.

Private business moves quickly into business. In the simulation runs the private sector is activated in 2008; shortly thereafter the simulated enterprises have established activities.

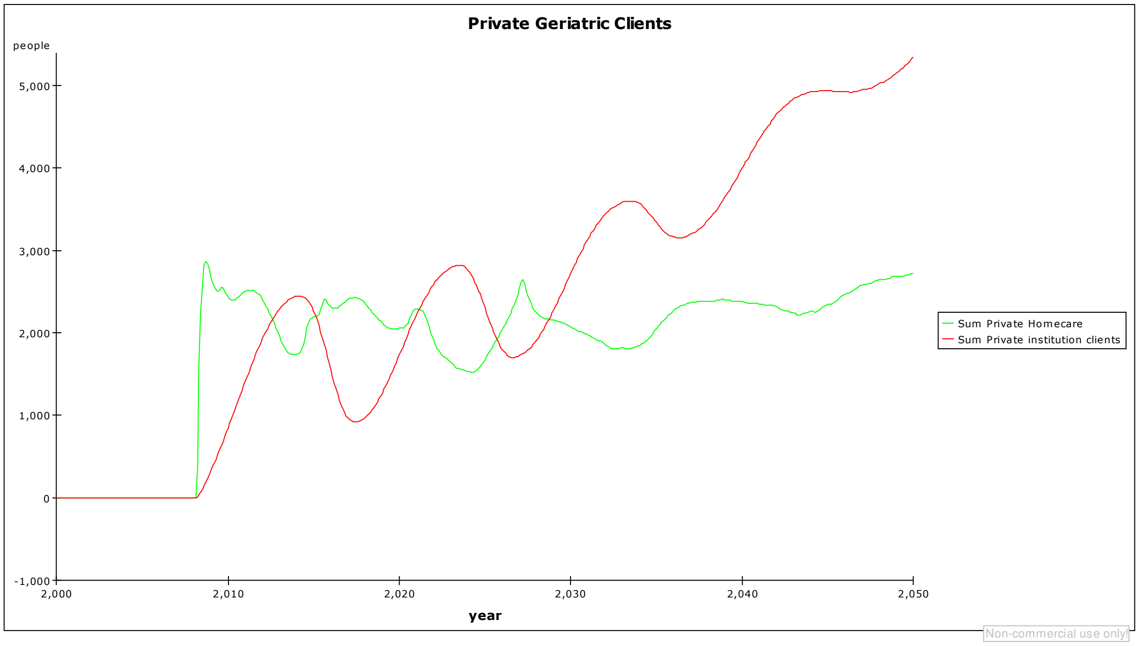


Fig 98: Private Care clients.

The above graph shows that private homecare quickly comes into play whilst private institutions are delayed somewhat. It takes time to raise buildings; also private business is subject to investment and construction delays but is enjoying shorter delays then the public sector. The private care clients exhibit oscillating behaviour. This relates construction and investment dynamics; due to delays in construction the private bed capacity is overshooting. This trickles down on the number of people in public homecare, many of whom are clients awaiting an institution bed. As private homecare clients are pulled from the public homecare clients, an accumulation of public homecare clients suggest an accumulation of private homecare clients. The two above trajectories roughly oscillate in polar phases; as institution clients increase, homecare clients decrease. The oscillating behaviour in general must be accredited to private business' eagerness to invest.

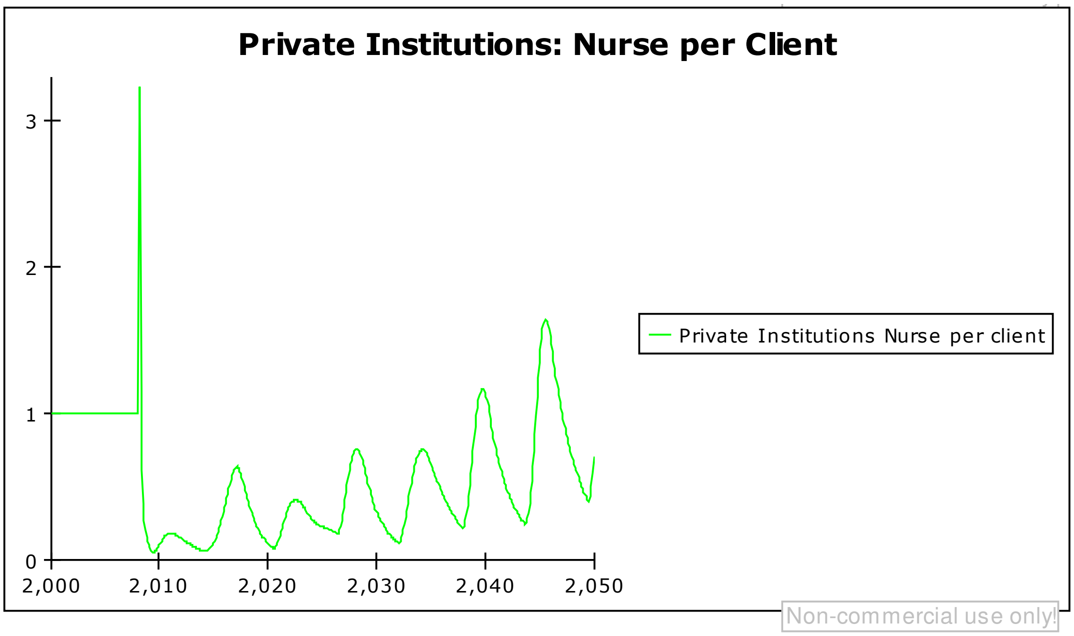


Fig 99: Private institutions – Nurse per Client

The above graph demonstrates the behaviour of the private institutions nurse per client ratio. An initial a gross overshoot is present before the workload generally increased ad exhibits oscillating behaviour. The trend of oscillation is traced back to the behaviour of the private client budgets described above,

It serves no purpose to discuss the behaviour of a hypothetical private care alternative related only to its own achievements. A private alternative should be investigated in light of its effect on the public care sector. The following discussion will therefore consider the private scenarios in relation to the public sphere.

The first private scenario is introducing interesting dynamics in both public care categories; private business significantly alters the behaviour of public home and institutional care.

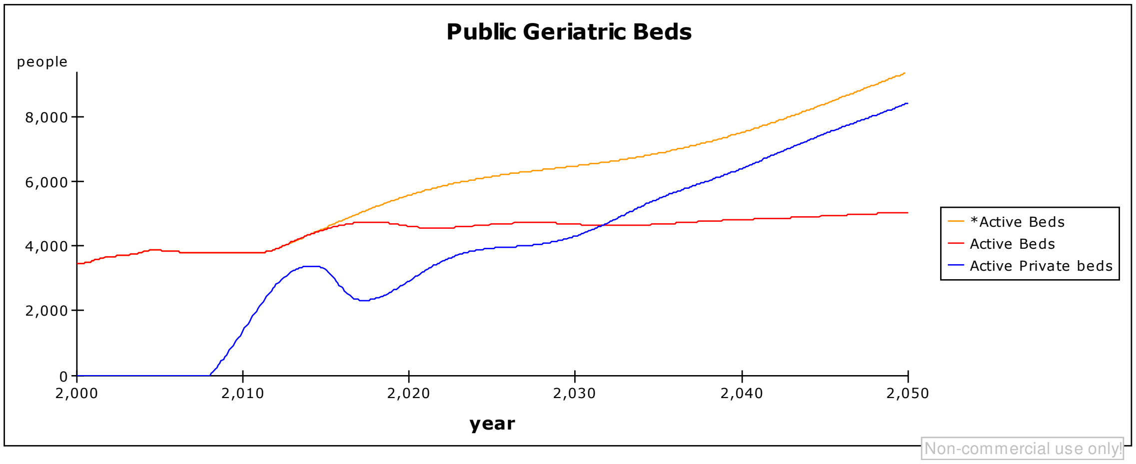


Fig 100: Private and public beds – public at 80 percent and long delays

The above graph shows the behaviour of public bed development at 80 percent and long delays as the reference trajectory. It is obvious that the introduction of a private alternative when the public sector is operating with reduced goal fulfilment and long delays is strongly affecting the development of institution investment in the public sector; as the private sector emerges the public institution investment is stabilizing. This suggests that the public may conceive the private as a relieving factor and allowing for a slowdown of investments. This may be unproblematic but behind these trajectories there may be elderly who are not getting the bed they require should they not afford a private bed. The model does however not capture dynamics of patient flows between private and public institutions; it merely suggest that internal swaps may occur and that the aggregated result may be the same.

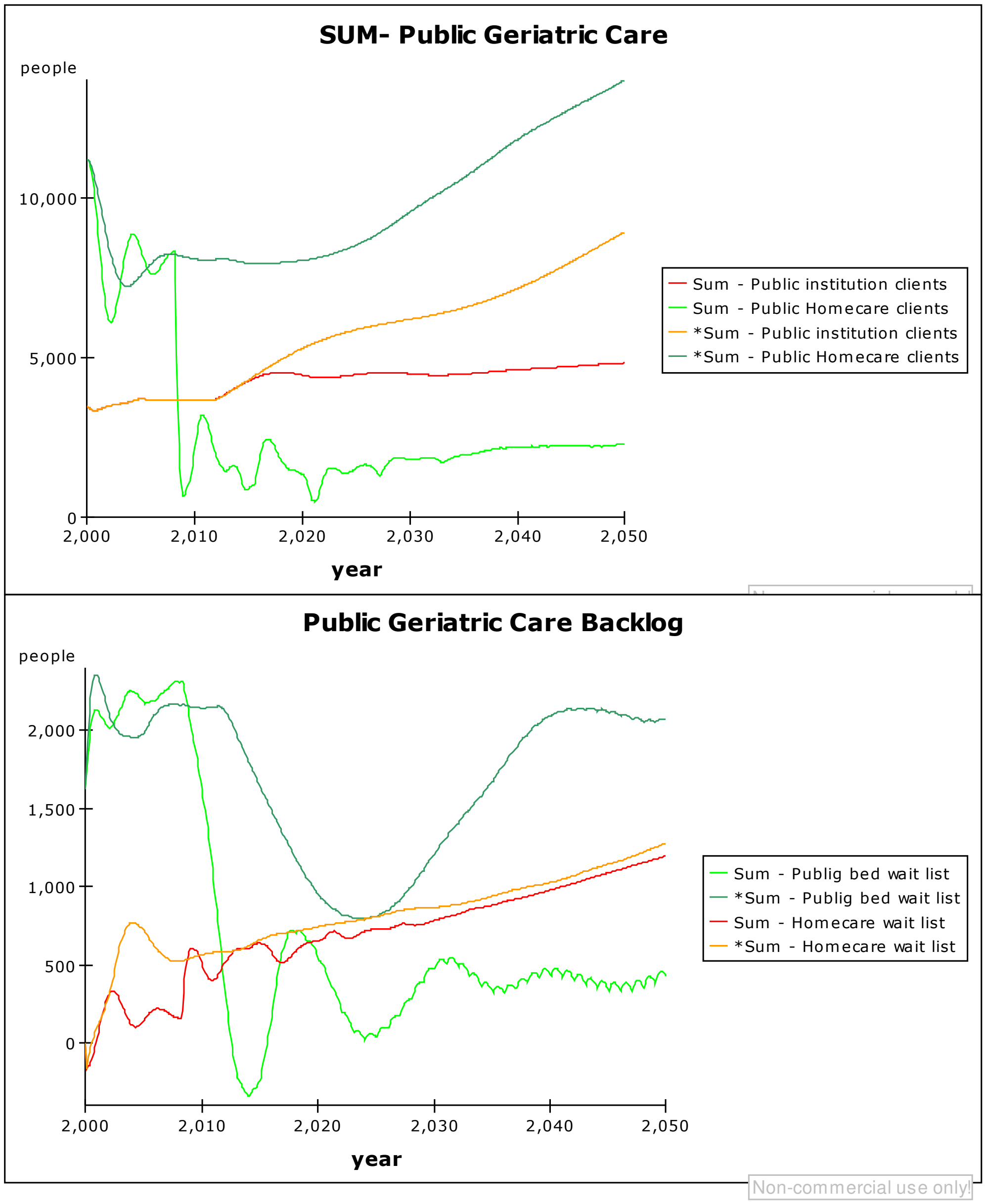


Fig 101: Effect of Private on public clients – Public sector at 80 % and long delays.

The reference trajectories in the above graphs are the scenario where no private alternative is present and 80 percent of goals are approached. The two graphs show dramatic changes in the public client behaviour; the amount of both institution and homecare clients are significantly reduced. The massive reduction of homecare clients is related both to the emergence of private homecare and the absorption of public waiting list. The backlog budgets are also reduced dramatically; this as there is an alternative care service available to those awaiting care. In this respect the homecare backlog is reduced much less then what is the case for institutions; the latter as the wait for receiving homecare is significantly shorter then for institutions where beds must be made available.

The number of deaths amongst people awaiting institution beds is also reduced. The latter is an obvious effect as the backlog is reduced and less people spend less time awaiting institution beds to clear. The reference trajectory is here the scenario where no private alternative is optional and the public sector approach an 80 percent goal fulfilment.

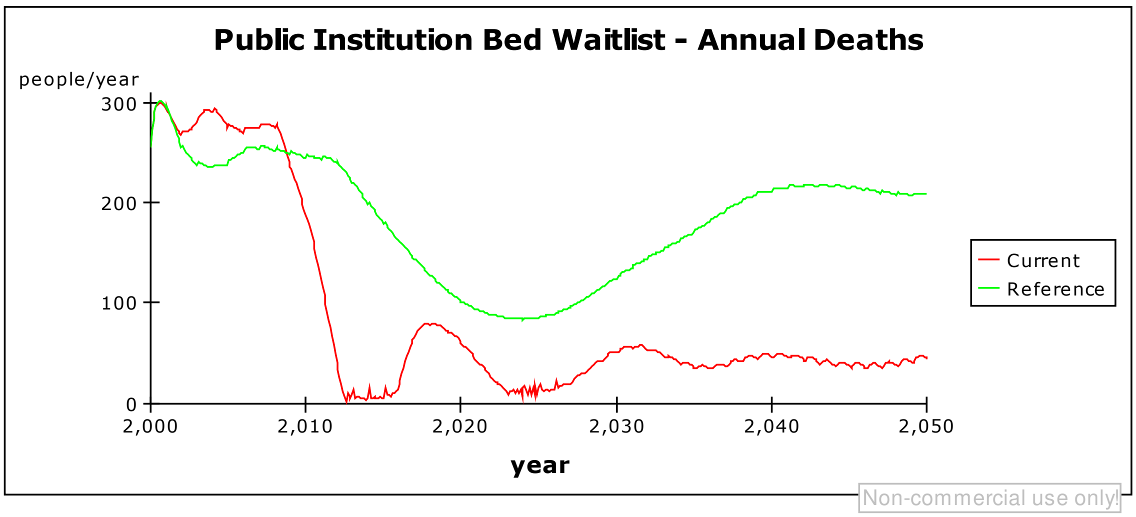


Fig 102: Waiting lists Death – Private active, Public at 80 percent and long delays

Due to the recruitment policies defined by the city of Bergen, still active in the model structure also in the event of a private alternatives the number of nurses recruited is strongly exaggerated in the homecare services. This effect is not present to the same extent in the institutional services. This simply relates to the fact that public institution clients are not reduced as significantly as the public homecare clients are. This effect merely underlines the fact that the public realm must redefine its recruitment goals if a private alternative was to come into play. The reduced workload in private homecare along with the unchanged recruitment goal manifests an interesting dynamic; the reduced workload increase the attractiveness and reduce the turnover amongst public homecare nurses. As the workload drops more nurses end up working in the public homecare sector.

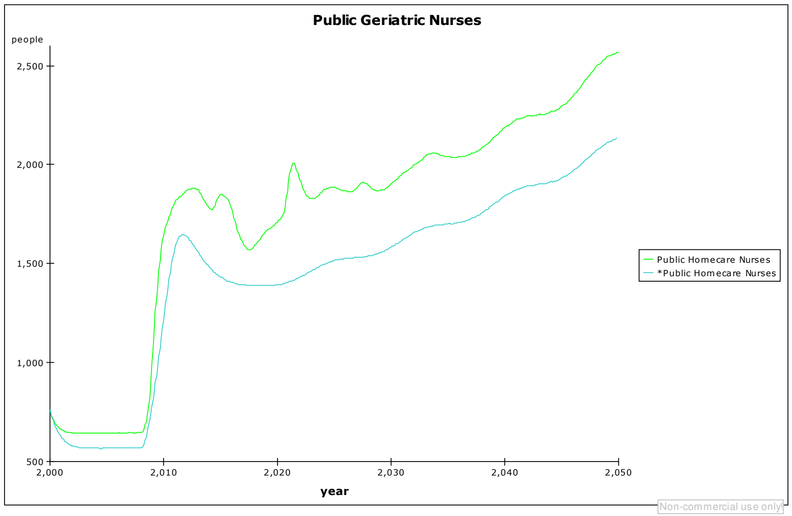


Fig 103: Workload effect on Homecare nurses, private relieve workload

Reference trajectory in the above graph is the 80 percent goal achievement at long delays with no private alternative activated. Although the above behaviour is consistent with the model structure it is not a valid representation of a likely real world development as the nurse recruitment premises are unrealistic. The behaviour does however underline the importance of workload on labour budgets; an effect of this may be enhanced attractiveness of public care employment resulting from pressure relieved by the private sector. this is an important dynamic to consider for public policy makers when defining new goals for recruitment.

Secondly the private alternative is tested in an environment where the public sector has managed to increase its efficiency. In order to compare the two scenarios the following graphs will employ the preceding scenario of 80 percent goal fulfilment and long time delays and an active private sector as reference. The difference in the development of care beds is not dramatic in any sense. The two scenarios are producing closely tied behavioural patterns.

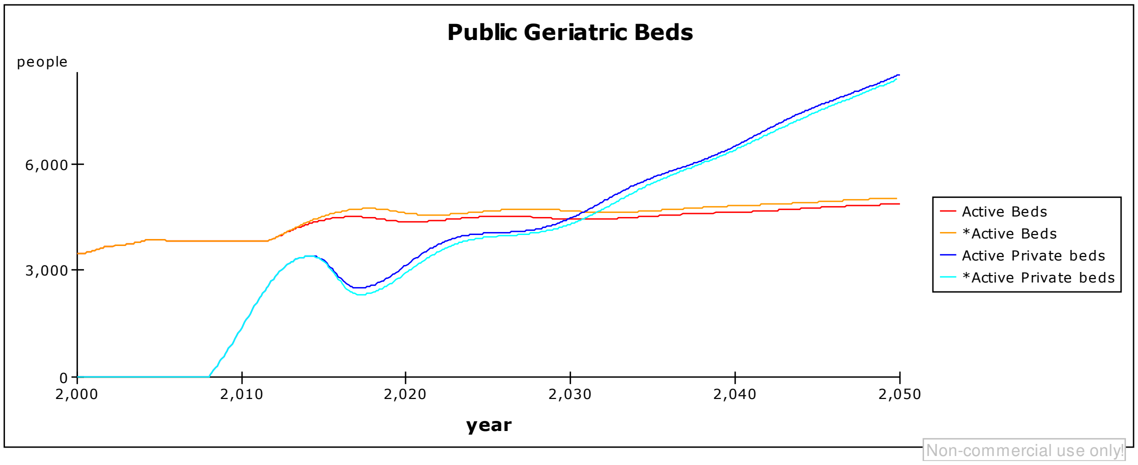


Fig 104: Private and public beds at different public delays

There is not much to be comment beyond what has been stated in the preceding scenario. There is however one important and counter intuitive difference between the two scenarios. As the public sector enhances its efficiency it also reduces its bed budget whilst the private sector does the opposite. This relates to the tendency of overshoots induced by delay times. As the public enjoy a more efficient investment it provides fewer public beds. Whether this is a desirable situation is a political question that will not be embarked upon here. It may however be stated in sober terms that an efficiency increase in the public sector may be reducing the public sectors ability to provide public beds demanded and this may to many with limited private assets be a problem. This tendency is reflected also in the amount of public care clients:

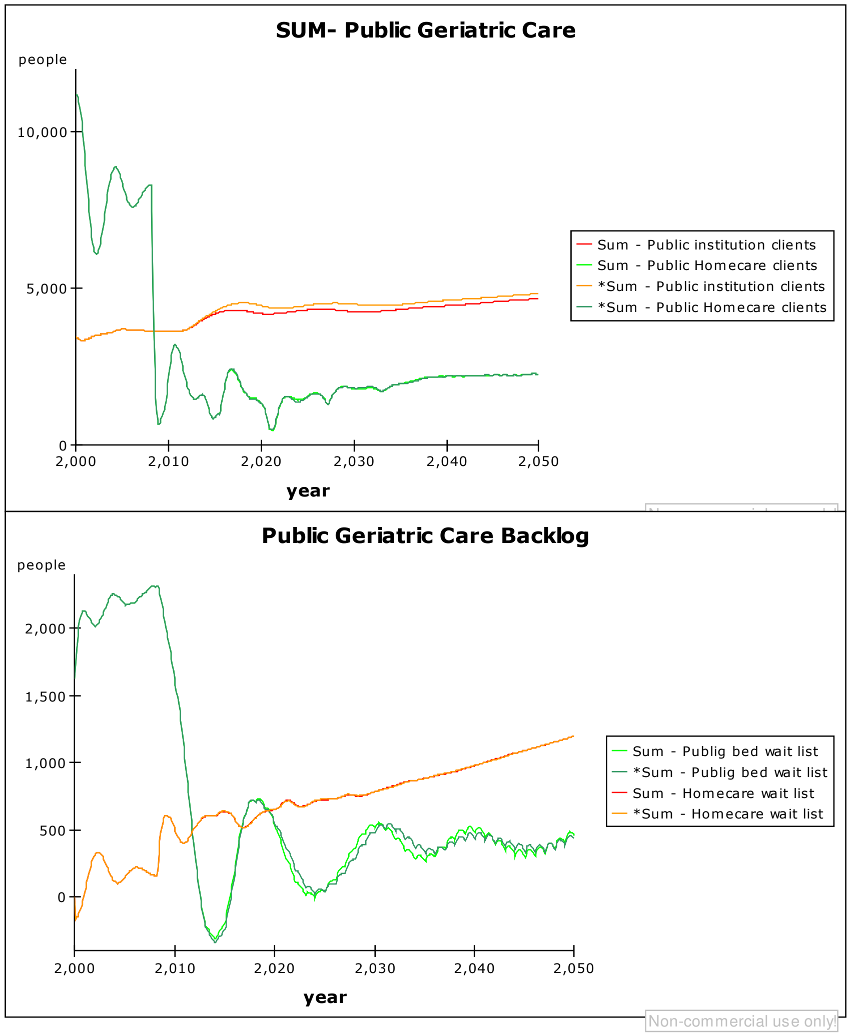


Fig 105: Care Clients - Short and Long delays in public sector

The difference between the two scenarios is subtle; yet, enhanced public policy efficiency tends to reduce the number of clients served. The same dynamic difference can be traced in the number of deaths amongst people on the institution waiting list.

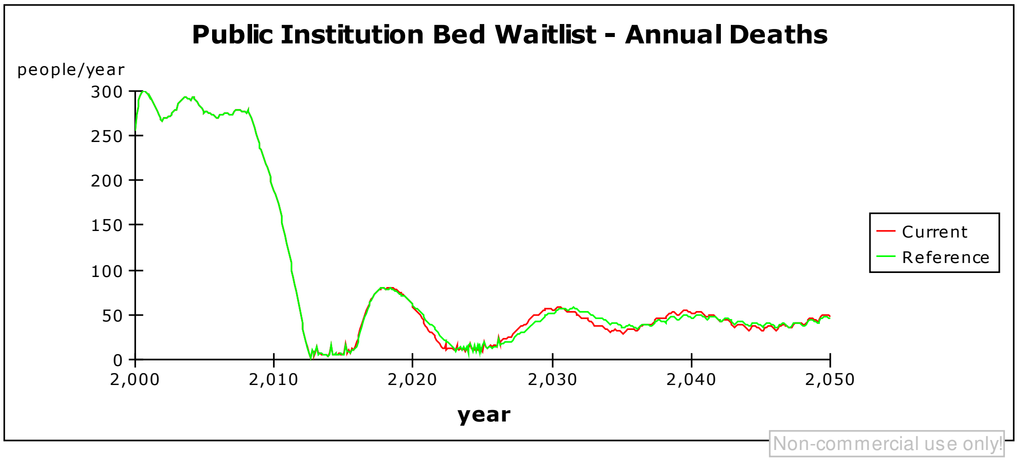


Fig 106: Deaths in waiting list difference short and long public delays

Also here the difference is subtle and requires no further explanation as the different dynamic behaviours are produced by the same effects as described above.

9.6 Further Discussion

It appears that enhanced achievements in the public sector do not affect the system behaviour much if there is a private alternative at play. This is an interesting perspective as a shortening of public policy delays produced significantly enhanced system performance when there was no private alternative active in the system. Rather, enhanced efficiency in the public sector appears to amplify the tendency of public downsizing and private growth. The latter is accredited two dynamics; the private sector relieves the demand for public institution services and thereby the public propensity to invest. By absorbing the public institution waitlists much of the pressure on the public homecare services is also removed. Furthermore; the private homecare sector moves towards a static nurse per client ratio goal. The nurse per client ratio or quality of care is therefore kept stable; this affords the private sector to maintain or even increase its attractiveness through staff expansion. This dynamic is more or less depleting the public homecare service.

The latter is not a realistic scenario as the private alternative is not a feasible reflection of Norwegian reality; it is however transcending an important dynamic message; private business has the power to reduce the expectations on the public sector. In the awe of plummeting expectations the public sector may display a tendency towards downsizing. A development of this nature could hold grave implications for a number of future care clients with limited assets; these clients benefit on public overshoots.

Availability of geriatric institution beds appears to be a major driving force behind the dynamic behaviour of the geriatric health care system as a whole. When insufficient bed capacity reins the pressure on the homecare services increases. When the institution availability is enhanced the situation in the homecare services is bettered. To avoid crisis in both the institutions and in the homecare services steps towards enhanced institutional capacity must be made at early stages to account for the long delays in the decision, investment and construction process early stages. The latter notion also lends virtue to the pronounced policy of improving and developing the range of care tasks to be handled by the homecare services(Byrådet, 2007). When the institution capacity falls short the waiting clients must be offered the required level of care in their homes; this calls for development of the homecare services. An improved homecare service will obviously also reduce the demand for institutional care as more clients potentially may receive their required care in their own residences.

To assume that the public care sector ever will get access to the funding required for 100 percent goal fulfilment is as discussed earlier not a likely real world scenario; to account for this the model has been tested at 80 percent goal fulfilment. At this level of spending the public sector performs considerably better when the policy process delays are reduced.

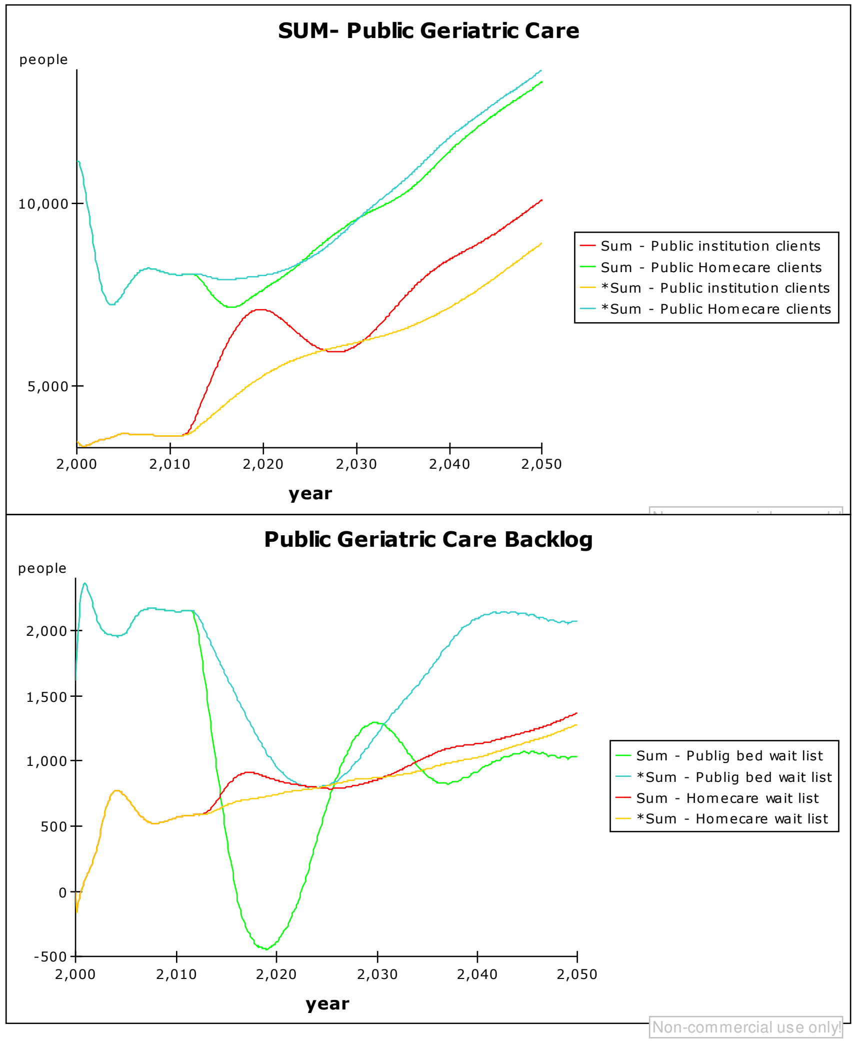


Fig 107: 80 percent goal fulfilment at short and long delays

The above graph compares the performance of the public sector at short and long delays when no private alternative is active and 80 percent of the capacity goals are approached; the long delay scenario is drawn as the reference trajectory. The graph indisputably argues that delays are causing significantly poorer performance in the public sector. This again is underlining the importance efficiency in public policy planning and implementation. It must be consider an irrevocable focal point for the public policymakers and bureaucrats to stress their own effective handling, impediments in the public policy process will come with a cost of considerable distress to future care clients. This point of argument is further stressed by the future general and massive growth of demand for geriatric health care services.

To accelerate the public policy process is as discussed earlier a difficult matter. The public policy system is inherently tedious and slow. Different interests and limited resources generate a squabble for assets and a course of compromise. Time consumption and time delays are omni present factors. The latter may however have its perks and virtues; delays may in some situations avoid overshoots-the latter if delays are present in acquisition but not to the same extent in loss. Alas, delays tend to do the opposite. Overshoots come at a great cost as superfluous investments are made. In many areas of business and public policy it is a vital point to avoid overshoots; it may be preferable to operate beneath preferred capacity if the alternative is an overshoot. This is not true in the case of care services. If a park is left to whither for a while the consequence is bearable. If elderly are ending their days in despair the public policy has failed. In matters where the population's health and quality of life are at stake overshoots should be considered acceptable losses.

Should it prove difficult to reform and accelerate the time consumption in public policy the policymakers need to come to terms with this reality. The GHPM works on along action-reaction logic; as demand emerges a response to that demand is initiated. The demand is met when the procedural delays have been surpassed. Such an Ad-Hoc approach is not an example of responsible policy making; indeed the city of Bergen has not been prone to adopt such a strategy. The City of Bergen has in several iterations attempted to plan ahead in order to be ready for future challenges in the public geriatric health care services. The question is whether the city officials have done so successfully. The population projection applied in the planning endeavours appears to be static and underestimating the full magnitude of the elderly boom, and it is not reaching far enough into the future. If planning is based on faulty assumptions the derived policies are prone to be inadequate. The author suggests that the demographic model applied in the GHPM may represent an enhanced projection as dynamic changes such as increased life expectancy is accounted for. This is not to say that the underlying demographic model in the GHPM is fit for this purpose, in that respect the model is to simplistic; it is however indicating that better population modelling is called for. The work here presented indicates that around 2020 a surge of care clients will emerge. The Norconsult projection ends in 2024. Granted the time it takes for the public sector to facilitate new care capacity this suggest that one cannot postpone the long process of upgrading the public geriatric health care system much longer. The latter is emphasized by the fact every client not receiving sufficient care is a manifestation of policy failure; care clients are people in despair and not comparable to park benches, intersections or tram tracks.

The Nurse Pool component of the GHPM is grossly simplified and indeed not well conceived. This is a shortcoming of the current state of the GHPM as it would be interesting to investigate the future availability of required labour. Such analysis is not possible with the GHPM at this stage. The author suspects that the future holds a grim perspective in this respect. Geriatric care is but one of many care segments requiring trained and licensed care personnel and therefore finds itself in a competition with a number of other health care services. It is however possible to infer that the geriatric health care sector will in the future require significantly more nurses then what is currently employed. Facilitating desirable work conditions, tariffs and agreements will in the near future be an irrevocable necessity. A potential policy in terms of staff challenges may be to up the work immigration. One could inspire both direct work immigration to the health care services as well as a general increase of immigration to free up resources from other segments of the labour pool. This policy is not captured by the GHPM but is certainly worth mentioning and further research.

Another interesting perspective on the future geriatric health care clients is their increased expectations and abundance of assets. The political columnist Trine Eilertsen suggests in a 2007 comment that the future cohorts of elderly have vastly different expectations to their years as elderly then the current seniors have(Eilertsen, 2007). This is a very interesting and very dynamic perspective not accounted for in the GHPM; it urges that not only must the private geriatric care be maintained at its current level of quality, that level of quality might need upward adjustments. The future elderly possess a greater wealth then the current generations. Altogether this lends credibility to the idea of emergence of a private sector in geriatric health care services.

10. Conclusion

The work here presented set out to investigate and to address the following dynamic null hypothesis:

H_0: "Due to delays in the realm of public policy making and implementation the future strains imposed on the geriatric healthcare system by the pending elderly boom must be addressed at an early stage in order to maintain or better the capacity and quality of the services rendered. It public policy is engaged in to late a stage the reinforcing loops of the geriatric healthcare system generate a vicious cycle of degradation in the geriatric health service "

The policy testing and various simulation runs conducted with the Geriatric Healthcare Projection Model affords strong support for accepting this hypothesis; delays in the public policy process are major impediments; an Ad Hoc approach renders significant shortcomings in the geriatric health care system. The model has not in fact tested a "Look Ahead" scenario; it has however highlighted the result of the alternative. To some extent the null hypothesis may be exaggerating the effects of the reinforcing feedback loops; this may be a result of feedback underestimation on the author's side but is likely to be a result of overestimated resource availability. The GHPM models nurse recruitment based on political goals; whether these goals can actually be fulfilled is not fully revealed by the GHPM. Nevertheless; the overarching perspective stated in the null hypothesis is one of planning; and the delays present in the public sector are irrefutably calling for early engagement towards the pending geriatric health care boom. As the null hypothesis is accepted the alternative hypothesis is dismissed.

The work here present urges conclusions beyond the stated null hypothesis. The development and application of the GHPM has indeed proven to be a matter of exploratory work. There are no similar System Dynamics models capturing the dynamics of geriatric health care and the effects of demographics on this niche of public health services.

Population dynamics is a dictating factor in the geriatric health care system. When scaling the future service portfolio the current and projected age distribution must be taken into account. Population dynamics are vastly important in three respects; firstly the number of care clients is of essence, secondly the availability of care workers is governing of the potential care offered and thirdly is the magnitude of the remaining labour pool essential to marinating the productivity of the community in general. The third point is not captured by the GHPM but is an obvious one; everyone cannot be either a nurse or a client. The work here presented has not fully captured the dynamics of the nurse pool. The model is however open-ended in this respect and may be elaborated on later stages. It seems however safe to assume, based on the development of required geriatric nurses, that a surge in demand for skilled nurses must be expected. With regards to the demographic composition this may present a number of challenges. The focal point of the underlying population model in the GHPM is to capture the expected development in life expectancy. The cohorts now approaching are already disproportionally large compared to the remaining population; they can also expect to experience reduced mortality. The model has demonstrated that this dynamic has significant implications for the demand for geriatric health care services.

The staff challenges are significant; the geriatric health care sector in the city of Bergen must at an early stage acknowledge this point and move to recruit nurses. The City of Bergen postulates that all care workers are to be educated practitioners in their field. This suggest in its own power a major challenge considering the number of unskilled care workers employed in the geriatric services(Byrådet, 2007). A further challenge is to attract nurses to the geriatric services; nurses may work in a number of fields. Knowing that the public realm moves slowly with respect to tariffs and salaries the city should commence with bettering the employment parameters for geriatric nurses at an early stage; if the geriatric service lags behind in this respect they may not be able to recruit the required number of nurses. Considering population dynamics it may also be a valid point to look into opportunities in work immigration. With respect to direct work immigration to the care services these raise questions of bi-lateral or international nurse licensing agreements as well as questions regarding measures taken to be taken to recruit foreigners. In the event of an emerging private sector in geriatric care the importance of establishing attractive and accommodating work situations in the public sector is emphasized; private enterprises tend to move more quickly in terms of establishing attractive work conditions.

Another policy that has not been tested but that may be highlighted is the policy of care-exports. There is a growing tendency of elderly moving to continental Europe in their early retirement years; if geriatric care is to be provided at these locations that may induce implications for the geriatric health care system.

The number of deaths in the waiting lists is affected by the efficiency of the care sector. This figure is emphasized in the thesis as its underlying and real world implications are grave. People deceasing whilst awaiting their required level of care are likely to suffer greatly; these people certainly need institutional accommodation. Accounting waiting lists deaths may be morbid; nevertheless, the account renders a chilling perspective. Care clients are not any other material flow; they are people and should be treated and accommodated thereafter.

The addition and introduction of a simulated private geriatric health care sector must certainly be considered as exploratory; Norway has no tradition for private enterprises competing with the public sector in the realm of geriatric health care. The tests here conducted revealed interesting dynamics. First and foremost a potential future market for private geriatric care enterprises was revealed; the waiting list in the public care sector affords a growing field of future business. Secondly an introduction of a private sector may alter the course of public care development. By relieving pressure on the public realm, the public sector may respond by reduced ambition and henceforth also reduced investment. The latter scenario would have grave implications for care clients with limited financial assets. The fact the future cohorts of care clients are likely to hold high expectations to the level and quality of care offered as well as many amongst these future clients are well set financially is a perspective not captured by the GHPM. This perspective may support the idea of a private sector in geriatric health care. Should such private services be introduced the public sector must both adapt and modify the goals for care capacity. In the event of such a scenario the public should consider inclusive policies; private care is not an option for all citizens and a private alternative has the potential not only to create great gap of equality but to further to deter the public sector from providing an acceptable level of care and magnitude of capacity. To avoid a development of this nature the public sector must move to define policies that ensure proficient care provision for the seniors outside the private care system. A Private sector and its addition to the total care capacity must be considered as an opportunity for the public sector to enhance their quality of care; not as an opportunity of downsizing during the wake of an elderly boom

It should again be emphasized how important delays are in the care system. The private sector is, as it is modelled here, performing much better then the public sector is. The predominant reason for this is the reduced delays in the private sector.

In conclusion it can be stated that the future of geriatric health care services is determined by a number of highly dynamic processes. Population dynamics dictate a number of challenges ahead. In order to accommodate the accelerating demands for geriatric health care the public policymakers must move quickly; the public realm is prone to delays and the future is not that far ahead. Challenges reside in construction of sufficient institutional capacity and in accommodation of attractive work environments for geriatric nurses. There may well be a market for private geriatric care. Should such an alternative emerge the public sector must be careful not to fail their duties to those outside the private care services. A dynamic model of the future prospects of geriatric health care may prove to be an important and efficient tool for policy planners seeking to facilitate responsible policies towards the geriatric health care situation

11. Further research

The Geriatric Healthcare Projection Model is developed with a number of open ends; many of which may be further explored and elaborated. The underlying population component in the GHPM has many virtues but could indeed be further advanced. At its current state the population component is not specifically modelling inter-borough migrational patterns, this may be added to expand the resolution of the simulation. These dynamics are however captured at a net migration level but this structural component is removing people completely from the city population for re-introducing then in another borough. Currently this is not an important dynamic of the GHPM but it could prove an important aspect if other areas of the model are further developed. A development of this nature is a higher resolution on the model elements capturing infrastructure. The GHPM is simply distributing all institution beds evenly between the boroughs; this is a simplification that could be modelled at a more detailed level whereas the actual capacity and capacity shortages of each borough could be captured. In this respect inter-borough migration must be accounted for in the population component of the model.

The model may also be further developed in the structural elements encompassing the nurse pool. As this thesis is concluded the nurse pool is highly simplified and is indeed going negative through the simulation. Although a negative nurse pool reveals a prospect of future staff shortage or at least an enhanced need for trained nurses the availability of nurses should be developed to manifest a constraint to nurse recruitment. In order to do this however one must obtain data that is currently not available to the author.

A number of parameters in the model is conceived somewhat ambiguously or arbitrarily in order to explore the effects of these parameters. Better parameterization allows for better simulation and prediction. Examples of parameters that could be further explored are the effects of nurse's work load and the base rates of sick leaves, turnover and attractivity. It may also be asserted that people already in homecare have different probabilities for developing a need for institutional care then what one would expect from the non-client population; parameters of this nature could add to the accuracy of the GHPM. As well one may assume that mortality rates are different for clients then they are for non-clients. In general it can be stated that the figures and the data provided by the city of Bergen appear to be somewhat skewed or manipulated; better data would enhance the quality of the model.

The GHPM is fit for exploring potential future trends, tendencies and effects policies in the health care services. It is not well suited for making accurate projections for policy making purposes. In order to use the GHPM in this way it must be further developed with respect to structure and parameters must be further calibrated.

There are also interesting feedbacks that are likely to be at play in the real world that are not implemented in the GHPM. An example of this is effects of the state of the geriatric health care system on the mortality amongst the elderly. It seems safe to assume that a bettered health care system has the potential of increasing the life expectancy of the population. To add such feedbacks to the GHPM would certainly afford interesting insights.

The private sector is in the GHPM conceived with a rather utopian perfect market assumption. This is not a likely framework for a potential private geriatric care sector in the city of Bergen. The private sector may therefore be developed to fit more probable constraints as they are likely to be defined for such enterprises.

The model may also be fitted with a user interface or an interactive learning environment interface. Such an addition could empower policy makers or others not trained in the use of Powersim or system dynamics software to investigate and explore potential policies or scenarios on their own.

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13. Appendix

The appendix is enclosed on a CD-ROM.

The appendix contains is the Geriatric Healthcare Projection Model. All equations and array parameters are embedded in the model. The author contemplated enclosing the equations as a print out but was advised by the project supervisor to refer to the Equations view in the Powersim model in matters relating to equations listings.

The CD-Rom also contains two excel files. If the GHPM is copied from the CD-ROM to a hard drive the user is advised to copy the entire folder in which the model and excel files are embedded; the relative path between the model the data files must not be changed, should the path be altered the model will be corrupted.