



Norwegian University of
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Socio economic metabolism of Norwegian Kindergartens

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MASTER THESIS

for

Student Avijit Pandit

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Socio-economic Metabolism of Norwegian Kindergartens

*Sosial-økonomisk metabølisme av norske barnehager***Background and objective**

The quality of kindergarten services depends heavily on the availability of pedagogical and infrastructural resources. In Norway, most children have access to kindergarten education. However, there are also some challenges: (i) there are large differences among counties and municipalities regarding the number of teachers available per student, (ii) many teachers do not have an education in “Early Childhood Education and Care”, (iii) there are large differences regarding the space availability, and (iv) the space of many kindergartens is considered as not suitable for transforming kindergartens in a social space for children. All of these challenges need to be faced under changing boundary conditions, such as (a) changing numbers of children entering kindergartens depending on the region – overall a growth is expected, (b) changing availability of teachers for example due to retirement, (c) teachers have different needs for further education, (d) kindergarten buildings have different ages and may need replacement or (e) are in need for renovation.

The candidate has conducted a project last fall, in which he analysed the kindergarten system from a stocks and flows perspective. Children were regarded as a stock of service demanders, teachers were regarded as a stock of service providers, and kindergarten buildings were regarded as a stock of infrastructures. This study demonstrated the applicability of this approach, however, the system was not refined enough in order to allow for a discussion of the level of education of the teachers or the suitability of the infrastructural space. The aim of this master thesis is to analyse these challenges from a quantitative systems perspective, and to address in particular the shortcomings of the quality aspects. The quality aspects should be addressed using a typology, analogue to the way this has been done with buildings and vehicles, and to test the suitability of using a Type-Cohort-Time approach for the entire model.

The following tasks are to be considered:

1. Conduct a literature review on the kindergarten education system of Norway, including:
 - The existing education supply-demand models used by Statisk Sentral Byrå (SSB).
 - Contacting the Knowledge Centre of Norway (KSU) to gain a better understanding of the challenges on the education level of the staff and the spatial distribution of kindergartens. Explore a basis for collaboration.
2. Develop a system definition for the kindergarten system in Norway that differentiates types of teachers and buildings.
3. Define and quantify the drivers (parameters, stocks and flows) of the system, and collect and characterise any other required data, by following a type-cohort-time (TCT) approach.
4. Develop a dynamic MFA model of the kindergarten system including the following subtasks:
 - Develop a mathematical model following a TCT approach.
 - Quantify the system and eventually calibrate the parameters.
 - Conduct a sensitivity analysis.
 - Historically recreate the model to validate the system.
5. Interpret the findings in terms of the methodological approach used and the policy implications for the kindergarten system.
6. Write the thesis report

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Within 14 days of receiving the written text on the master thesis, the candidate shall submit a research plan for his project to the department.

When the thesis is evaluated, emphasis is put on processing of the results, and that they are presented in tabular and/or graphic form in a clear manner, and that they are analyzed carefully.

The thesis should be formulated as a research report with summary both in English and Norwegian, conclusion, literature references, table of contents etc. During the preparation of the text, the candidate should make an effort to produce a well-structured and easily readable report. In order to ease the evaluation of the thesis, it is important that the cross-references are correct. In the making of the report, strong emphasis should be placed on both a thorough discussion of the results and an orderly presentation.

The candidate is requested to initiate and keep close contact with his/her academic supervisor(s) throughout the working period. The candidate must follow the rules and regulations of NTNU as well as passive directions given by the Department of Energy and Process Engineering.

Risk assessment of the candidate's work shall be carried out according to the department's procedures. The risk assessment must be documented and included as part of the final report. Events related to the candidate's work adversely affecting the health, safety or security, must be documented and included as part of the final report. If the documentation on risk assessment represents a large number of pages, the full version is to be submitted electronically to the supervisor and an excerpt is included in the report.

Pursuant to “Regulations concerning the supplementary provisions to the technology study program/Master of Science” at NTNU §20, the Department reserves the permission to utilize all the results and data for teaching and research purposes as well as in future publications.

The final report is to be submitted digitally in DAIM. An executive summary of the thesis including title, student’s name, supervisor's name, year, department name, and NTNU's logo and name, shall be submitted to the department as a separate pdf file. Based on an agreement with the supervisor, the final report and other material and documents may be given to the supervisor in digital format.

- Work to be done in lab (Water power lab, Fluids engineering lab, Thermal engineering lab)
- Field work

Department of Energy and Process Engineering, 15. January 2017



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Socio Economic Metabolism of Norwegian Kindergartens

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Abstract

Using a socio economic metabolism (SEM) approach, the case of Norwegian kindergartens is studied in the wake of a contemporary challenge facing the system: shortage of qualified staff. Through the case study, the thesis aspires to demonstrate the utility of SEM based models in examining quality provision in the educational service, and for addressing the topic of resource requirements. A '*dynamic stock driven time cohort type model*' is constructed that studies the Norwegian kindergarten system in terms of (i) children as demander stock (ii) teachers and assistants as provider stocks (iii) built area as resource stock and their associated flows. The model developed for the thesis is a starting point for SEM studies to develop in the education sector. The model also demonstrates the alternative of modelling population as a dynamic time cohort type model providing an alternative to linear statistical models.

The thesis shows that under a medium growth demographic scenario, between 2015 and 2040 the net stock of children increases by 9.6%. Subsequently, stock of teachers and assistants in the system increases by 10.5% and 9.9% respectively. In 2015, 9.9% teachers and 57.9% assistants were without relevant background. The thesis shows that at least 0.93% of unqualified teachers and 5.58% of unqualified assistants will be present in the system by 2040, assuming that the newly recruited staff in the future have formal qualifications. Through scenario analysis, interventions for achieving target of 'having all staff with formal background' are studied.

Preface

Werner von Braun, a famous German aerospace engineer said '*Research is what I do, when I don't know what I am doing*'. I believe that good research always is a leap into learnings of mankind without knowing what you find.

As you read the thesis, you will see that the goals of our work have evolved with our understanding of the problems. We realized that we need focussed efforts to make best use of our constrained time. I hope you enjoy reading.

I would like to sincerely thank Daniel and Felipe, for liberally sharing all their learnings and excitement. I have come to share their passion for society and knowledge. I wish them a good luck for all their endeavours.

This work would not have been complete without the help of my family and friends. I would like to thank my parents for their unflinching faith in me and all the love they send me every day despite being oceans apart. A special thanks to Sigrid Kleveland, for all the patience and being an amazing person that she is.

Thank you Norway for providing me some of the most cherishing moments of my life.

'ಸರ್ವೇಜನೋ ಸುಖಿನೋ ಭವಂತು (may all beings on this planet find happiness)'

- ಅವಿಜಿತ ಪಂಡಿತ
(Avijit Pandit)

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List of Abbreviations

SEM – Socio Economic Metabolism

OECD – The organisation for economic Co-operation and Development

SSB – Statistics Norway (*Statistisk sentralbyrå*)

LÆRERMOD – supply demand model for labour in education

FTE – Full time equivalent or Man year

ABF/ABLU - Arbeidsplassbasert barnehagelærerutdanning – workplace based kindergarten teachers education.

Utdanningsdirektoratet – Directorate of Education

Kunnskapsdepartementet – Ministry of Education and Research

Styrer – Head teacher

Pedagogue – pedagogical leader

Barnehagelærer – Pre school teacher

Barne og ungdomsarbeider – Childcare and youth worker

Barnehagelærer utdanning - Kindergarten Teacher Education

Forskrift – Regulatory Framework

Barne og ungdomsarbeiderutdanning-Child and youth worker education

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1 Introduction

Sustainable development involves meeting the needs of the present without compromising the ability of the future generation to meet their own needs. It is not a state of harmony but a process of change involving consistent alignment of our resources, direction of technological and economic developments and institutional change to work together (Butlin, 1989). In the agenda for sustainable development of the United Nations, 17 goals have been laid, keeping human needs at the heart of sustainable transition goals (Nino, 2015a). Ensuring inclusive and equitable quality education forms one of these goals. It is deemed that education is the key that will allow many other sustainable goals to be reached (Nino, 2015b). Education is basic human need (Nino, 2015b) and education system is a service offered to a population to meet this need (Qiu, 2014).

Equitable education systems are fair and inclusive and support their students to reach their learning potential without either formally or informally pre-setting barriers or lowering expectations (OECD, 2012). An equitable education system can redress the effect of broader social and economic inequalities. In the context of learning, it allows individuals to take full advantage of education and training irrespective of their background (Faubert, 2012; Field et al., 2007)

One of the tensions that run through policy makers in ensuring equitable quality in educational institution, is maintaining the fundamental functions of the educational institution i.e. teaching, research and ensuring overall development of children, while being under the pressure of limited resources in terms of faculty, facilities and income (BALL, 1998; Barlas and Diker, 1996; OECD, 2012). Furthermore, the policies developed have to take into account changing boundary conditions like (i) numbers of students using the education system (ii) availability of staff (iii) Educational requirements of staff (iv) Infrastructural requirement. This makes the educational system, a complex dynamic system where cause and effect are not often together in time and space (Kim and Senge, 1994). This means that obvious interventions do not always produce obvious outcomes and that long time delays under changing boundary conditions makes it hard to judge the effectiveness of those actions (Ghosh, 2015; Kim and Senge, 1994; Sterman, 1994).

The problems faced in contemporary policy making in educational institutions have been studied at both macro and micro level by many researchers (Kennedy, 2011). While some studies describe the qualitative requirements to be considered (Bakken et al., 2017; Field et al., 2007; Kogan and Bauer, 2006), some others delve to quantitative target development (Barlas and Diker, 1996; Kennedy, 2011). However, most studies conducted to address problems in educational institutions do not have quantitative foundations. Also, some quantitative studies fail to describe the dynamic nature of the educational system (Barlas and Diker, 1996). Another challenge is to translate the qualitatively set goals into quantitative targets while still maintaining the context of the issue (Wolstenholme, 1999).

Studies that aspire to quantitatively address policy making in education have the challenge of describing human and resource requirements together. Furthermore, most researches that describe human elements consider a linear statistical model to describe a population, undermining its dynamic nature (Harte, 2007). Also, linking qualitative attributes of human elements (for example educational background) to quantitative modelling is often a challenge. Hence, research is required to systematically study the educational sector under a framework that allows quantitative and realistic representation of the education system (Barlas and Diker, 1996).

The models developed henceforth, should be able to simulate the dynamic interlinkages of humans and resources that make the education system. It should aid the policy makers in quantitatively studying education system by early recognition of problems, priority setting, to analyse and improve the effectiveness of measures and to design efficient resource management strategies. Socio economic metabolism (SEM) approach promises a potential in this regard (Hendriks et al., 2000).

Using a socio economic metabolism (SEM) based model, the thesis addresses the quality provision and resource requirements of this service. It uses the conceptual framework of describing a service through SEM being developed at NTNU. The thesis describes the case study of Norwegian kindergartens to demonstrate the use of this model to address contemporary challenges in quality provision of the kindergarten services.

Kindergartens are a part of the early childhood education and care (ECEC). The case study of kindergarten was chosen because of its prominence in the early years of one's

life. Kindergartens are often the first step in a child's educational journey (*Starting Strong III*, 2011). Research from a number of disciplines including psychology, medicine and education iterate the importance of early childhood education and care (Bakken et al., 2017; Reynolds et al., 1996). Developments in a child during the early years of life has significant long term outcomes (Bakken et al., 2017; Campbell and Ramey, 1994; Gorey, 2001). There is a widespread acknowledgement of the role of early childhood education and care to bring a wide range of benefits. These include better child well-being; stronger learning outcomes and foundation for lifelong learning; more equitable child outcomes and reduction of poverty; increased intergenerational social mobility; more female labour market participation; increased fertility rates; and better social and economic development for the society at large (Meisels and Shonkoff, 2000). However, a conditional to achieve these outcomes is ensuring quality provision of the education service (*Starting Strong III*, 2011).

2 Conceptual framework

The conceptual framework used in this thesis is being developed at the Industrial Ecology faculty of NTNU. It uses the elements of service sciences and socio economic metabolism to provide a comprehensive framework to study education as a service and its interaction with nature, society and economy.

Socio economic metabolism (SEM) is a paradigm for sustainability within Industrial Ecology (Pauliuk and Hertwich, 2015) that studies the human-nature nexus (Baccini and Brunner, 2012; Fischer-Kowalski, 1998; Fischer-Kowalski et al., 2014). Studies in socio-economic metabolism have so far been concerned with accumulation of resources, materials and energy; its quantifications and identification of patterns (Baynes and Müller, 2016). These type of studies have helped quantify the relationship between technological developments, economic developments and resource use (Fischer-Kowalski et al., 2014).

Service science is a newly emerging field, that concerns itself towards the understanding of services - its role in business and economy (Bithas et al., 2015; Paulson, 2006; Qiu, 2014). It is a multidisciplinary field in itself that seeks to bring together knowledge from different areas like business, anthropology, engineering and economics to improve service industry's operation, performance and innovation (Paulson, 2006). According to service sciences, the successful provision of a service

consists of five factors- (i) Resource, (ii) Provider (iii) Consumer (iv) Time and (v) Benefit. Factors (i-iv) make up the service elements. In SEM terms these service elements can be represented through flows and stocks of different nature – economic, material, energy, human, animal and time. To provide benefit is the goal of the service. However benefit itself is described as intangible. Here, stocks refer to a set of objects of interest (Pauliuk et al., 2016). It can be any objects that accumulates in the society such as infrastructure, buildings, vehicles, machines and other fixed capital, consumer products, human beings or livestock (Baccini and Brunner, 2012; Fischer-Kowalski, 1998; Pauliuk et al., 2016). Flows occur between the processes or stocks in order to build, maintain and operate these stocks (Brunner and Rechberger, 2003).

Typically the consumer or demander of a service are individuals (Maglio and Spohrer, 2008). However, providers can be firms or governments. Although, since provision of the service ultimately requires specialized knowledge, skills and competences; ultimately they rely on individuals (Qiu, 2014). At a given point in time, the providers and demanders together use the resources to obtain the desired benefit or create value (Maglio and Spohrer, 2008).

It is hypothesized that in order for a service to provide optimal benefit the service elements have to be aligned in certain proportion at a given time (Figure 1). A misalignment in this proportion can lead to non-optimal benefit of a service. Ultimately, the use of resources – material, energy and economic relies on the alignment of the service elements.

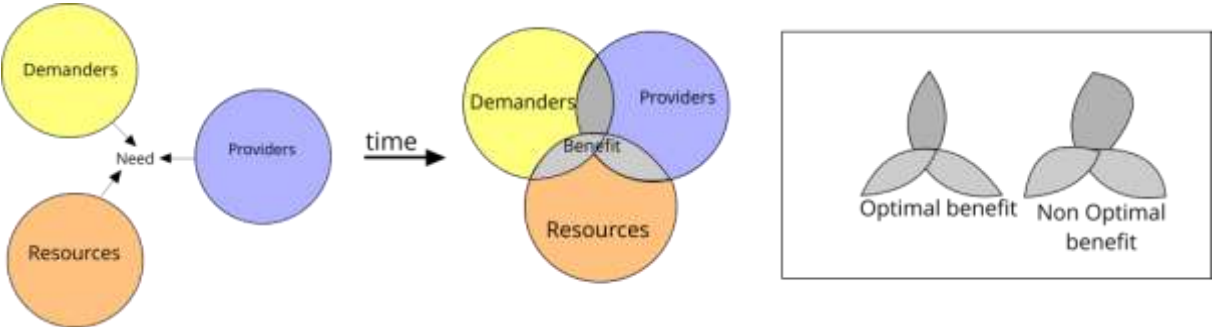


Figure 1: Conceptual framework to describe service: The service elements are brought together by a need. The proportionate alignment decides the optimal benefit

This conceptual frame work can be extended to the service of education. In this case, the service elements are made by the stakeholders of education. Demanders of this service are the children (between the ages of 0-6). Teachers, educators and related

personnel can be regarded as the providers. The resources in the case are the educational buildings, playgrounds and utilities like books, stationaries and internet. Hence, demanders, providers and the resources of kindergartens can be described in a given time as a system working together to obtain the benefit of educating students. The stocks and flows in the system are estimated by the principles of mass balance.

3 The case of Norwegian Kindergartens

3.1 Background

Norway provides, and realises, a strong entitlement to universal early childhood education and care in the best interests of parent and children (Engel and Barnett, 2015). The Norwegian term for institutions providing early childhood education and care for children in the age of 1-5 is *barnehage*. This directly translates to kindergarten in English (Haug and Storø, 2015). In the past decades kindergarten has changed from being a place of play, to being a place of increased pedagogical importance (Haug and Storø, 2015). The purpose of the kindergartens in Norway is defined as *'to ensure an overall development of children- by catering to their need for care and play and promoting learning and formation'* (Ministry of Education and Research, 2011a). The kindergarten system in Norway has exemplary strengths when it comes to having an efficient de-centralised governance structure, diversity and stability of pedagogical staff.

The government has taken great efforts in the past to ensure appropriate access to all children. The government has drastically expanded the number of seats offered in kindergarten while making them affordable (Ministry of Education and Research, 2013). These efforts have paid off and access to a kindergarten has increased greatly in recent years, reaching high levels of participation, including at very young ages (Engel and Barnett, 2015).

A challenge facing the system currently is a persistent shortage of qualified staff. This has implications on the quality of kindergarten service provision. Also, the kindergarten staff lacks sufficient status, career and pay options. In order to address these challenges specialized training programs and competence building activities have been put in place. However, according to the recommendations of the recent evaluation of kindergartens by OECD committee (Engel and Barnett, 2015) it was

mentioned that short programs do good to raise the competencies but are not strictly enforced. Also, they are not enough to provide the staff with a formal background.

The evaluation studies conducted on the kindergarten system do not provide a clear understanding of the occurrence of this problem (Engel and Barnett, 2015; Ministry of Education and Research, 2011a). According to Gunnes et al (Gunnes and Knudsen, 2016) it is possible that when a qualified teacher is not available for a given position, a less qualified person fills the place. The kindergarten act gives the municipalities a power to grant such dispensations from educational requirement to address the shortages of qualified staff, in turn inviting unqualified staff into the system (Engel and Barnett, 2015). However, research that quantitatively measures the shortage and studies plausible solutions, needs to be conducted. Nonetheless, the recommendation of the OECD evaluation to handle this challenge is to introduce mandatory staff programs that provide a formal qualification. Also, it calls for a national strategy with quantitative targets (Engel and Barnett, 2015).

3.2 Quality in Kindergartens

Quality in kindergartens is multidimensional concept mainly covering two attributes: structural characteristics and process quality (NICHD, 2006; OECD, 2012) .

Structural characteristics of quality (or structural quality) covers the aspects that are directly subject to regulation by policy and funding. These aspects include class or group size, teacher-child-ratios, formal staff qualification levels, built area requirements and materials provided (Engel and Barnett, 2015).

Process quality is more of an intangible attribute that refers the pedagogical approach and interaction of children with teachers and with space and materials (*Starting Strong III*, 2011). Also, some approaches include the quality of interactions between staff and parents and aspects such as warm climate, spatial arrangements and child-appropriate behaviours (Lamb-Parker et al., 2001; Reynolds et al., 1996). Standardised approaches to quantify process quality is yet to be developed. It is conjectured that process quality has a direct effect on children while structural quality has an indirect effect through its influence on process quality (Pianta et al., 2012).

International research has been focussed on developing reliable and valid instruments to measure preschool and kindergarten quality (Tayler et al., 2013). However, there is

need for instruments that can independently assess quality and provide feedback on the policies that can be put into practice (Engel and Barnett, 2015).

3.3 Policies and Governance

The first Kindergarten Act in Norway came into force in 1975. Later, in 2005 it was rewritten to provide clearer regulations for the content of kindergartens. Also, it provides descriptions of the roles and tasks of kindergartens and of kindergarten authorities. The Kindergarten Act of 2005 also adjusted the division of responsibilities between different levels of administration and importantly, reinforced the role of municipality as kindergarten authority supervised by the county governor (Ministry of Education and Research, 2011a). In addition, kindergartens were included in the portfolio of the Directorate for education and training (called *Utdanningsdirektoratet*) in addition to primary and secondary education. The directorate is the executive wing of the ministry of education responsible for evaluation of the education system through the National Quality Assessment System (Engel and Barnett, 2015).

In 2006, Norway integrated the responsibility of ECEC provision and schooling under the Ministry of Education and Research. Also, in 2006 clear regulations were laid down regulations providing a framework for the content and tasks of kindergarten. In 2009, the government introduced the legal right guaranteeing all children between ages of 1-5, a place in kindergarten (Haug and Storø, 2015). This was done to ensure appropriate access, to provide social equality and importantly to secure a good start to all children (Engel and Barnett, 2015).

3.4 Kindergarten workforce

The workforce of a kindergarten is made of head teachers, pedagogical leaders and assistants. Two new positions called *barnehagelærer* and *barne og ungdomsarbeider* have been created in 2013 that is equivalent to a pedagogical leader and assistant respectively (Engel and Barnett, 2015; Ministry of Education and Research, 2013). Both head teachers and pedagogical leaders are involved in pedagogical interactions with children. However, head teachers are as managers, responsible for the whole kindergarten. To qualify for these positions, one has to have a three-year tertiary degree in kindergarten teacher education (called *barnehagelærer utdanning*), or equivalent pedagogical degree at tertiary level, with additional education focusing on working with children. This is mentioned in the sections 17 and 18 of the kindergarten

act (Ministry of Education and Research, 2011a) with clearer explanations in the regulatory framework (called *forskrift*) of the act (Ministry of Education and Research, 2011b).

The regulations for staffing as per the section 18 of the kindergarten act dictates that number of staff should be adequate to carry satisfactory pedagogical activity in kindergartens (Ministry of Education and Research, 2011a). In the majority of ordinary kindergartens, children are organized in separate groups for the 1–2 and 3–5 age cohorts. The regulatory framework (called *forskrift*) of this act further recommends that average of 14-18 children should have a minimum of pedagogical leader when the children are over three years and when the children are under three years of age one educational leader should be present. In all the cases the residence time of the child is over six hours (Ministry of Education and Research, 2011b).

There no formal requirements laid out for the assistants in terms of staffing regulations or in qualification. However, they should preferably have completed a four-year vocational training programme at upper secondary level, consisting of two years of school-based training and a two-year apprenticeship (called *barne og ungdomsarbeiderutdanning*) (Ministry of Education and Research, 2011b).

According to Pettersson (Pettersson, 2017), it was found that there was seldom any difference between assistants and teachers in terms of the interaction with children. Also, teachers were often involved in other administrative activities while assistants were involved in monitoring the children. This shows that the role of assistants in pedagogical development of children is quite significant. Hence, it is important that the assistants possess formal qualifications and competencies to fit into the role. Furthermore, in 2013 about 37.5% of the kindergarten workforce were qualified teachers (Engel and Barnett, 2015). This means that most of the pedagogical activity is being conducted by unqualified staff.

3.5 Shortages of Qualified Staff

In 2000, majority of the employees working as head teachers and pedagogical leaders came from a *barnehagelærer* utdanning educational background and assistants majorly from a *barne og ungdoms arbeidere* (BU) background. *Barnehagelærer* utdanning is a 3 year bachelor programme that gives qualifications to work in the capacity of a head teachers, pedagogical leader or *barnehagelærer*. The name of this

program was changed from *forskolelærer utdanning* to *barnehagelærer utdanning* in 2013. Additionally, a national curriculum was laid for the studies that defined clear learning outcomes (Ministry of Education, 2012).

According to the statistical sources (SSB, 2017a); In 2015 there are 2% head teachers, 3% pedagogical leaders and 48% assistants with other background in the system. This is already an improvement compared to the past levels, between 1997 and 2013, the percentage of head teachers or pedagogical leaders working on dispensation has decreased from 19% to 2.1% for head teachers and 13.2% for pedagogical leaders (Engel and Barnett, 2015). A clear accounting for assistants is harder for the past because of a change in the way assistants are accounted in the statistical sources. A new category called childcare and youth workers were reported separately. These were formerly included in the category for assistants. The statistics are not directly comparable with previous years (SSB, 2017b).

There is a shortage of staff of both pedagogical leaders and assistants. The total shortage of pedagogical staff was approximately 4400 teachers in 2013 (Engel and Barnett, 2015). The number of graduates in 2013 was 2059, however not all of them would work in a kindergarten (Ministry of Education and Research, 2013). The shortage of teachers is expected to persist in the system in the coming period.

3.6 Infrastructure and Resources

According to the Kindergarten Act Chapter IV Section 10 (Ministry of Education and Research, 2011a), the indicative norm for children's play area indoors is four square metres net per child over three years of age and approximately one third in addition per child under three years of age. However, the outdoor area needs to be approximately six times as large as the play and living space indoors. Parking spaces, access roads etc. are not included in the outdoor area.

Municipalities play a key role in ensuring availability of resources in Kindergartens. It supervises and monitors across all kindergartens to ensure that services are registered meeting necessary approvals and are subject to health and safety inspections. Necessary approvals include articulation of the clear purpose of the institutions (e.g. particular educational or religious purpose), opening hours and criteria for access and physical space (Ministry of Education and Research, 2013).

4 Strategies to foster staff quality

In order to create a conducive pedagogical environment for children, it is important that the staff possesses necessary qualifications and competencies (*Starting Strong III*, 2011). Efforts are constantly underway to ensure the availability of a qualified and competent staff (Ministry of Education and Research, 2013). However, development of a clear roadmap with quantitative targets needs further effort (Engel and Barnett, 2015).

The Ministry of education has established additional places in the kindergarten teacher education to increase the number of qualified staff in kindergartens (Ministry of Education and Research, 2013). The new framework developed for barnehagelærer utdanning has been developed such that it aligns with the European Qualification Framework (EQF)(European Commission, 2008). Also, workplace based programs that involve the active cooperation and involvement of kindergarten owner/employers, students, staff and the university colleges/universities are being encouraged. Since 2009, a guided first year is also provided to all new employees (Ministry of Education and Research, 2013).

Another strategy being discussed is *cash for care scheme* (Engel and Barnett, 2015). Under this scheme, families with children between 1 and 3 years who do not use a kindergarten receive a certain monthly sum from the state. This measure can reduce the number of children using the kindergarten, thereby demanding lesser staff. However, not all political parties are in favour of this measure making it a hotly debated topic (Haug and Storø, 2015).

In order to raise the overall competencies in staff, strategies are underway. A series of strategies for improving the competence of kindergarten staff was presented in 2013 by the Ministry of Education (Ministry of Education, 2013). A project called GLØD was created with the ambition to raise the number of staff with competence in all positions (i.e., head teachers, kindergarten teachers and assistants).

Competencies are acquired through initial training, on-the-job training and professional development programmes (Ministry of Education and Research, 2015). The strategies also propagate encouraging workplace based diploma for all staff without relevant background (Ministry of Education, 2013). For the teachers, a work-based, part-time bachelor-level programme (Arbeidsplassbasert barnehagelærerutdanning or

ABF/ABLU) has been developed comprising of 180ECTS and duration of 4 years. For the assistants a similar program at upper secondary level (Arbeidsplassbasert barne og ungdoms arbeider utdanning) is being offered by many universities which comprises a duration of 3 years. Both the programs entail a study intensity of 50% (Utdanning.no, 2014). This means that the students of this course study 50% of the full time equivalents (FTEs or man years) and are essentially working in the kindergarten for up to 50% of a man year.

The strategies being discussed do not provide any clear quantitative targets. Generally, quantitative target development in planning and strategy related to education and labour requirement are developed using the supply demand forecast developed by labour forecasting tools. However, development of such quantitative goals is a challenging task since it entails creating interventions in both kindergarten system and the labour market.

4.1 Labour Forecasting tools

The ministry of finance, the Norwegian parliament, other ministries and publically appointed committees use labour forecasting models to gain a supply demand understanding of their policies. To some extent private sector also uses these tools for internal planning (Boug and Dyvi, 2008).

In Norway there are different models are in use. Some of these models are intended to understand the economy, some are intended to aid planning of budget and tax and others intended to generate understanding of employment and labour trends (SSB, 2017c). Appendix I gives a detailed idea of the different tools currently in use.

LÆRERMOD is the supply demand model of the education sector (SSB, 2016a). In this case, supply refers to the amount of teachers being graduated and demand refers to the number of teacher to be employed (Gunnes and Knudsen, 2016). The purpose of LÆRERMOD is to forecast the excess and deficit of teachers by different training areas at national level. LÆRERMOD uses a combination of probabilistic and econometric approaches to obtain this understanding(Gunnes and Knudsen, 2015). It is mentioned in the LÆRERMOD reports (Gunnes and Knudsen, 2016, 2015) that it consists of three important pillars.

- Distribution of teachers by employment areas.

- The ratio between numbers of teachers and number of users, called 'teacher density'
- Demographic development as basis for development of future users.

Supply and demand in LÆRERMOD are independently calculated. According to (Gunnes and Knudsen, 2015) the supply of teachers is calculated by supplementing the inventory of employed teachers by accounting for the new candidates and subtracting the teachers who go out of work activity because of age. However, this not modelled directly. It is mentioned that the share of people by age in the employed stock is reduced at retirement age to account for retirement (Gunnes and Knudsen, 2016). New teacher candidates are phased into the original stock of teachers based on student admission, length of study program and degree of completion. They are assigned the same characteristics as that of the already employed teachers in terms of employment rates and average number of years work per worker. Furthermore, the age and gender distribution of the stock is assumed to be constant during the period of projection (Gunnes and Knudsen, 2016).

LÆRERMOD takes into account that teachers in all the training categories can work in different sectors (Gunnes and Knudsen, 2016, 2015). However, it does not look at whether these teachers are actually qualified to work in these sectors. Furthermore, it does not study and account the consequences of aging, recruitment and retirement flows and structural quality changes due to policy interventions. This creates a need for tools that can be integrated with LÆRERMOD to provide a comprehensive quantitative understanding of the labour, material and economic implications of policy development.

5 Objective and Research Questions

The objectives of the thesis is (i) to aid target setting and strategy development for increasing formal qualification of already existing staff without relevant qualifications in Norwegian Kindergartens (ii) Demonstrate the use of socio economic metabolism based models in examining quality provision and addressing the resource requirements of educational services through scenario analysis of Norwegian kindergarten services.

The following thesis questions have been formulated in order to achieve these objectives:

- (i) What is influence of development of the stock of children on structural quality of kindergartens?
- (ii) How can a goal of achieving 'all staff with formal qualifications' be reached through traditional diploma and workplace based diploma?
- (iii) What is the time frame for this transition given that different study programs are of different lengths, study intensities and teacher requirements?
- (iv) What are the impacts of the different transition paths for the teacher availability and demand for new teachers?
- (v) How can population and infrastructure be modelled together? What are the limitations of such models? How can they be improved further?
- (vi) What inferences can be drawn from this model for future SEM models in education services?

6 Methodology

6.1 System Development

In a SEM study, development of a system serves as a basis to physical and mathematical framework of the system. According to (Brunner and Rechberger, 2003), a system consists of a system boundary in which physical elements i.e. stocks, processes and flows between them are described. Nonphysical elements i.e., parameters, drivers of the system are also described in addition. Figure 2 shows a system description of the Kindergarten system in Norway.

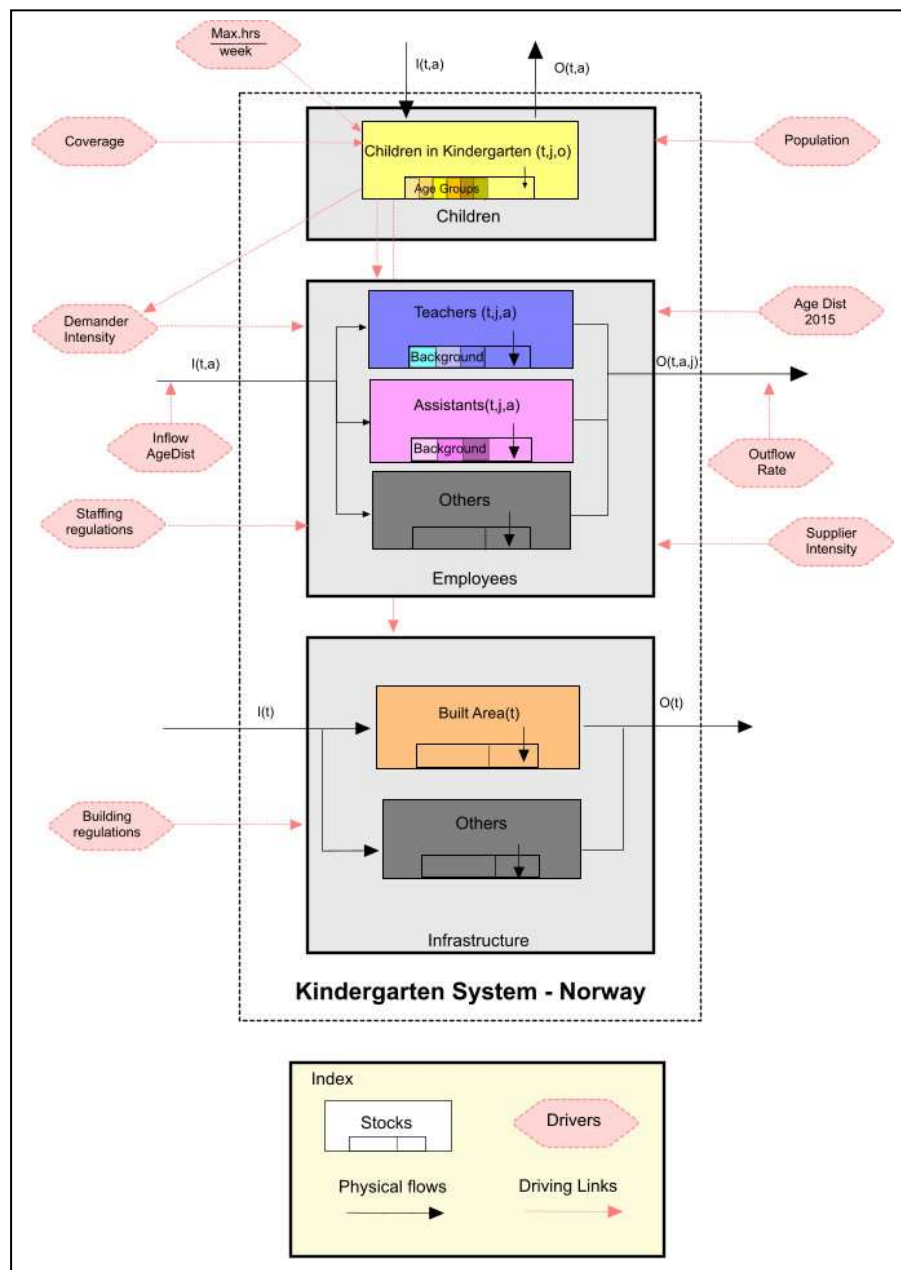


Figure 2: The kindergarten system of Norway.
 Note: The colour coding is followed throughout the report

The Kindergarten system in Norway consists of three basic service elements: Children as Demanders; Employee as providers and the Infrastructure element. In time they come together to provide kindergarten services to the population. The stocks and flows associated with the system are studied. In order to provide further resolution of processes and stocks in the system, subsystems have been developed and presented in Appendix II.

The purpose of the system is to first quantify the stocks and flows of the system and then to provide estimations about evolution of these stocks and flows; both historically and in the future. The system has the regional perimeter of Norway.

A dynamic stock driven time cohort type model (Sandberg et al., 2017; Vasquez et al., 2016) is constructed based on the principles of SEM. Time and cohort together describe the ageing and evolution of the stocks in time. For simplicity, the model is described in terms of age instead of cohort. In children, type refers to different age groups and in employees it refers to different backgrounds. Every stock consists of an Inflow and an outflow described by the black arrows (Figure 2). The influence of the parameters to the stocks is shown by red arrows. Also, red arrows can be seen from the stock of children towards other stocks, this is to show that children are the drivers of the system. It should be noted that the background of the employees are also coded by colour hues. As the hue of the colour gets stronger, the employee can be seen to have more background. For example, assistants without background are described by light pink, relevant background by a medium pink and assistants with '*barne og ungdoms arbeider*' i.e. secondary level education background are described by a dark pink.

6.2 System Definitions

The model developed to simulate the system is a stock driven dynamic time cohort type model. The model consists of a demander stock element, three provider stock elements and two Infrastructure elements. Table 1 describes the stock elements of the system.

Number	Stocks	Symbol	Unit	Nature	Characterization
1	Children in KG	C	Capita	Demander	Time, Age, Hours of attendance
2	Teachers in KG	T	Capita	Provider	Time, Background, Age
3	Assistants in KG	A	Capita	Provider	Time, Background, Age
4	Other employees	-	Capita	Provider	<i>Not studied further</i>
5	Built Area	B	Area (m ²)	Infrastructure	Time, Area
6	Other Infrastructure	-	-	Infrastructure	<i>Not Studied further</i>

Table 1: Stock elements of the system

All the stock elements are studied between the years 2000 and 2040. The reference year used for the model development is 2015. The reference period for the reporting of stocks in 15.12. Year in the official statistics (SSB, 2017a, 2017d). It can be safely assumed that stocks are accounted for at the end of the calendar year. Subsequently it is assumed that all the flows pertaining to the given year occur before the accounting of the stocks.

The observed values of Children in kindergarten are collected at national levels (SSB, 2017d). Children in kindergarten are reported by 7 age categories and hours of attendance ranging between 0-44 hours in 6 heterogeneous class intervals.

There are two different tables presented for employees: (i) by sex (SSB, 2017e) (ii) by background (SSB, 2017a). The total employee stock is obtained by aggregating employees by sex (SSB, 2017e). SSB reports the employees in kindergarten by 10 different backgrounds (SSB, 2017a). For simplicity, they have been re categorized as teachers, assistants and others. The categorization is made as shown in Table 2. The rationale for such categorization is that pedagogical leaders and head teachers have similar pedagogical role in kindergartens. Only Teachers and Assistants stocks are studied further.

Classification categories	Teachers	Assistants	Others
Reported categories	Directors (Styrer; Head teachers)	Assistants	Office staff
	Directors assistants (Styrerassistent)	Bilingual assistants	Other educational personnel
	Early childhood educators or other employees with the same qualifications (barnehagelærer)	Childcare and youth worker (barne og ungdoms arbeider)	Other paid help
	Educational leaders (AKA pedagogical leaders)		

Table 2 : Classification of employees into teachers, assistants and others

6.3 Model development

6.3.1 Children

The stock of children in kindergarten is calculated as the product of the population between the ages of 0-6 and coverage. Coverage gives the fraction of the total population of kindergarten going age that is a part of the kindergarten system.

Inflow and Outflows of this system are calculated by making an assumption that children that enter kindergarten at any age only leave as 5 or 6 year olds. Also, children do not enter kindergarten as 5 or 6 year olds. The net stock change of children between 0-5 years is assumed to be the total inflow and net stock change of children greater than 5 years is the total outflow for a given year.

For every age category, the number of hours spent per week by children is multiplied. Then demander intensity α_{tc} is calculated as the man hours of kindergarten by the max possible man hours of kindergarten usage. Demander intensity indicates intensity of usage of kindergartens. This is used as a parameter for the development of employee stocks. The maximum hours of kindergarten usage per week is reported to be between 41-44 hours by LÆRERMOD. In their model an average of 42.5 hours is considered to be the maximum hours of kindergarten usage per week (Gunnes and Knudsen, 2016) . This value is assumed to be the maximum hours of kindergarten usage per week in the model.

6.3.2 Teachers and Assistants

SSB reports employees by 11 different background categories (SSB, 2017a). These are classified into three main types: *Barnehagelærer* background for teachers and *Barne og ungdoms arbeider* background for assistants; other relevant background and other background. A detailed model description along with model equations are presented in Appendix II.

Teachers and Assistants are described by background (b) and age (a) for a given time (t). Man years (M) of work is collected at an aggregate level. The man year demand

(M) of both teachers and assistants comes from the model constraints (see 6.3.4) and is based on the stock of children. This is multiplied by the respective correction factors to obtain an actual man year demand.

A parameter work intensity is introduced such that it describes the average work done by the employee in relation to the actual man years of work. Total stock of teachers and assistants for a given time is calculated as a product of actual man years of work and the inverse of work intensity.

6.3.2.1 Characterization into Age and Background

Age distribution is the fraction of people in the successive age categories in the total stock. Background distribution is the proportion of teachers and assistants from a given background in the teacher and assistant stock respectively. The teachers and assistants stocks are multiplied by age and background using age distribution and background distribution respectively to obtain the time age type matrices.

This can be represented mathematically as

$$A_{tba} = A_t \times B_b \times Y_a \qquad T_{tba} = T_t \times B_b \times Y_a$$

Where T and A are stock of teachers and assistants respectively. B is the background distribution by background categories b . Y is the age distribution for each age category a .

6.3.3 Built Area

The observed values of the total built area of kindergartens is obtained from national statistical sources (SSB, 2017f). Due to lack of data on construction and demolition or lifetime of kindergarten buildings, they have not been modelled as a time cohort type matrix. However, a linear vector of built area by time is constructed. Furthermore, based on the regulations the model estimates only the demand for indoor area.

6.3.4 Model Constraints

The regulations for structural quality (see 3.3) is what defines the independence of the stocks.

A parameter (ϵ) and demander intensity (α) in has been used to relate the children for each age group (a) to the employees and infrastructure. Mathematically, these model constraints are formulated as follows:

Total Man Year demand (M) of teachers for a year (t) is calculated as

$$M_t = \sum_{a=0}^6 C_{tc} \times \alpha_{t,a} \times \varepsilon(a)_{teachers}$$
$$\varepsilon(j)_{teachers} = \begin{cases} \frac{1}{9.7}, & age < 3 \\ \frac{1}{16}, & age \geq 3 \end{cases}$$

Total Man Year demand (Asst_M) of assistants for a year (t) is calculated as

$$Asst_M_t = \sum_{age=0}^6 C_{tc} \times \alpha_{tc} \times \varepsilon(age)_{assistants} \quad \varepsilon(j)_{assistants} = \begin{cases} \frac{1}{9.7}, & age < 3 \\ \frac{1}{16}, & age \geq 3 \end{cases}$$

The built area demand (B) of indoor area of the kindergarten is calculated as

$$B_t = \sum_{age=0}^6 C_{ta} \times \varepsilon(j)_{infrastructure} \quad \varepsilon(j)_{infrastructure} = \begin{cases} 5.3, & age < 3 \\ 4, & age \geq 3 \end{cases}$$

The outflows in the teacher and assistant stocks is calculated using outflow rate. Outflow rate is the proportion of reduction per year of workforce due to retirement, dropouts, sickness and death.

The outflow for a given year is calculated as the product of the outflow rate (μ) and the stock in the previous year. The outflow rate remains same for both assistants and teachers but changes for different background categories

$$Teach.O_{(t)ba} = T_{(t-1)ba} \times \mu_{ba} \quad Asst.O_{(t)ba} = A_{(t-1)ba} \times \mu_{ba}$$

Where Teach.O and Asst.O is teacher and assistant outflow respectively.

The total inflow for both teachers and assistants for a given year is calculated as the sum of the net addition to the stock and the total outflow in a given year. The net addition to the stock responds to the change in children stock, work intensities and demander intensities. Mathematically this is shown as

$$\Delta T_t = T_t - T_{t-1}$$

$$Teach.I_t = \Delta T_t + O_t$$

$$\Delta A_t = A_t - A_{t-1}$$

$$Asst.I_t = \Delta A_t + O_t$$

Where Teach.I and Asst.I is teacher and assistant inflow respectively. The total Inflow for a given year is divided into the age categories using an Inflow age distribution (ϵ). Inflow is divided into age categories as

$$\text{Teach. } I_{tba} = \text{Teach. } I_t \times \epsilon_a \qquad \text{Asst. } I_{tba} = \text{Asst. } I_t \times \epsilon_a$$

6.4 Parameter estimation

The model for children consists for coverage, total population aged between 0-6 years in 1 year age categories and maximum hours of kindergarten usage as the main parameters. It is assumed that the coverage has reached a stable value and remains constant throughout the future (Figure 3). The total population of children in kindergarten going age is obtained from the national statistical sources (SSB, 2017g). The future values are obtained from the demographic projections (SSB, 2016b). Figure 4 shows the total population of children in kindergarten going age. The future values of the demographic population represent the main alternative based on observed fertility and population values of 2014 (MMMM2014).

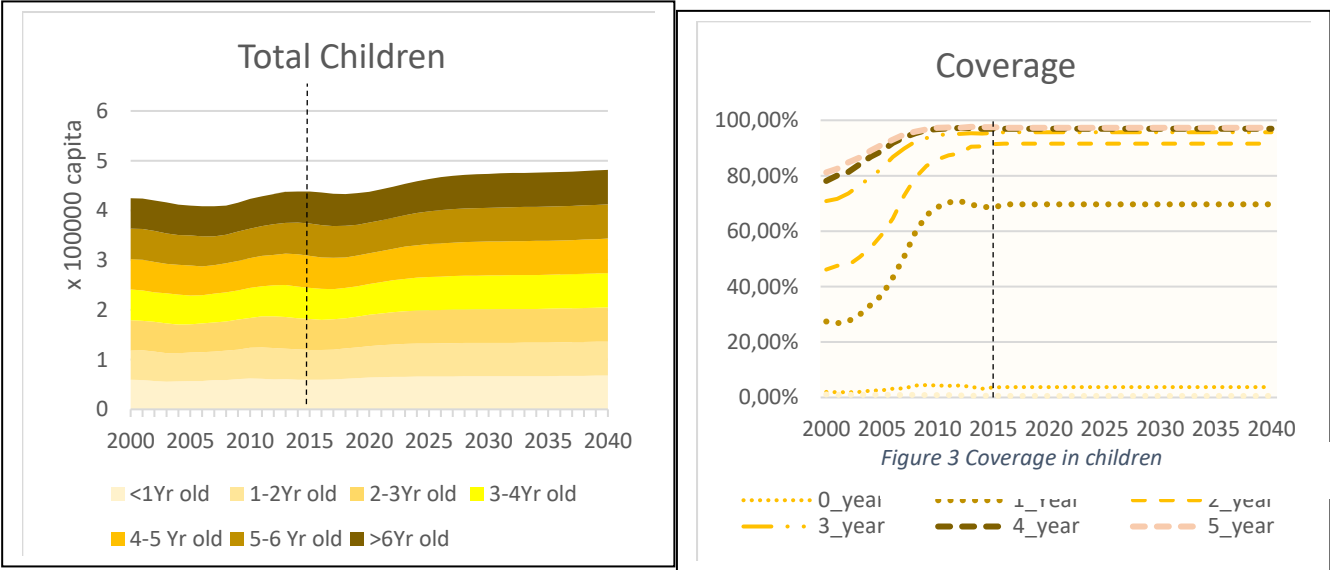


Figure 4 Total Population in Kindergarten going age

The model for teachers and assistants of four parameters: Background Distribution (B), Age distribution (A), Outflow rate (μ), Inflow Age distribution, Work intensity (β) and User intensity (α). Figure shows the values of the parameters. All the parameters are assumed to remain constant in the future.

Age Distribution is first calculated for the year 2015 using the data of stock by age as reported by LÆRERMOD (Gunnæs and Knudsen, 2015). It reports the stock of

teachers by 1 year age groups between the ages 24-74. This implicitly sets the age of the working population to be in this range. It serves as the initial condition for the development of the model. Although this data has been reported for the year 2013; it is assumed that the age distribution in the reference year 2015 is the same. Furthermore, LAERERMOD reports this data for both genders, male and female. This data is aggregated to derive the age distribution (Figure 5).

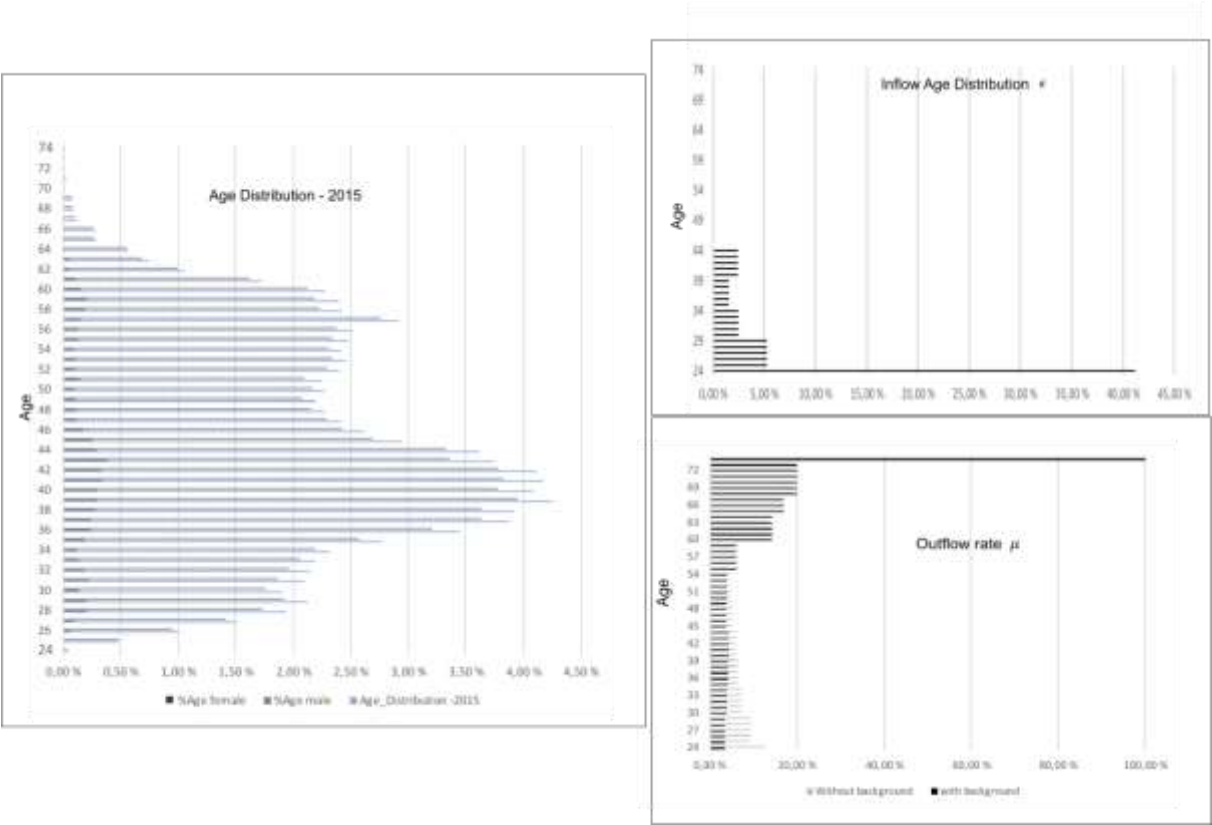


Figure 5 Parameters for modelling of teachers and assistants: Age distribution; Inflow Age distribution; Outflow rate

Information about the teachers and assistants reported by background and employment position are used to create background distribution by calculating the fraction of staff from a given background by the total staff. This parameter is independently calculated for both teachers and assistants (Figure 6).

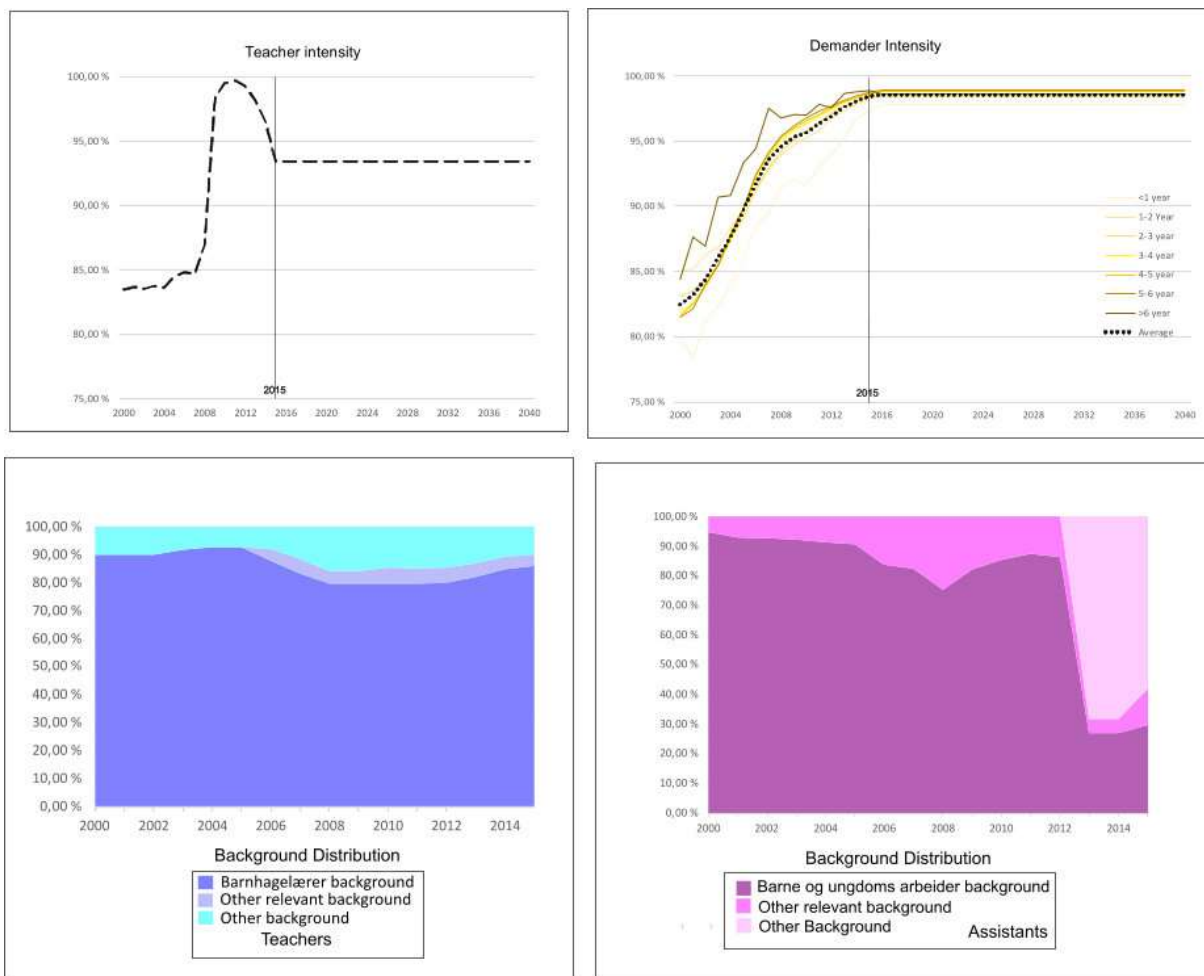


Figure 6 Parameters for teachers and assistants contd. Teacher intensity;Demander intensity;Bankground distribution

Outflow rate remains the same for both sexes and is calculated using the information presented in Gulbrandsen (Gulbrandsen, 2015). In this article the stock of employees in 2007 and their evolution in 2012 by age is reported. This information is also reported for both employees with and without relevant backgrounds separately. Hence an outflow rate is calculated for each background category b and age category a .

Information regarding inflow age distribution is obtained from Gulbrandsen (Gulbrandsen, 2015). It gives the age at the end of the exam for preschool teachers after the exam year and are reported in class intervals of varied age groups. It is assumed that graduates are present uniformly in the age groups. Although, in this report the graduates can be under the age of 24 (reported as age group 20-24), it is assumed that these are all 24 year olds because of the working age limits of the model. It is assumed that the age of the employees during their recruitment is the same as when they are graduating.

7 Scenario Development

Scenario development is a tool used to understand the unfoldment of different strategies. A scenario describes an alternative image of the future (Nakic´enovic´ et al., 2000). Here, scenarios describe storylines. Each storyline narratively describes the use of an alternate strategy and associated target.

Scenarios are developed to study the goal of having ‘all teachers and assistants with formal background’ is explored. For this purpose existing teachers and assistants go through either a traditional diploma or a workplace based diploma. For teachers this program is offered at bachelor’s level and for assistants at upper secondary level.

Training the teachers and assistants would involve provision of a new service. Demanders of this service are the teachers and assistants without background. New teachers would have to be sourced to be providers and infrastructure needs to be created.

In system terms, a new system called ‘training system’ has to be created as shown in Figure 7. The purpose of this system is to train the employees already a part of the kindergarten education system and convert them into employees with relevant background. Teachers and Assistants without background being trained form the ‘Teachers in Training’ and ‘Assistants in Training’ stocks respectively. Teachers required for Training the assistants without background are sourced from the existing Teachers with a *Barnehagelærer* background. However, Teachers required to train teachers in training are not sourced from this stock. This is because a level 7

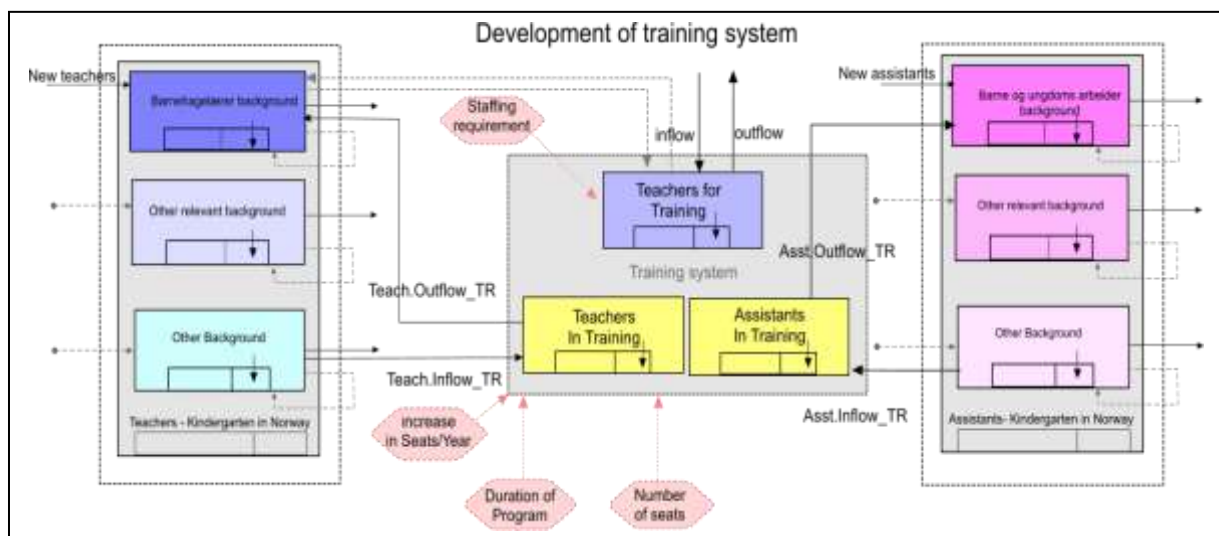


Figure 7 : Development of a training system

qualification with training in pedagogy is needed to teach at this level (NOKUT, 2017). This is not essentially possessed by all teachers.

The parameters for this system include teacher requirement for the training, initial number of seats offered, and increase in number of seats per year, study intensity of the program and duration of study. This is described by developing an alternate system diagram, Figure 7.

The new model constraint is introduced to the system such that the total inflow of teachers and assistants is the sum of the net change of the respective stock, the outflow in the year, and the respective flows to the training system. The outflow of the training system coming back to the stock is regarded as a part of the total inflow. Detailed description of model development is provided in the Appendix III.

7.1 Scenarios

Two forecasting scenarios and one back casting scenario are developed for the analysis.

SC1: Teachers and Assistants without background undergo training through a traditional diploma. The duration of this training program is 2 years with a 100% study intensity. The associated teacher requirement is set to be low at 1:20 teacher per student. The training provision is slowly introduced with 200 seats for teachers and 2000 seats for assistants and is built to increase over time. The increase of number of seats for both teachers and assistants is 20.

SC2: Teachers and Assistants without background undergo training through a work place based diploma. The duration of this training program is 3 years with a 50% study intensity the associated teacher requirement is set to be high at 1:10 teacher per student. The training provision is drastically introduced and maintained at a constant level of 6000 assistants and 600 teachers.

SC3: Ambitious targets are set to educate all teachers and assistants without background by 2025. By trial and error, the values of the parameter required to achieve this goals are found.

8 Results

8.1 Children

Figure 8 shows both the historic and future stock development in Children. Children in kindergarten have seen a drastic rise between the years 2000-2015. In this period the stock of children in kindergarten has increased by 95,996 children. However, the stock

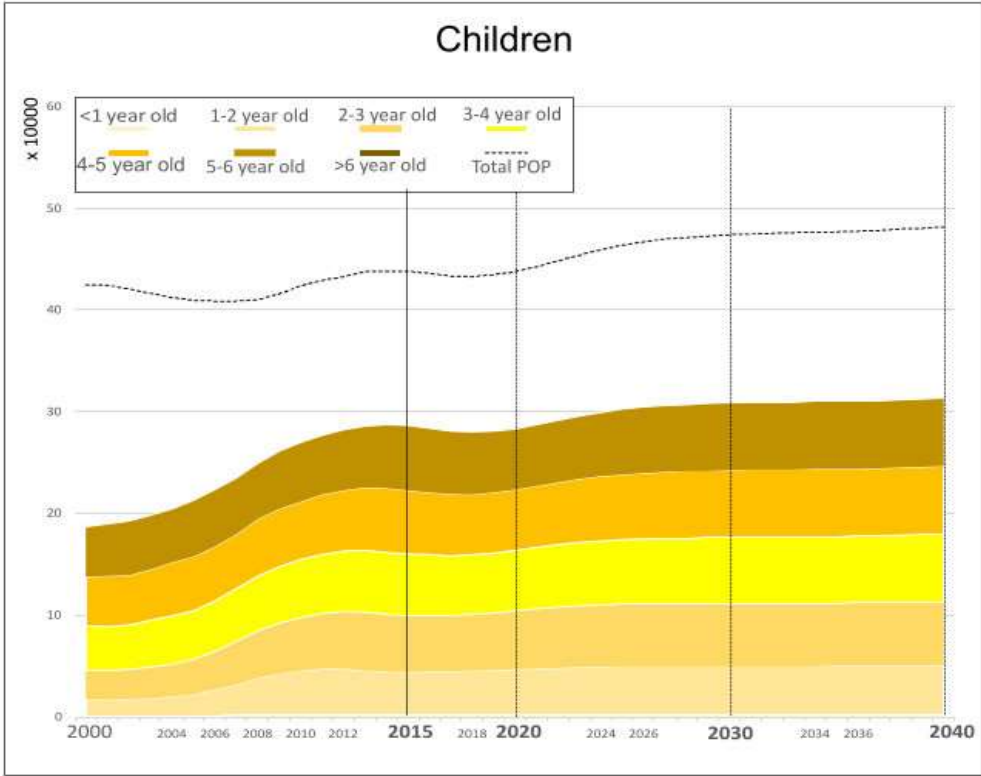


Figure 8 Children in Kindergarten. The total children in kindergarten are cumulative of the individual age groups. Total POP here refers to the population in the age group of 0-6

is not expected to increase further until 2020. On the contrary it reduces by 2896 children. Between the years 2020-2030, the stock is expected to increase further by 25,388 children. The number of children in kindergarten reach a value of 313,841 in 2040. The associated inflows and outflows have only been studied for the future as in Figure 9.

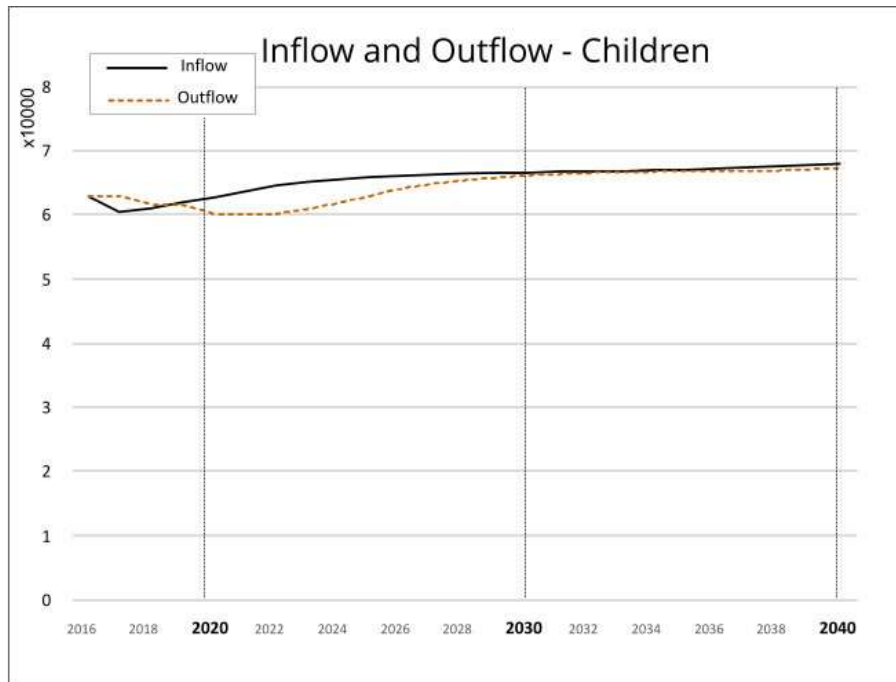


Figure 9 Inflows and Outflows of Children in kindergarten

Contrary to the stock, the inflow of the children is seen to be rising between the years 2015-2020 and continues to reach a stable value of around 66,750 by 2030. The outflow of children increases between the years 2020-2030. After 2030 the inflow exceeds the outflow by an average of 509 children until 2040.

8.2 Teachers

In teachers, both man year demand and the number of teachers are seen to be increasing between the years 2000-2015 as shown in the Figure 10. The man year demand based on regulation (theoretical man year demand) follows a similar profile as that of demographic development of children. It increases from 10,185 in the year 2000 to reach 19,303 in 2015. However, the actual man year demand is 34(±5) % more on an average than the theoretical man year demand in the same period. The number teachers has also increased from 16,378 teachers in 2015 to 34,196 teachers in 2020. This corresponds to actual student to teacher ratio 1:12.8 as of in 2015.

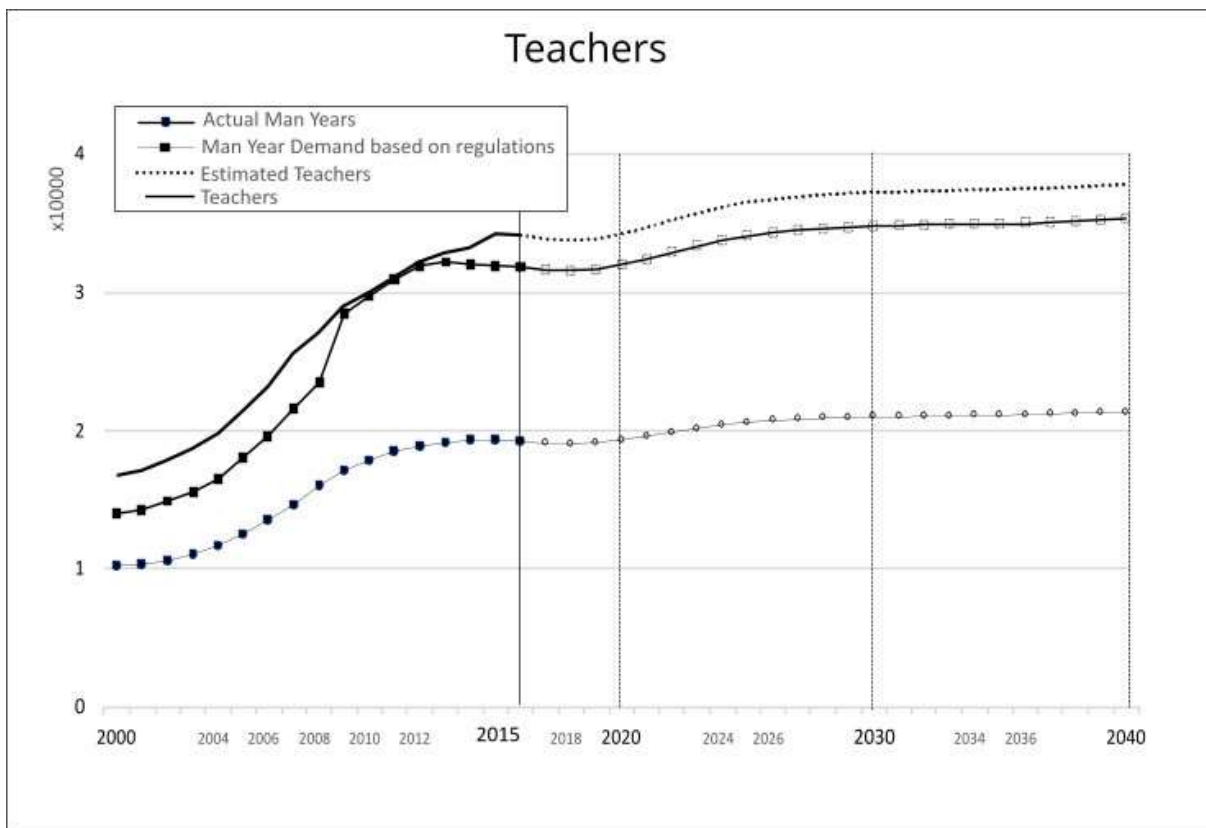


Figure 10: Stock and man years of teachers

In the future, the number of teachers stay relatively stable until 2020. Later the stock of teachers increases every year to reach a value of 34,753 in 2030. In 2040, the stock of teachers reaches a value of 35,316 teachers.

The information about teachers by background is provided in Figure 11. The figure shows the accumulation of teachers without relevant background between the years 2000 and 2015. There has been a net increase of 666 teachers without background. Also, teachers with barnehagelærer background and other relevant background have

increased in the same period. A net addition of 15769 teachers with barnehagelærer background and 1056 with other relevant background is observed between this period.

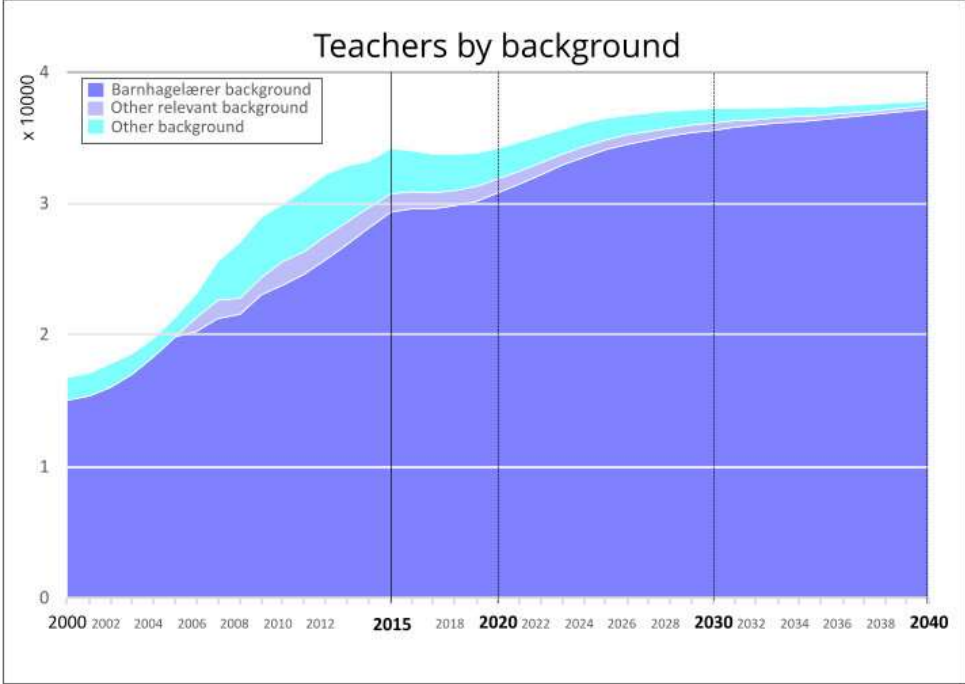


Figure 11 Teachers by background

In the future the number of teachers without background naturally decrease. By 2040, there are 351 people in the stock without background.

The inflow of teachers is seen to be decreasing in the immediate future Figure 12. However, from 2017 a wave of increase in demand of new teachers is expected. The inflow of teachers reaches a maximum value of 2412 in the year 2023 and in 2030 it reaches a value 1,980 teachers. A small increase in inflow seen later. In the year 2040,

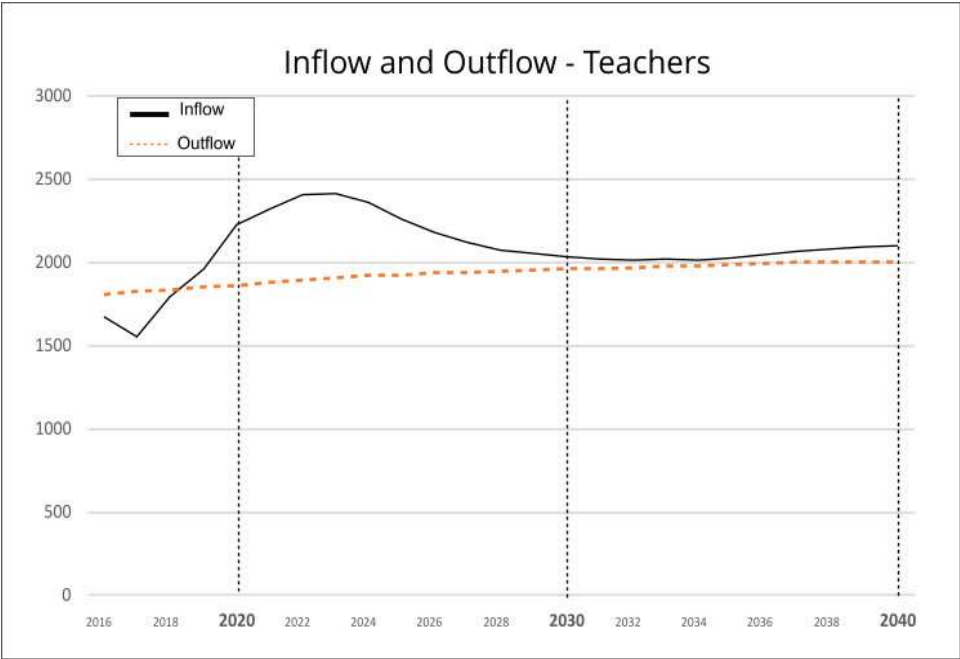


Figure 12: Inflow and Outflow of teachers

an inflow of 2094 teachers is expected. In this period the outflow is steadily increasing. In 2016, an outflow of 1800 teachers and in 2040 the outflow is expected to be 1,994 teachers.

8.3 Assistants

The observed man years is 9 % higher than the theoretical man year in 2000 Figure 13. However in 2015, both attain the value of 37,132 man years. Correspondingly, 43,818 assistants are present in 2015. The number of assistants is continues to increase in the future to reach values 43,801 47,725 and 48,487 in 2020, 2030 and 2040 respectively.

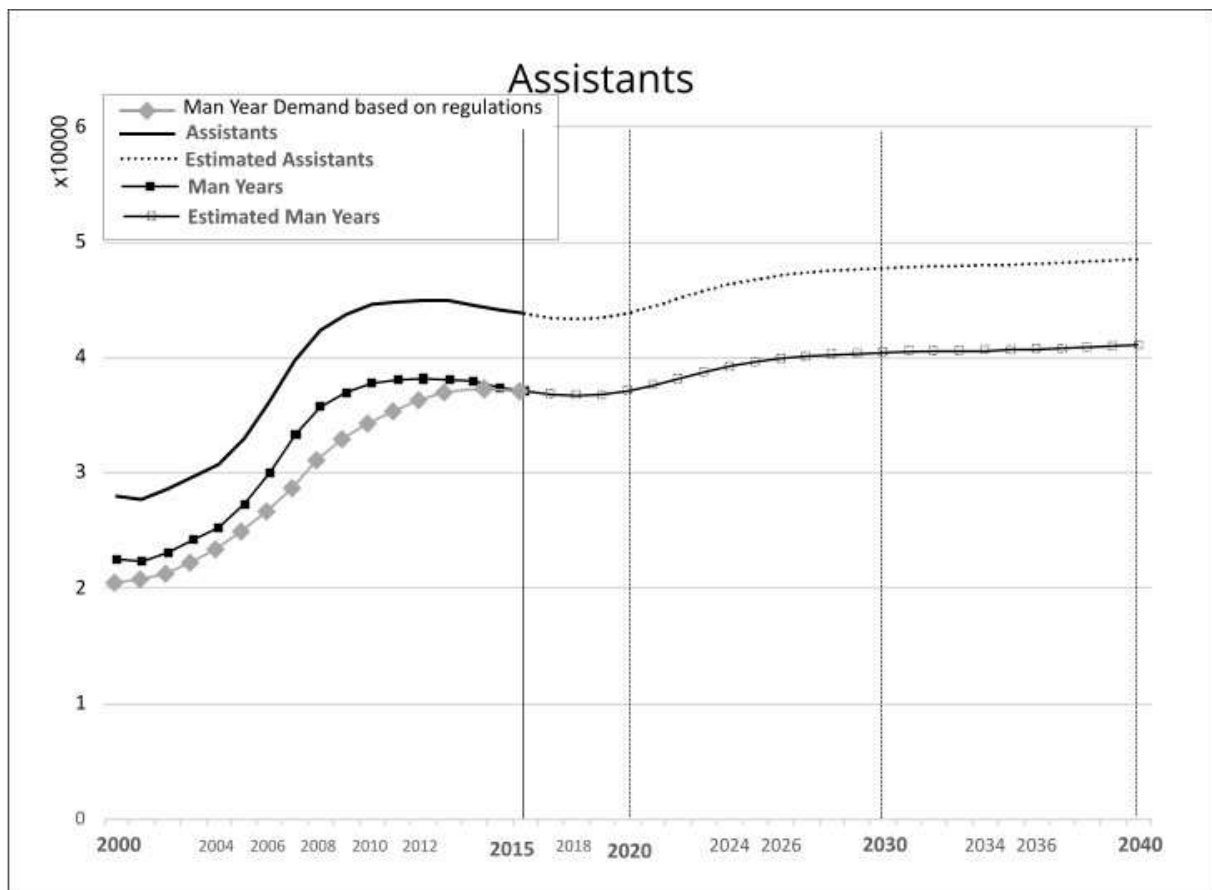


Figure 13: Stock and man years of assistants

The information about the background of assistants is provided in the Figure 14. Here it can be seen that the assistants without background were introduced into the system only in 2013. A total of 30,549 assistants without background were introduced to the system. This corresponds to 68% of the total stock. In 2015, they amount to 57% of the stock. The number of assistants without background gradually reduce until 2040. In 2040, the total number of assistants without background is 2435 making up 6% of the stock. As no new assistants are added to system are without formal qualifications, the stock of assistants with background is seen to increase in the future. Between 2015

and 2040 a net increase of 30,817 is expected. This is the net inflow during this period. The inflows and outflows are shown in Figure 15 .

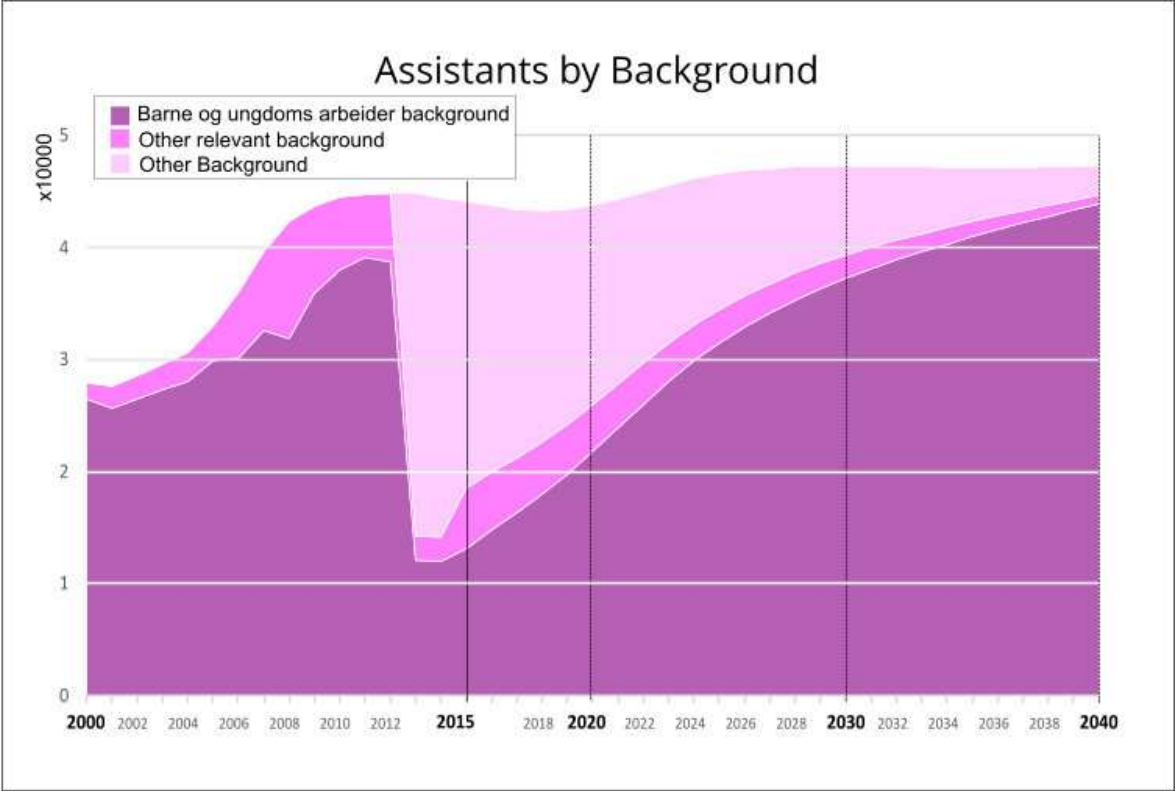


Figure 14: Assistants by background

Similar to teachers, the inflow of assistants is seen to be immediately decreasing in the future. However, from 2017 the inflow begins to increase and reaches a peak of 3,225

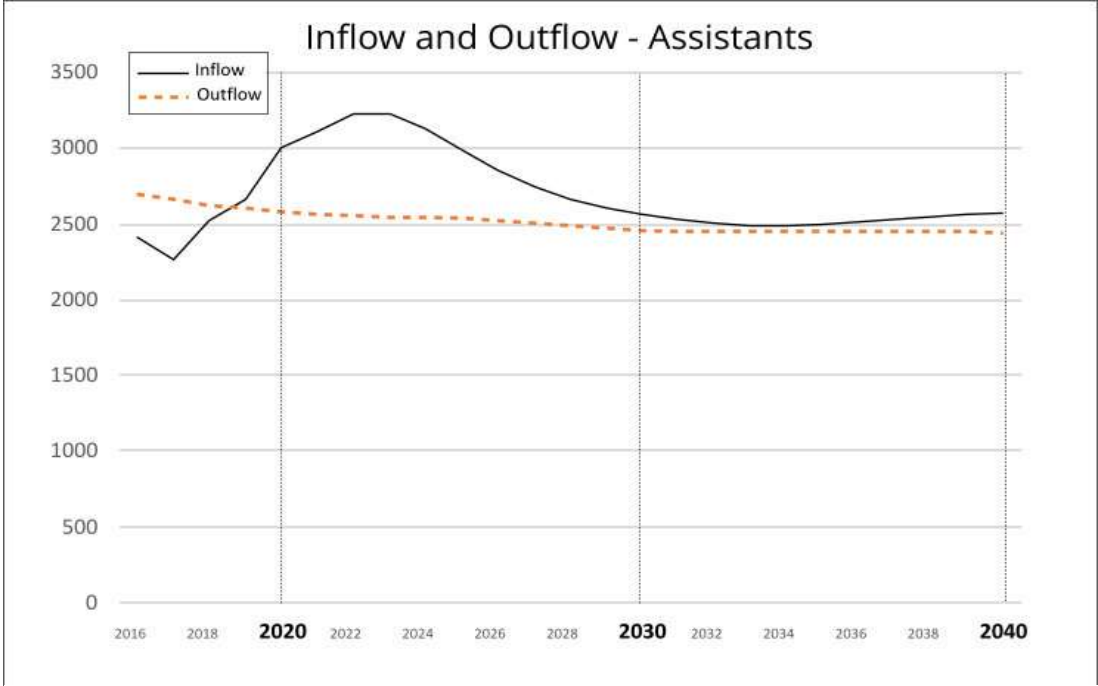


Figure 15: Inflow and Outflow of Assistants

assistants in 2023. Later the inflow of assistants gradually reduces. In 2040, the inflow of assistants is expected to be 2562. The outflow of assistants is seen to be steadily reducing. In 2016, the total outflow is 2,694 assistants. In the 2020, 2030 and 2040 it is 2,574; 2,451 and 2,431 respectively.

8.4 Built Area

The total stock for built area is given by the Figure 16. This is the indicative of the indoor area based on the regulations laid for minimum infrastructure (see chapter 3.6). In 2000, it is estimated that the 773,016 m² of area was present. The stock is expected to increase due to rise in children, in 2015 it reaches a value of 1,201,933 m². The observed value from the statistics reports the total area inclusive of playground and indoor areas. This value is found to be 1,574,133 m². In the same year the estimated indoor area is 1,191,757 m². This implies that the outdoor area in the corresponding year is 424,808 m².

In the future, the stock is expected to increase. In 2040, the estimated indoor area is 1,320,685 m². This corresponds to net addition of 118,751 m² between 2015 and 2040.

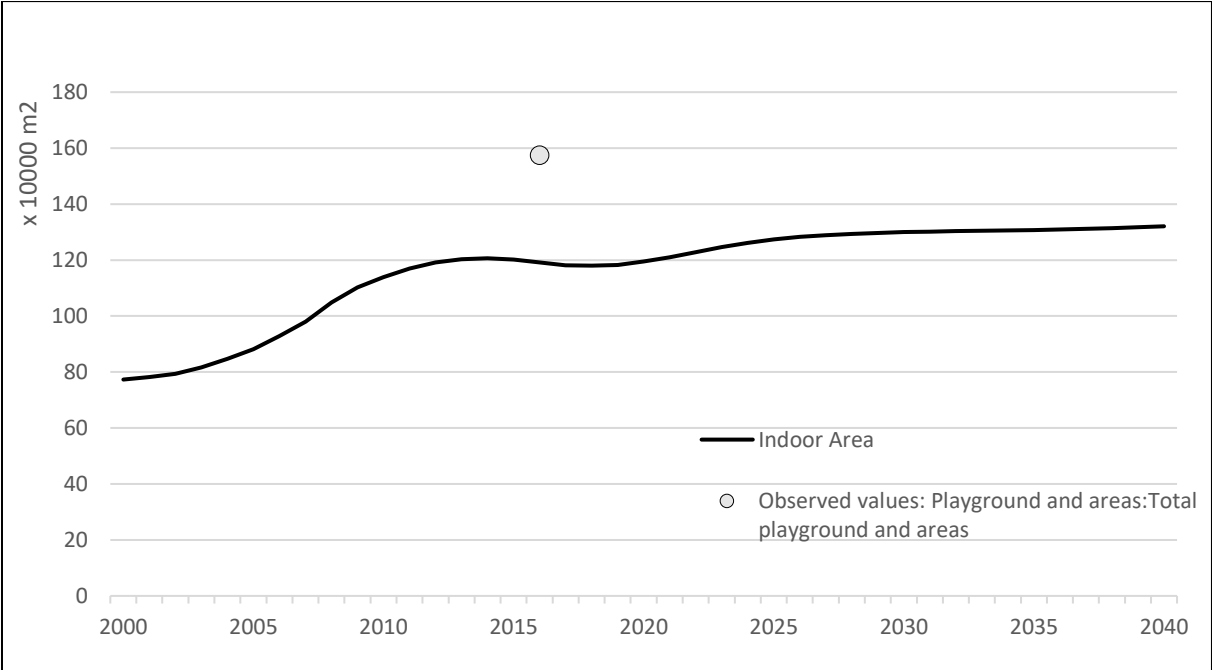


Figure 16 : Stock of built area

8.5 Aging

The dynamics of the aging, the accumulation and the exit of teachers and assistants is shown in reference to the stock of children in Figure 18 and Figure 17. Together they show that as time passes by, these people age; some of them exit the stock and there will be new recruits entering the stock.

In 2015, about 16.37% of the total teachers and assistants are in the age group of 24-

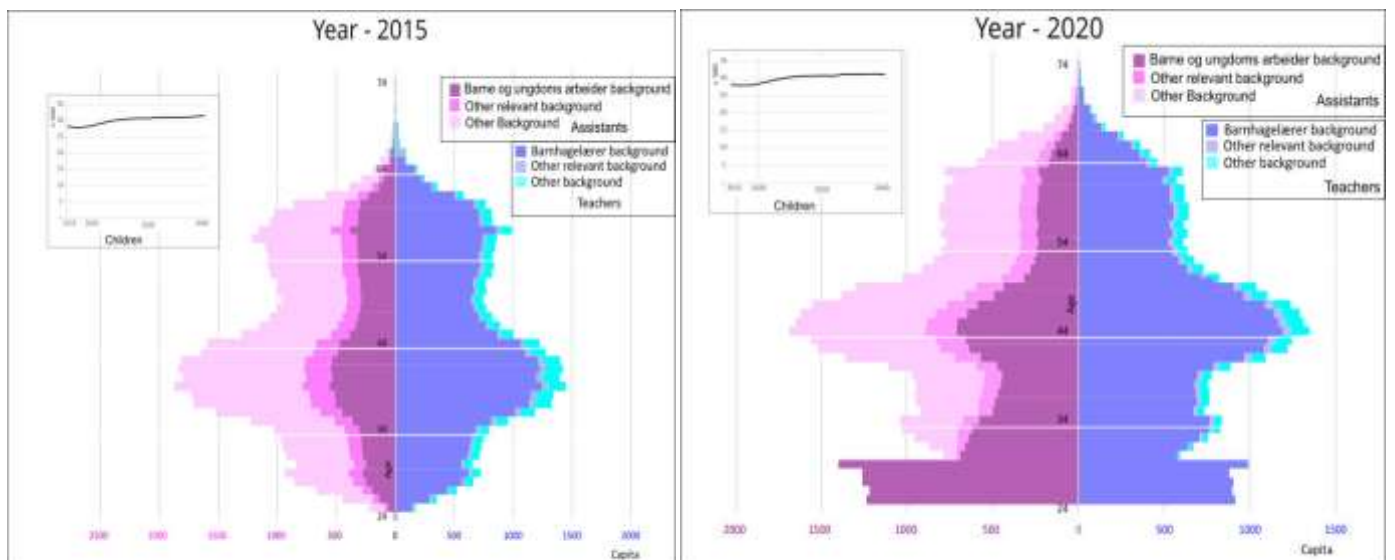


Figure 18 : Teachers and assistants by age: 2015 and 2020

34. Most people in stock belong to the age group of 34-44 making 35% of the stock. In 2020, it can be seen that a new younger share of population has entered the stock. The people in the age group 24-34 now make up to 18.24% of the stock in teachers and 25.32% in assistants. Most of the people in the both stocks range in the age group

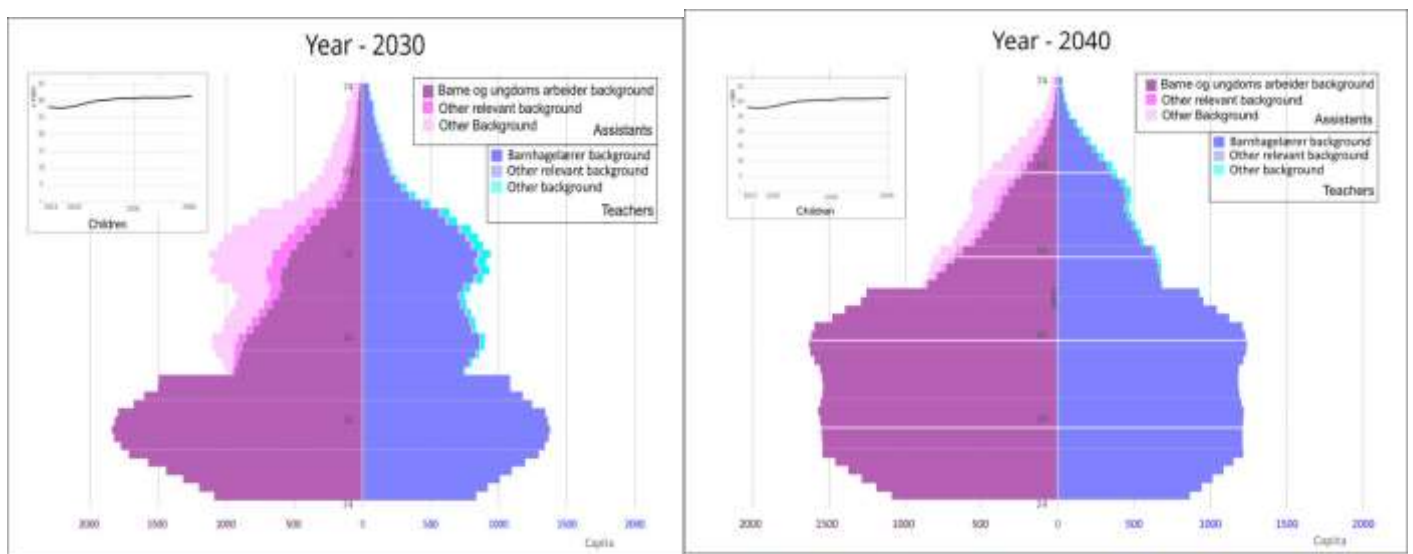


Figure 17: Teachers and Assistants by age contd.: 2030 and 2040

of 44-54. In the years 2030 and 2040, the number of children have increased relative to 2015. Correspondingly, the total stock has increased. The profile of the population pyramid has significantly changed since 2015. In 2030 44-54 age group consists of 28% of the teachers and most assistants are aged 34-44 amounting to 29.6% of the stock. In 2040 the largest share of assistants is in the age group of 34-44 amounting to 31.9% of the stock while most teachers are aged 34-44 to make 32.4% of the stock.

8.6 Scenario

In the following sections, results of the scenario development are presented. First an overview of the stock by background is provided. Later results about the training system and corresponding flows are presented.

Through SC1, assistants without background are educated by 2038 (Figure 19). In 2020 and 2030, assistants without background make 38% and 11% of the stock respectively. All the teachers are trained 7 years before the assistants. In 2020, teachers without background make 8% of the stock. In the period where assistants and teachers are being trained, larger inflows are seen in the system relative to the baseline scenario. The maximum demand for new assistants is expected to be 3254 in 2023. In this year 300 personnel also finish training and are re recruited. Correspondingly, the total inflow is 3554.

Through SC2, assistants are educated by 2028 (Figure 19). In 2020 and 2030, assistants without background make 36% and 2% of the stock respectively. In 2018, the first batch of assistants finish training. Drastic increases and decreases can be seen in the inflow of assistants during 2019 and 2031. In 2019, the total inflow is 3453 (570 new assistants and 2000 re-recruited). It reaches a maximum of 3370 in 2023 and in 2031 it reaches a value of 2483. In 2040, 3290 new assistants are estimated to enter the system. The associated outflows reach a maximum value of 3469 in the year 2033.

SC3 explores the back casting scenario of having a completely qualified stock by 2025. In order to achieve this target, parameters are set by trial and error. For assistants, it was found that the target can be reached by new training program with a duration of 2 years with a study intensity of 70%. Initially 2000 seats would have to be created and the increase in number of seats should be set to be 200 seats per year. For teachers, the target was reached by the workplace based diploma (same as SC2), initially 100

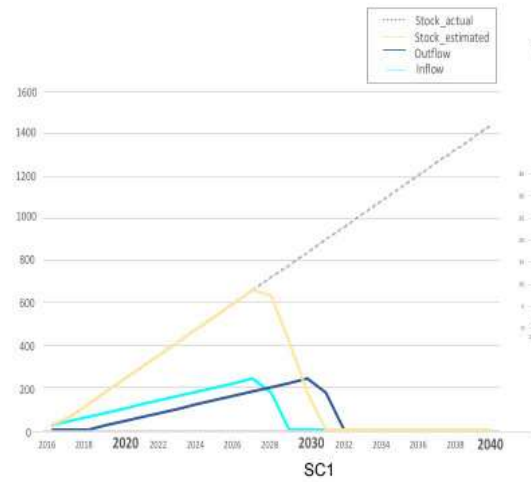
seats would have to be created and increase in the number of seats per year should be 30. Interesting to note that setting this target entails forcibly removing 3785 assistants from the system.



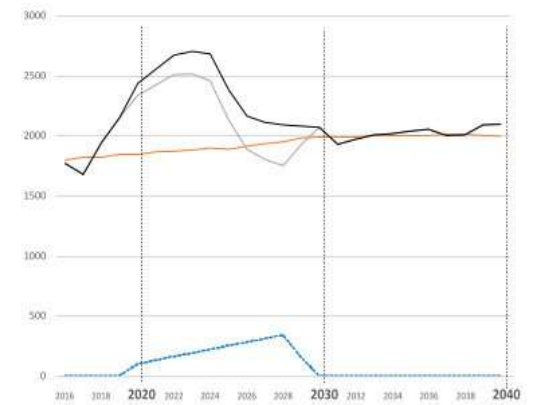
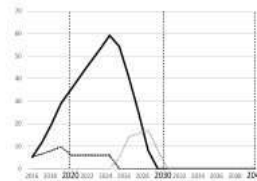
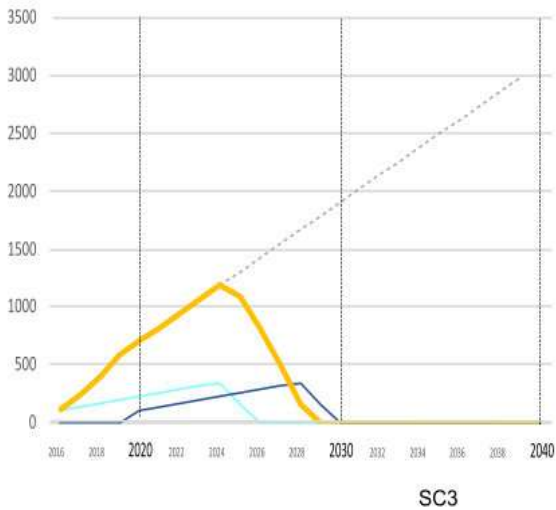
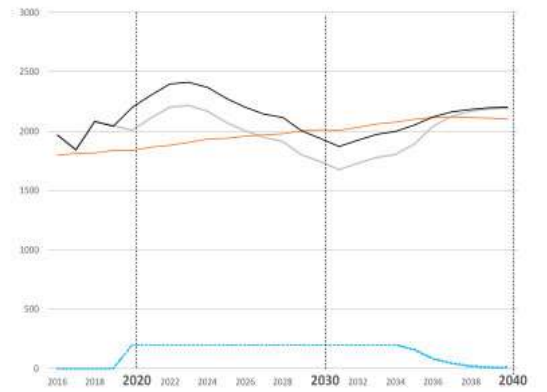
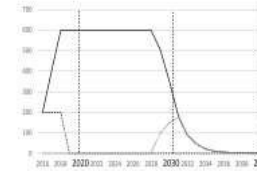
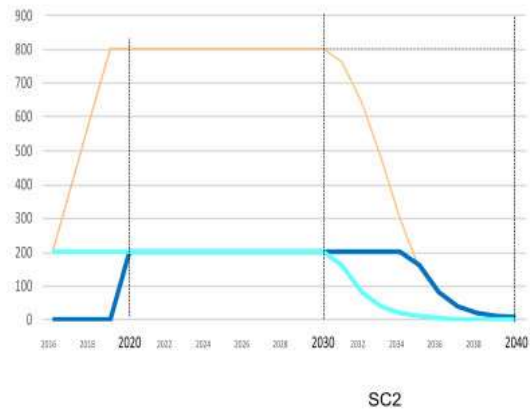
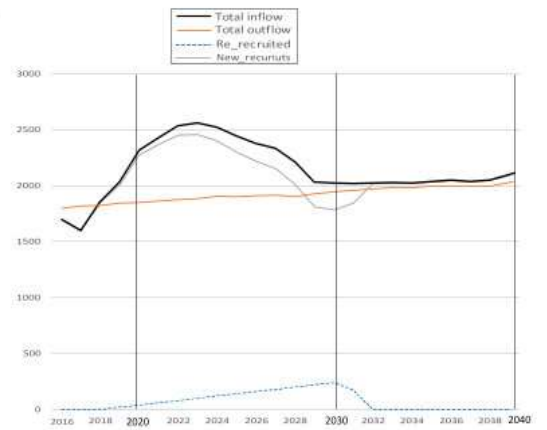
Figure 19: Scenario results- Overview of stock.

Training System

Inflows and Outflows



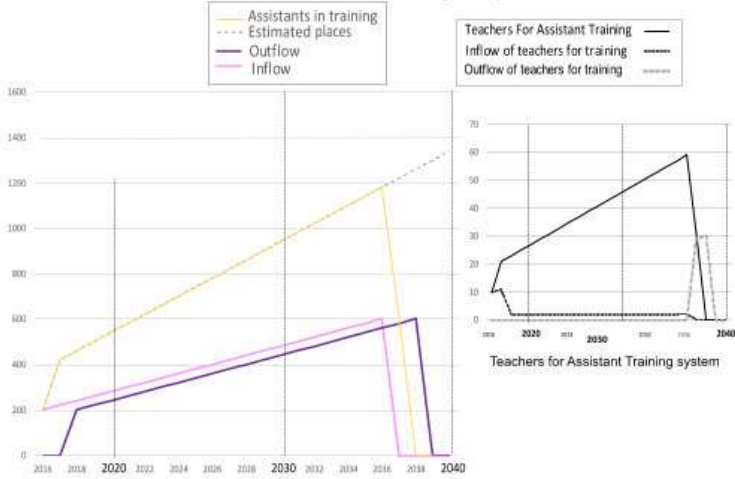
Teachers for Teacher Training system



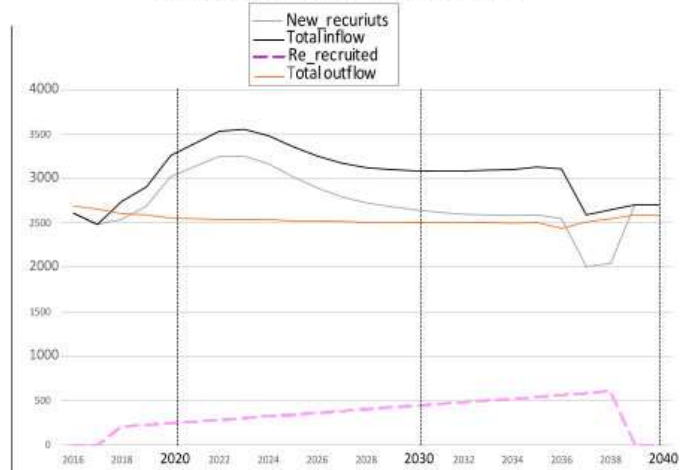
Teachers

Figure 20 Scenario results: Training system and associated flows: Teachers

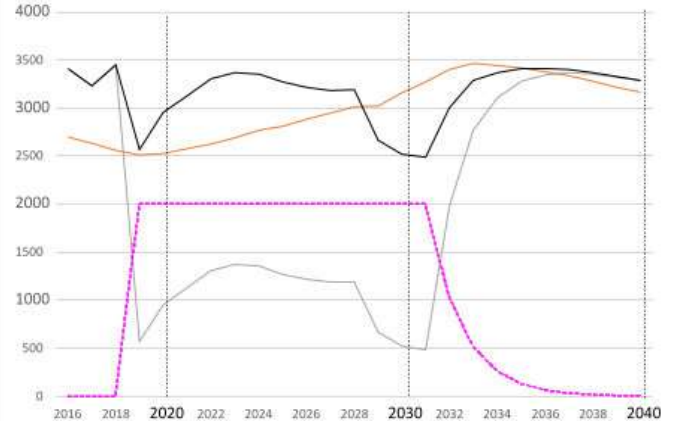
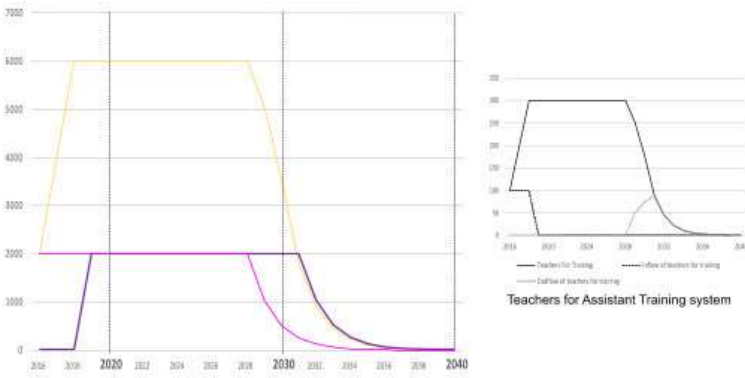
Training System



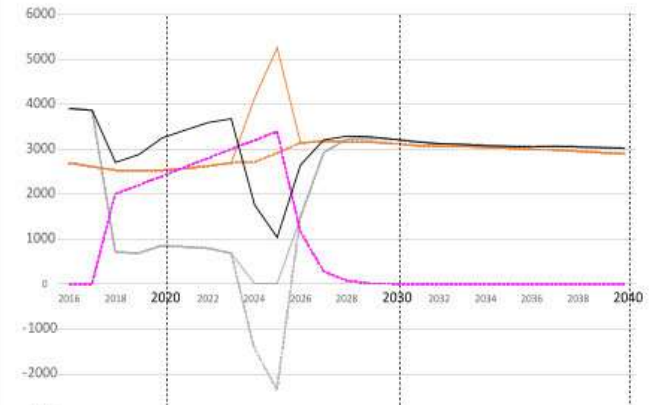
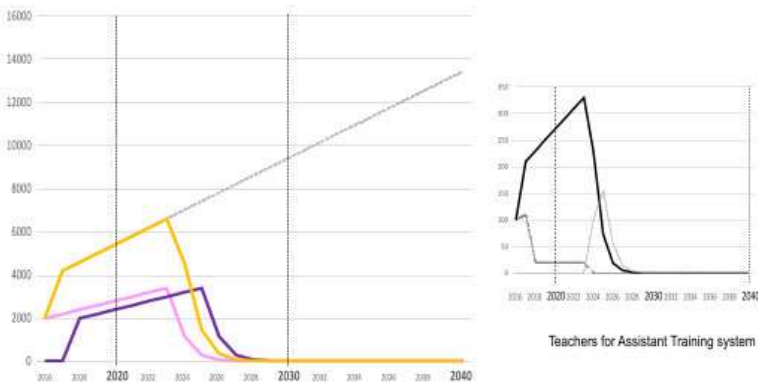
Inflows and Outflows



SC1



SC2



SC3

Assistants

Figure 21 : Scenario results - Training system and associated flows: Assistants

9 Discussion

9.1 Children and Structural quality

Children are the drivers of the system (Figure 2). When the stock of children increases, more infrastructure and staff are consequently demanded by the system and vice versa. In order to maintain optimum structural quality in kindergartens, stocks and flows of children needs careful monitoring.

In the past, the stock of the children has increased half fold between 2000 and 2015 (Figure 8). This is mainly due to the efforts of the government to ensure appropriate access for all children. Also, more children have started using kindergarten, the increase is particularly high for children in the age of 1-5. Although, the mandatory access to kindergarten is only for children between 1-5, some children younger and some older children are found in the system naturally. Furthermore, the time spent by children in kindergarten has also increased (Figure 6). Furthermore, access to a kindergarten is one of the key strengths of Norwegian kindergarten system. Despite the cash for care scheme, the usage has increased. Since the coverage and user intensity are already close to maximum attainable values, the model assumes that they remain constant in the future. It is unlikely these parameters change drastically.

The focus of the strategies regarding the children in future should be towards retention and sustaining the current levels of coverage and user intensity. These parameters could be used as benchmarks in order to monitor the system of children in future.

In the future, it can be seen that the inflow is drastically increasing between the years 2017-2023. Policy makers need to deliberate on this before designing any strategies that could affect the availability of adequate availability of staff.

9.2 Staff Qualifications

In the past, the accumulation of the teachers without background in kindergartens is clearly seen (Figure 14). As more children were added to the system, the demand for new teachers increased. In the period of 2006-2014 the stock of teachers without background have accumulated in the system. This is the period where the children in kindergarten were also drastically increasing. Hence, teachers without background were recruited to ensure adequate number of teachers are available. This reiterates the importance for quantitative monitoring the stock of children as a measure for anticipation of challenges.

The reasons for the accumulation of the assistants without background is quite ambiguous (Figure 14). In 2013, assistants without background are suddenly introduced to the system. However, this does not create changes in the total stock size but only stock composition. This was due to a reporting or classification in the statistical sources. However, clearer explanations for the sudden accumulation assistants without background are yet to be obtained.

The results of the baseline scenario (Figure 19) shows that the stock of teachers and assistants without a background reduces significantly by 2040. This is mainly because of the assumption that the new teachers recruited in the future possess formal qualification.

9.3 Staff Training programs

In order to achieve the goal of having 'all staff with formal qualifications' interventions will be necessary. The current measures being discussed for achieving this goal directly affects the demand for new staff and the stock composition in the future. Furthermore, since the number of teachers and assistants without background differ significantly, targeted measures for staff training need to be developed. However, the understanding obtained through the thesis is not sufficient to recommend clear quantitative targets for the program. This is because the supply of the new teachers in the future will be an important factor in this decision. The model does not provide this understanding.

Information about the age composition, can be crucial in many cases. If the stock is already comprising mostly of an older age group; there might be inertia for drastic changes. For instance, introducing computer based teaching in classrooms where most teachers in the stock are in in the age group of above 50 is might be harder than when the teacher stock is younger. The policy makers should also deliberate on the age composition of the stock before taking drastic intervention measures.

In order to achieve optimal benefits from the intervention, the re-educated staff should be retained for a certain period. Policy makers would have to decide as to the optimum period the staff need to be retained in order to get optimum benefit from the intervention strategies. For example, most teachers and assistants are currently in age group of 24-34years old. If a teacher 34 years old undergoes a work based training program of 3 years, he/she will be 37 years old when finishing. Potentially, he/she can work for 37

years more as a teacher. Hence, on an average a teacher undergoing the training can be expected to work for 37 years after the training.

9.3.1 Teacher Training

The scenario analysis shows that in the baseline scenario existing stock of teachers without background would almost disappear by 2040. Furthermore, by 2030 they would only amount to about 5% of the total stock. It can be seen that in SC1, a higher reduction of teachers without background is achieved compared to SC2 despite the fact that number of seats created for training of teachers is higher in SC2. However, the duration of training in SC1 is lesser. Furthermore, SC3 and SC1, which have similar duration of training but different number of seats. Still, they achieve similar stock compositions throughout the projection period. This shows that the duration of the program is of higher importance. Any intervention strategy designed should encourage shorter training programs, and number of vacancies created mattered relatively less. Also, it can be seen in these results that any measure taken does not yield a substantial benefit by 2020. This shows the need for studying and developing more measures that can yield quick benefits.

The demand for teachers in the scenarios increases because new teachers are required to (i) replace the teachers without background who are leaving the system for training (ii) to replace the teachers with background who are leaving for training the assistants.

The demand for new teachers is naturally increasing in the future as seen by the baseline scenario. This shows that the government's strategies to increase the number of seats for *barnehagelærer* education is a much necessary step for the preparation of future. However, as shown by the inflows of SC2 it can be seen that introducing a teacher training program with high seats can reduce the demand for new teachers in the future. This is because when the teachers without background finish their training, they need to be assured a place in kindergarten as a teacher. As more teachers without background finish their studies, the demand for new teachers reduce further. This shows the need for careful deliberation on quantitative target setting. Hence, the training system should have lesser seats but should effectively educate teachers through short courses.

9.3.2 Assistant Training

In scenario analysis results (Figure 19), it can be seen that the goal of 'having all assistants with formal background' is not possible in the baseline scenario by 2040. The share of '*assistants without background*' makes to about 8% of the stock in 2040 in the baseline scenario. In the short term, a substantial benefit can be obtained by introducing training programs that have low duration, high intensity and more number of seats being offered. In the long term, the number of seats offered for training programs play a higher role. This by comparing results of SC1 and SC2. SC2 achieves a higher reduction of assistants without background compared to SC1. Furthermore, by 2030 SC2 and SC3 achieve similar stock composition (Figure 19; Figure 21).

The demand for new assistants depends largely on the number of seats offered for training of existing assistants without background. Having 200 seats creates the situation of a steady increase in demand of new assistants but as more assistants gets trained the demand for new ones keep reducing. The counter option of having 6000 seats for the training programs initially creates a high demand for new teachers. Later, as assistants finish their and return to the system, the demand for new assistants drastically reduces (Figure 21). However, it is unlikely that the replacements would be by new assistants with formal qualifications. However, in case the new assistants are coming without a formal background, it is possible that they are given temporary work until a new assistant who has finished a training program is available. However, there is still a risk of lock in of assistants without background. Such scenarios need to be further investigated through the model.

In SC3 it can be seen that when the number of seats offered are more than 6000, some assistants need to be forcibly removed from the system, to ensure that the assistants who finished training are ensured a place. This should be a factor to consider when deciding number of seats to offer.

In summary, the number of seats offered to assistant training factor is a key factor in achieving the goal. It number of seats have to be such that it is effective enough to educate more assistants but creating too many seats might result in excess of assistants.

9.4 Built Area

The stock of built area estimated by the model is only based on the regulations laid by the government. However, since the regulations laid describe the minimum area per

child. Hence, it can be safely concluded that the stock estimated by the model as shown in Figure 16, shows the stock of minimum indoor area that exists in the system.

The observed value of the actual area is available for the year 2016 only. This is inclusive of both indoor and outdoor area associated with the kindergartens. Comparing the values of estimated and observed values for this year, it is deduced that 424,808 m² of outdoor area exists in 2016. This is lesser than the indoor area estimated for the same year. However, as per the regulations for infrastructure (chapter 3.6) this area is expected to be six times more than the indoor area. Further research and data collection of infrastructure is required to validate the estimated data and make further comments on the availability of sufficient outdoor area. Regardless, since the regulation for infrastructure have been set on the basis of number of children, the demand for infrastructure responds to a change in stock of children. In the future, since the stock of children is seen to be increasing more infrastructure will need to be built to cater to the demand.

9.5 Education sector and socio economic metabolism

A key success of this project is the development of a model to systemically study education. According to Ghosh (Ghosh, 2015), a key use of such models is that they provide future decision makers with tools to take a more systemic view of the problems they face, thus greatly benefitting the society. Furthermore, the model contributes to SEM studies with a better way to model population.

The model is a vital starting point for SEM studies to also develop into the education sector. This pushes forward our ability to describe social systems and services using the metaphors from our understanding of the physical world. This produces a simple, yet powerful outline to quantitatively describe of the participants of education. This way, population and infrastructure can be studied under one system.

The thesis shows the possibility of modelling population as a *dynamic type cohort time matrix*. This provides opportunities to study population as different types and explore the dynamics of aging and accumulation of people. This can help SEM studies to better understand the drivers of anthropogenic resource use.

9.6 Uncertainties and Limitations

Uncertainties in the model are a result of the systematic and random errors that occur in the model. Assumptions made during the model development can lead to systematic

errors. Random errors occur in the data sources inherently. Limitations in the model occur due to the assumptions made during system development.

As shown in figure (Figure 2), stock of other employees, other infrastructure have not been studied. Also, migration and immigration flows have not been studied. Furthermore, it is assumed that there are no re-recruitment and re-education flows hitherto. In addition, due the interdependence of the service elements there is a risk of error propagation. Uncertainties and limitations pertaining to system are discussed by each stock in the system is discussed in the following sections.

9.6.1 Children

Stock of children is estimated using two parameters total population and coverage. Also assumptions have been made regarding the inflows and outflows of the system. Since children stock influence the employee and built area stocks, an uncertainty in estimation children of children has a higher risk of uncertainty propagation.

Historical data on population is of low uncertainty as it is based on official statistics (SSB, 2017g). The future projections are based on main alternative population projection of 2015 (SSB, 2016b). Although it is reported by the national agency, it is based on assumptions about demographic parameters such as fertility, life expectancy, domestic migration and immigration. It is not possible to predict these parameters accurately, hence the projections include inherent uncertainties. According to SSB (SSB, 2017h) the uncertainties increase with time and vary by geographical regions. The percent wise error is greater for smaller municipalities.

The parameter coverage has been calibrated with the observed values of children in kindergarten in the past. Children in kindergarten are reported by the official sources and contain low uncertainty. In the future coverage is assumed to be stable at the values of the reference year. This results in uncertainty in this parameter and subsequently in the estimation of the children stocks.

Children stock has developed with an assumption that there are no dropouts in kindergartens, they leave naturally at the age of 5 or 6. This results in a systematic error and an uncertainty in the estimated inflows and outflows of children.

9.6.2 Teachers

In the teacher subsystem, uncertainties are due to the assumptions made during the estimation of the parameters. The estimation of the stock of teachers is sensitive to

changes in the parameters. Also, a discrepancy was found in the two data sources of reported staff (SSB, 2017e, 2017a). The total teachers reported by sex exceed the reported teachers by background by 7 % in 2015. In reality, this could be due to gaps in the data source regarding the information about background of teachers.

Both Demander intensity and Work intensity influence the estimation of the total stock of teachers. Both the parameters have seen a clear rising trend in the past years. It is unlikely that that demander intensity increases further in the future. However work intensity is more sensitive to policy changes. Hence, uncertainties can be expected due to this assumption.

Age distribution was obtained from lærermod (Gunnæs and Knudsen, 2015) which reported age distribution was for the year 2013. The report creates this data from population models (Aase et al., 2014). Hence an inherent uncertainty can be expected in this data. Also, it sets a range for employee age to be in between 24-74. While a person older than 74 is relatively unlikely, it is possible that there is a higher share of younger people. Furthermore, it is assumed that the age profile of the stock in 2015 in our model is similar to that of age profile of lærermod in 2013. This results in a bias in the estimation of age of the stock. Also, since the outflows are dependent on age composition of the stock, error propagation in the employee stocks and flows can be expected.

The inflow age distribution and outflow rate are both calculated from the Gulbrandsen (Gulbrandsen, 2015). Here data is obtained by surveys and official sources. However, assumptions are made in order to use this data into the model (Appendix II). In order to calculate the inflow rate it is assumed that the age profile of the graduates makes the inflow age distribution for the future (Appendix II). This creates an uncertainty in the age of people getting recruited. However, the author mentions that average age of people taking exams has increased since 1970s but since the 1990s the age of students taking the exams of preschool studies have the median age of around 25.

In outflow rate, the information used is also collected by Gulbrandsen (Gulbrandsen, 2015). In order to use this data in the model an outflow rate is calculated making an assumption that the outflow in the period of 2007-2012 is uniform (Appendix II). This introduces uncertainties in the system.

9.6.3 Assistants

As there are no strict regulations for the requirement of assistants in kindergarten, the estimated demand is highly sensitive to the role of assistants in the future. Furthermore, data regarding assistants is yet to develop. This makes the validation of data harder, causing high uncertainties in the estimation.

9.7 Model limitations and suggested improvements

The model can be improved further by improving system definitions and parameters. In the children stock, categories of children can be also based on usage of resources can be included. Children who demand additional resources can be included in the model further. Also, children be can distinguished further by region and status of their families.

In describing teacher and assistant stock, the model has several limitations. Age distribution, inflow age distribution and outflow rate for assistants is assumed to be the same as that of teachers. Further research is needed to check the validity of this assumption. Inflow age distribution is designed to map the age of the newly graduated teacher candidates. But, in case of assistants, they finish studies at an upper secondary level unlike teachers who obtain a tertiary level education. Hence, in reality inflow age distribution could contain a significant share of people younger than the lower age limit. Also, outflow rate is obtained from studies about teachers. Using this parameter for assistants creates uncertainty in the age profile of the assistants. Work intensity of the assistants has seen a clear increasing trend in the past. However, the model assumes it to stabilize at the current levels. A continuation of the increase can lead to overestimation of the total stock of assistants.

The key improvement to be made to the model for teachers and assistants is by including the education systems that creates them. This is crucial in understanding the supply of new teachers and assistants. This understanding is essential to develop clear quantitative strategies. This type of modelling can also create opportunities to find out optimal solutions to handle shortages of the supply of teachers.

Infrastructure models has not been adequately described using a type cohort approach in the model. The main reason for this is the lack of data on construction and demolition activities. Models in the future need to explore the infrastructure status of kindergartens and include a typology of the different buildings. Furthermore, creation of the training

system would also entitle its own infrastructure demand. This has not been included in the model.

9.8 Limitations of the study

The model does not address the challenge of shortage of supply of teachers and assistants. In order to develop strategies that can quantitatively set goals for this intervention, an understanding of the supply of teachers and assistants from secondary level education and upper secondary level education respectively will be needed. Furthermore, infrastructure has not been studied thoroughly in the study. Also, scenario developed only discuss formal qualifications. They do not include the competence building measures that already underway. Also there is possibility that assistants can obtain a certificate of apprenticeship without taking any courses, thereby granting them formal qualifications. This option has not been studied under the scenario.

10 Conclusion

The aim of the thesis is in providing a simple and effective framework to quantitatively study education as a system. The model developed for the thesis is a vital starting point for SEM studies to develop in the education sector. The model also demonstrates the alternative of modelling population as a dynamic type cohort type model providing an alternative to linear statistical models. Furthermore, the thesis has been successful in understanding the development of the stocks of the kindergarten system, demand for new teachers and assistants and changes in this demand due to invention strategies aimed at raising formal qualifications of the existing teachers and assistants without background.

The contemporary challenge analysed in the thesis is the design of intervention strategies for teachers and assistants without relevant background in the system. This problem of teachers without qualified background was created between the years 2000-2015, where a drastic increase in children stock was seen. The reasons for the accumulation of assistants is ambiguous due to a change in how assistants are accounted in the official statistics since 2013. Further investigation into the problem is necessary. Such accumulation could have occurred because; in order to cope with the rising number of children and shortage of supply of qualified staff, more people without qualified background were employed to work as teachers and assistants. Some of these might also be working in temporary positions. In the thesis it is expected that this

accumulation results in a lock in effect and persists in the future creating a need for intervention.

The intervention measures studied through the thesis are: using (i) traditional and (ii) workplace based training programs to provide relevant qualifications. The duration of the training, teacher and infrastructure requirement for the training programs, the number of seats offered per year have to be designed to yield optimal benefit. The intervention strategies should take targeted measures for teachers and assistants to ensure that a goal of 'having all staff in kindergartens with formal qualifications' is reached.

The duration of the program plays a larger role in training of teachers while the number of seats offered is more significant for assistants. The intervention directly affects the demand for new teachers and assistants in the future. Initially more staff would be required to replace the teachers and assistants who are undertaking training. As more people finish their training, the demand for new teachers correspondingly reduces. Also, the training programs should be developed keeping the current shortage of qualified staff and the rising demand for new staff in mind.

The thesis shows the changes in the demand for new teachers and assistants in the future. The development of children stock plays a key role in the subsequent demand for teachers, assistants and infrastructure. It is important to monitor this stock and take measures aimed at ensuring current levels of participation in kindergarten so that usage is sustained. The demographic projections used in this thesis indicate a growth of children stock in the future. This growth is especially faster between the years 2017-2023, where the new children stock entering the system is also high. The demand for new teachers, assistants and infrastructure is correspondingly increasing.

The thesis does not provide optimal quantitative targets for the intervention strategies. This can be done by developing further models that estimate the supply of teachers in the future. The supply and demand for teachers and assistants need to be collectively understood to develop optimal targets.

11 Future work

The thesis conducted is only a starting point for SEM studies in the field of education. The possibilities for future work are seemingly endless. An immediate requirement to comprehensive target development for kindergartens in Norway, the supply of new teachers and assistants needs to be included. This can be done by extending the model to include the respective upper secondary and secondary level education systems. A possibility for such an extension of the system is provided in Appendix II.

The thesis also creates an opportunity to study the dynamics of children in kindergarten through high school. The journey of a child from being a demander of services to a provider can be chalked at different regional levels using this model. This type of understanding can clearly show the future supply demand in physical terms. This can be integrated with economic models to enhance their strengths and provide better physical understanding for development of economic policies.

The conceptual framework used in the development of the thesis is a general theory that can be used to study any service. Service sector itself is a large part of the economy that is yet to be understood in SEM studies. As theory and models develop, public sectors like health and private sectors like consultancies, NGOs, small business or large corporation in the service sector can be studied.

References

- Aase, K.N., Tønnessen, M., Syse, A., 2014. Befolkningsframskrivingene Dokumentasjon av modellene BEFINN og BEFREG.
- Baccini, P., Brunner, P.H., 2012. *Metabolism of the Anthroposphere: Analysis, Evaluation, Design*. MIT Press.
- Bakken, L., Brown, N., Downing, B., 2017. Early Childhood Education: The Long-Term Benefits. *J. Res. Child. Educ.* 31, 255–269. doi:10.1080/02568543.2016.1273285
- BALL, S.J., 1998. Big Policies/Small World: An introduction to international perspectives in education policy. *Comp. Educ.* 34, 119–130. doi:10.1080/03050069828225
- Barlas, Y., Diker, V.G., 1996. An Interactive Dynamic Simulation Model of a University Management System, in: *Proceedings of the 1996 ACM Symposium on Applied Computing, SAC '96*. ACM, New York, NY, USA, pp. 120–128. doi:10.1145/331119.331162
- Baynes, T.M., Müller, D.B., 2016. A Socio-economic Metabolism Approach to Sustainable Development and Climate Change Mitigation, in: Clift, R., Druckman, A. (Eds.), *Taking Stock of Industrial Ecology*. Springer International Publishing, pp. 117–135. doi:10.1007/978-3-319-20571-7_6
- Bithas, G., Kutsikos, K., Sakas, D.P., Konstantopoulos, N., 2015. Business Transformation through Service Science: The Road Ahead. *Procedia - Soc. Behav. Sci., Proceedings of the 3rd International Conference on Strategic Innovative Marketing (IC-SIM 2014)* 175, 439–446. doi:10.1016/j.sbspro.2015.01.1221
- Boug, P. al, Dyvi, Y., 2008. MODAG-en makroøkonomisk modell for norsk økonomi. Statistisk sentralbyrå a.
- Brunner, P.H., Rechberger, H., 2003. *Practical Handbook of Material Flow Analysis*.
- Butlin, J., 1989. *Our common future*. By World commission on environment and development. (London, Oxford University Press, 1987, pp.383 £5.95.). *J. Int. Dev.* 1, 284–287. doi:10.1002/jid.3380010208
- Engel, A., Barnett, W.S., 2015. *Early Childhood Education and Care Policy Review*. European Commission, 2008. REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS.
- Faubert, B., 2012. *A Literature Review of School Practices to Overcome School Failure (OECD Education Working Papers)*. Organisation for Economic Co-operation and Development, Paris.
- Field, S., Kuczera, M., Pont, B., 2007. *No more failures: ten steps to equity in education, Education and training policy*. OECD, Paris.
- Fischer-Kowalski, M., 1998. Society's Metabolism. *J. Ind. Ecol.* 2, 61–78. doi:10.1162/jiec.1998.2.1.61
- Fischer-Kowalski, M., Krausmann, F., Pallua, I., 2014. A sociometabolic reading of the Anthropocene: Modes of subsistence, population size and human impact on Earth. *Anthr. Rev.* 1, 8–33. doi:10.1177/2053019613518033
- Ghosh, A., 2015. *Dynamic Systems for Everyone*. Springer International Publishing, Cham. doi:10.1007/978-3-319-10735-6
- Gulbrandsen, L., 2015. *Barnehagelva ererne*. Yrkesgruppen Som Sluttet Slutte.
- Gunnes, T., Knudsen, P., 2016. *LÆRERMOD: Forutsetninger og likninger*.
- Gunnes, T., Knudsen, P., 2015. *Tilbud og etterspørsel for ulike typer lærere mot 2040: Framskrivinger basert på LÆRERMOD*.
- Harte, J., 2007. Human population as a dynamic factor in environmental degradation. *Popul. Environ.* 28, 223–236. doi:10.1007/s11111-007-0048-3
- Haug, K.H., Storø, J., 2015. Kindergarten — a Universal Right for Children in Norway. *Int. J. Child Care Educ. Policy* 7, 1. doi:10.1007/2288-6729-7-2-1
- Hendriks, C., Obernosterer, R., Müller, D., Kytzia, S., Baccini, P., Brunner, P.H., 2000. *Material Flow Analysis: A tool to support environmental policy decision making*. Case-

- studies on the city of Vienna and the Swiss lowlands. *Local Environ.* 5, 311–328. doi:10.1080/13549830050134257
- Kennedy, M., 2011. A review of system dynamics models of educational policy issues, in: *Proceedings of 24th International Conference of System Dynamics Society*, Washington DC, USA.
- Kim, D.H., Senge, P.M., 1994. Putting systems thinking into practice. *Syst. Dyn. Rev.* 10, 277–290. doi:10.1002/sdr.4260100213
- Kogan, M., Bauer, P.M., 2006. Higher Education Policies: Historical Overview, in: Kogan, M., Henkel, M., Bauer, P.M., Bleiklie, P.I. (Eds.), *Transforming Higher Education, Higher Education Dynamics*. Springer Netherlands, pp. 25–38. doi:10.1007/978-1-4020-4657-5_2
- Lamb-Parker, F., Piotrkowski, C.S., Baker, A., Peay, L., 2001. Understanding barriers to parent involvement in Head Start: A research-community partnership [WWW Document]. ResearchGate. URL https://www.researchgate.net/publication/223266744_Understanding_barriers_to_parent_involvement_in_Head_Start_A_research-community_partnership (accessed 6.19.17).
- Maglio, P.P., Spohrer, J., 2008. Fundamentals of service science. *J. Acad. Mark. Sci.* 36, 18–20. doi:10.1007/s11747-007-0058-9
- Meisels, S.J., Shonkoff, J.P., 2000. Early childhood intervention: A continuing evolution. *Handb. Early Child. Interv.* 2, 3–31.
- Ministry of Education, 2013. *Kompetanse for framtidens barnehage: Strategi for kompetanse og rekruttering 2014-2020*.
- Ministry of Education, 2012. *National Curriculum Regulations for Kindergarten Teacher Education*.
- Ministry of Education and Research, 2013. *OECD – Thematic Review of Early Childhood Education and Care Policy in Norway*.
- Ministry of Education and Research, 2011a. Act no. 64 of June 2005 relating to Kindergartens § 1.
- Ministry of Education and Research, 2011b. *Veileder om kravene til pedagogisk bemanning i barnehageloven med forskrifter*.
- Nakic-enovic, N., Davidson, O., Davis, G., Grübler, A., Kram, T., Shukla, P., Swart, R., 2000. *Emissions scenarios: summary for policymakers : a special report of IPCC Working Group III. WMO (World Meteorological Organization) : UNEP (United Nations Environment Programme)*, Geneva.
- NICHHD, 2006. *The NICHD study of early child care and youth development*.
- Nino, F.S., 2015a. *Sustainable development goals - United Nations*. U. N. Sustain. Dev.
- Nino, F.S., 2015b. *Education*. U. N. Sustain. Dev.
- NOKUT, 2017. *The Norwegian table of qualifications - NOKUT [WWW Document]*. URL <http://www.nokut.no/en/Facts-and-statistics/The-Norwegian-Educational-System/The-Norwegian-qualifications-framework/The-Norwegian-table-of-qualifications/> (accessed 6.21.17).
- OECD, 2012. *Equity and Quality in Education*. OECD Publishing. doi:10.1787/9789264130852-en
- Pauliuk, S., Hertwich, E.G., 2015. Socioeconomic metabolism as paradigm for studying the biophysical basis of human societies. *Ecol. Econ.* 119, 83–93.
- Pauliuk, S., Majeau-Bettez, G., Müller, D.B., Hertwich, E.G., 2016. Toward a Practical Ontology for Socioeconomic Metabolism. *J. Ind. Ecol.* 20, 1260–1272. doi:10.1111/jiec.12386
- Paulson, L.D., 2006. Services Science: A New Field for Today's Economy. *Computer* 39, 18–21. doi:10.1109/MC.2006.277
- Pettersson, K.E., 2017. Teachers' actions and children's interests. Quality becomings in preschool documentation. *Tidsskr. Nord. Barnehegeforskning* 14.
- Pianta, R.C., Hamre, B.K., Allen, J.P., 2012. *Teacher-Student Relationships and Engagement: Conceptualizing, Measuring, and Improving the Capacity of Classroom*

- Interactions, in: Christenson, S.L., Reschly, A.L., Wylie, C. (Eds.), *Handbook of Research on Student Engagement*. Springer US, Boston, MA, pp. 365–386. doi:10.1007/978-1-4614-2018-7_17
- Qiu, R.G., 2014. Education as a Service and Educational Service Systems, in: *Service Science*. John Wiley & Sons, Inc., pp. 199–247. doi:10.1002/9781118551820.ch7
- Reynolds, D., Sammons, P., Townsend, T., 1996. *Educational Effectiveness Research (EER)*. State Art Rev. 4–7.
- Sandberg, N.H., Sartori, I., Vestrum, M.I., Brattebø, H., 2017. Using a segmented dynamic dwelling stock model for scenario analysis of future energy demand: The dwelling stock of Norway 2016–2050. *Energy Build.* 146, 220–232. doi:10.1016/j.enbuild.2017.04.016
- SSB, 2017a. 09345: Employed persons in kindergartens, by ownership, employment position and education (M).
- SSB, 2017b. Kindergartens, 2016, final figures [WWW Document]. ssb.no. URL <http://www.ssb.no/en/utdanning/statistikker/barnehager/aar-endelige/2017-03-21> (accessed 6.20.17).
- SSB, 2017c. Beregningsmodeller [WWW Document]. ssb.no. URL <http://www.ssb.no/forskning/beregningsmodeller> (accessed 6.20.17).
- SSB, 2017d. Table: 09220: Kindergartens, by ownership structure of kindergarten (M).
- SSB, 2017e. Table: 09344: Employed persons in kindergartens, by ownership, employment position and sex (M).
- SSB, 2017f. Table: 04683: C. Kindergartens - basic data (M) [WWW Document]. URL <https://www.ssb.no/statistikkbanken/SelectVarVal/Define.asp?MainTable=Kostra3KCBarneha&KortNavnWeb=barnehager&PLanguage=1&checked=true> (accessed 6.21.17).
- SSB, 2017g. 07459: Population, by sex and one-year age groups. 1 January (M) [WWW Document]. URL <https://www.ssb.no/statistikkbanken/SelectVarVal/Define.asp?MainTable=NY3026&KortNavnWeb=folkemengde&PLanguage=1&checked=true> (accessed 6.20.17).
- SSB, 2017h. Population growth in foreseeable future [WWW Document]. ssb.no. URL <http://www.ssb.no/en/befolkning/statistikker/folkfram/aar/2014-06-17?fane=om> (accessed 6.21.17).
- SSB, 2016a. LÆRERMOD: Forutsetninger og likninger [WWW Document]. ssb.no. URL <http://www.ssb.no/arbeid-og-lonn/artikler-og-publikasjoner/laerermog-likninger> (accessed 6.20.17).
- SSB, 2016b. Table: 11167: Population projections 1 January, by sex, age, immigration category and country background, in 15 variants.
- Starting Strong III, 2011. . OECD Publishing. doi:10.1787/9789264123564-en
- Sterman, J.D., 1994. Learning in and about complex systems. *Syst. Dyn. Rev.* 10, 291–330. doi:10.1002/sdr.4260100214
- Taylor, C., Ishimine, K., Cloney, D., Cleveland, G., Thorpe, K., 2013. The quality of early childhood education and care services in Australia. *Australas. J. Early Child.* 38, 13.
- Utdanning.no, 2014. Barne- og ungdomsarbeiderfag [WWW Document]. utdanning.no. URL https://utdanning.no/studiebeskrivelse/barne-_og_ungdomsarbeiderfag (accessed 6.20.17).
- Vasquez, F., Løvik, A.N., Sandberg, N.H., Muller, D.B., 2016. Dynamic type-cohort-time approach for the analysis of energy reductions strategies in the building stock. *Energy Build.* 111, 37–55. doi:10.1016/j.enbuild.2015.11.018
- Wolstenholme, E.F., 1999. Qualitative vs Quantitative Modelling: The Evolving Balance. *J. Oper. Res. Soc.* 50, 422–428. doi:10.2307/3010462

Appendix I – Forecasting tools

Labour Demand Forecasting tools

In Norway there are different models in use. Some of these models are intended to understand the economy, some are intended to aid planning of budget and tax and others intended to generate understanding of employment and labour trends. A summary of the models in use is provided by table

Sl.no	Model	Description
1	ADMOD	Supply demand for education into the future
2	REGARD	Analytical apparatus to study labour market performance
3	KOMMODE	Study municipalities' financial behaviour
4	MAKKO	Macro model of the municipal economy
5	KVARTS	Macro-economic model of Norway using quarterly data
6	MSG	General equilibrium model for Norwegian economy
7	MODAG	Macro-economic model of Norway using annual data
8	LOTTE	Central planning tool in preparation of tax policy
9	MOSART	Dynamic Microsimulation model for projections and analysis of future employment, education and social security

Source of information: <https://www.ssb.no/forskning/beregningsmodeller>

The important models that deal with supply demand at macroeconomic level are MODAG, MOSART, and ADMOD. These tools are developed by the official statistics department, Statistiskentral burea SSB. In these models, demand refers to employment demand in the economic and supply refers to of consumption and supply means the educated personnel.

MODAG and MOSART together form the macroeconomic supply demand models of SSB. Supply and demand are both individually projected but in a consistent manner. MODAG is a multi-sectoral macroeconomic model for the demand side while MOSART is the dynamic microsimulation model on the supply side.

MODAG is a macro economic model for the Norwegian economy. The purpose of the model is to provide a simplified description of the economy. It is mainly used by the ministry of finance for medium term economic forecasts and policy analyses.

Although the model is also used by SSB for internal analysis and publications. In some cases, national and local agencies also use the model. The model comprises of an inter industry matrix arranged together in a Leontief model. Demand for labour is modelled by five education groups for each industry. In addition, a sub model is developed that studies labour demand by 28 different educational fields.

MOSART is an acronym for "*model of micro simulation of Schooling, employment and social security.*" It simulates the population in terms of immigration and emigration, births, deaths, household formation, education and impact on education, employment and labour income and transitions to long-term social security benefits. It uses probabilistic models to simulate a person's choices regarding education, areas of employment. In addition, age of people and probability of completion are also simulated by 28 different fields of education. However, in the developed model the transition probabilities are kept constant. This implies that the labour force participation rates and the educational propensities do not vary during the projection period. The main purpose of the projections is been to analyse the consequences of different designs of the pension system; in addition to providing the supply side understanding.

ADMOD is developed by integrating the MODAG and MOSART results to generate a supply demand model divided by education. Every three years, a new projection for MOSART and MODAG is generated. In the in between years ADMOD is used to put the results into supply demand context. There are different sub models in use. HELSEMOD is used to forecasting supply and demand of labour in health sector. LÆRERMOD is a sub model of ADMOD that is used in forecast of teachers. In the following section, LÆRERMOD is elaborated further.

LÆRERMOD

LÆRERMOD is the supply demand model of the education sector. In this case, supply refers to the amount of teachers being graduated and demand refers to the number of teacher to be employed. The purpose of LÆRERMOD is to forecast the excess and deficit of teachers by different training areas at national level. LÆRERMOD uses a combination of probabilistic and econometric approaches to obtain this understanding. LÆRERMOD mentions that model consists of important three pillars. Like all other models, LÆRERMOD also consists of many assumptions. The authors mention that understanding these assumptions are the key to correct interpretations of the results.

LÆRERMOD was established by SSB in 1998. A report projecting the availability of teachers is published once every three years by SSB ().It is used by the public administration, universities and colleges and the ministry of education. Both supply and demand of teachers is reported by five categories: Kindergarten teachers, primary school teachers, subject specific teachers and other teachers, Teachers with practical pedagogical education for general subjects (PPU-A). Teachers with practical pedagogy education for vocational subjects (PPU-Y). Further information about Kindergarten teachers in LÆRERMOD is provided in _.

Supply and demand in LÆRERMOD are independently calculated. According to (2012, LÆRERMOD) the supply of teachers is calculated by supplementing the inventory of employed teachers by accounting for the new candidates and subtracting the teachers who go out of work activity because of age. However, this not modelled directly. In (lærerm, 2016) it is mentioned that the share of people by age in the employed stock is reduced at retirement age to account for retirement. New teacher candidates are phased into the original stock of teachers based on student admission, length of study program and degree of completion. They are assigned the same characteristics as that

of the already employed teachers in terms of employment rates and average number of years work per worker. Furthermore, the age and gender distribution of the stock is assumed to be constant during the period of projection. The demand of teachers is calculated by studying the trend in the future users of education by different employment areas.

It is mentioned in the report () that LÆRERMOD consists of three important pillars.

- Distribution of teachers by employment areas.
- The ratio between numbers of teachers and number of users, called ‘teacher density’ ()
- Demographic development as basis for development of future users.

LÆRERMOD takes into account that teachers in all the training categories can work in different sectors. Teachers can work in kindergartens, elementary school, upper secondary school, adult education or other education, universities and colleges or outside the sector. For example, not all teachers who acquire training to be a kindergarten teacher essentially work in a kindergarten. The model consists of distribution of teachers by employment areas that maps the requirement of the different types of training categories by different sectors. This is intended to show the mismatch in the labour market and the reserve strength of teachers trained for a given sector. It is assumed that this distribution stays constant over the projection period (LÆRERMOD, 2015, summary).

The ratio between the number of teachers and number of users for a starting point for the calculations of demand (). Teacher density is derived for different employment areas based on the age group of the users. Table gives the user categories by age group. Teacher density is assumed to be a static element in the projections. However different user growth is assumed in different employment areas.

Sl.no	User Age groups	Employment area
1	0-5 years	Kindergarten and day care
2	6-15 years	Primary and lower secondary education
3	15-99 years	Upper secondary education
4	19-49 years	Universities and colleges

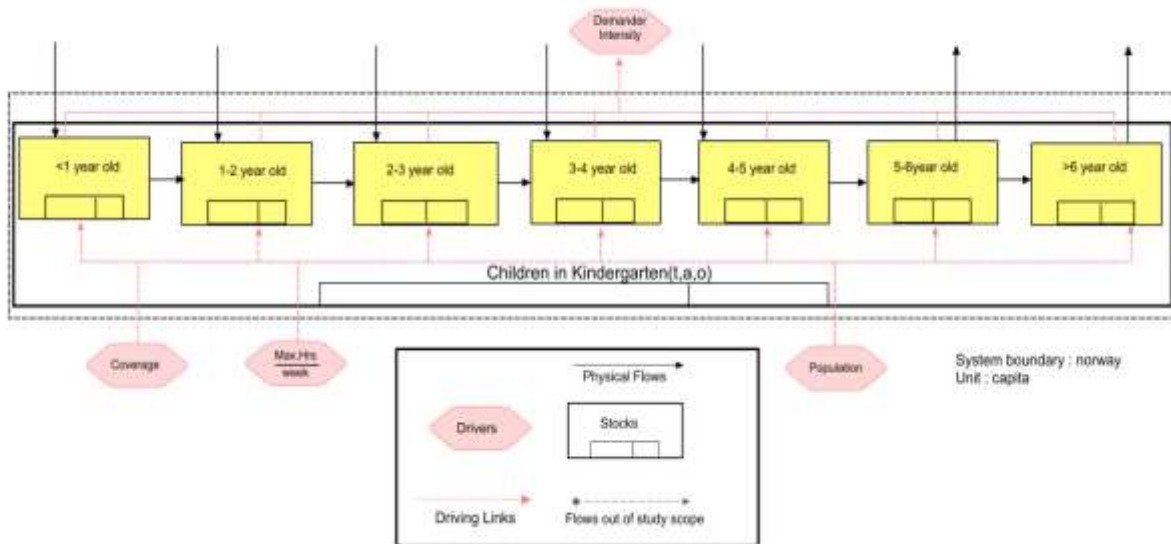
Derived from lærermod 2016

Demographic projections are used to understand the development of the future users in the employment sectors. The demand for teachers is based on these developments. SSBs population projections are used for these purposes. Different scenarios of population projections are explored in the model.

Appendix II – Subsystems

Subsystem: Children

In order to further illustrate the dynamics of children a subsystem is developed. **Figure** shows the subsystem followed by modelling equations children and parameter considerations. This subsystem serves as the basis for the development of the mathematical model.



Children are divided by age groups (a) and hours of attendance (o). Complete lists of models variables and paramters are given in the tables.

Variable	Nature	Dimensions	Symbol	Unit
Children in KG	Stock	t,a,o	<i>C</i>	capita
Inflow of children	Flow	t,a	<i>I</i>	capita
Outflow of children	Flow	t,a,	<i>O</i>	capita
KGhours	System Variable	t,a	<i>KGhrs</i>	Hours/week
ManYr Demand of teachers	System Variable	t,a	<i>M</i>	ManYrs
ManYr demand of assistants	System Variable	t,a	<i>Asst_M</i>	ManYrs
Demander Intensity	System variable	t,a	α	-
Parameters				
Coverage	dynamic		ω	
Maximum Hours per week	constant		<i>Max.</i>	Hrs
Total children	dynamic	t,a	<i>TC</i>	capita

System equations

Model Approach equations

The model approach equations are as shown as following. Later using the principle of mass balance consistency, the flows pertaining of children through the kindergarten are calculated.

For a given t ,

$$\text{Children in Kindergarten } C_t = POP_{ta} \times \text{Coverage } \omega_{tj}$$

1

$$\frac{KG_{hours}}{week} O_{ta} = C_{to} \times \frac{\text{number of hours } s_{oj}}{week}$$

2

$$\text{Demander intensity } \alpha_{ta} = \frac{O_{ta}}{C_{ta} \times \text{Max. } \frac{hours}{week}}$$

3

Where C is the stock of children in kindergarten. O_{ta} is called KG hours per week which gives the total man hours of the kindergartens used by the children. Demander intensity α_{tc} is calculated as the man hours of kindergarten by the max possible man hours of kindergarten usage. Demander intensity indicates intensity of kindergartens.

Mass balance equations

Mass balance consistency given by

$$C_{tj} = I_{ta} - O_{ta}$$
$$\Delta C_{ta} = C_{ta} - C_{(t-1)a}$$

Where S is the stock of Children in KG; I is the inflow of children and O is the outflow. As seen in the **figure**, an important assumption made in order to proceed is that children that enter KG at any age only leave as 5 or 6 year olds. Also, children do not enter KG as 5 or 6 year olds. A rationale for this assumption is the unavailability of data regarding enrolments and dropouts which correspond to inflows and outflows in

For $a < 5$

$$I_{ta} = \Delta C_{ta}$$

$$O_{ta} = 0$$

For $a > 5$

$$I_{ta} = 0$$

$$O_{ta} = C_{ta}$$

4

the system. Mathematically:

5

Therefore,

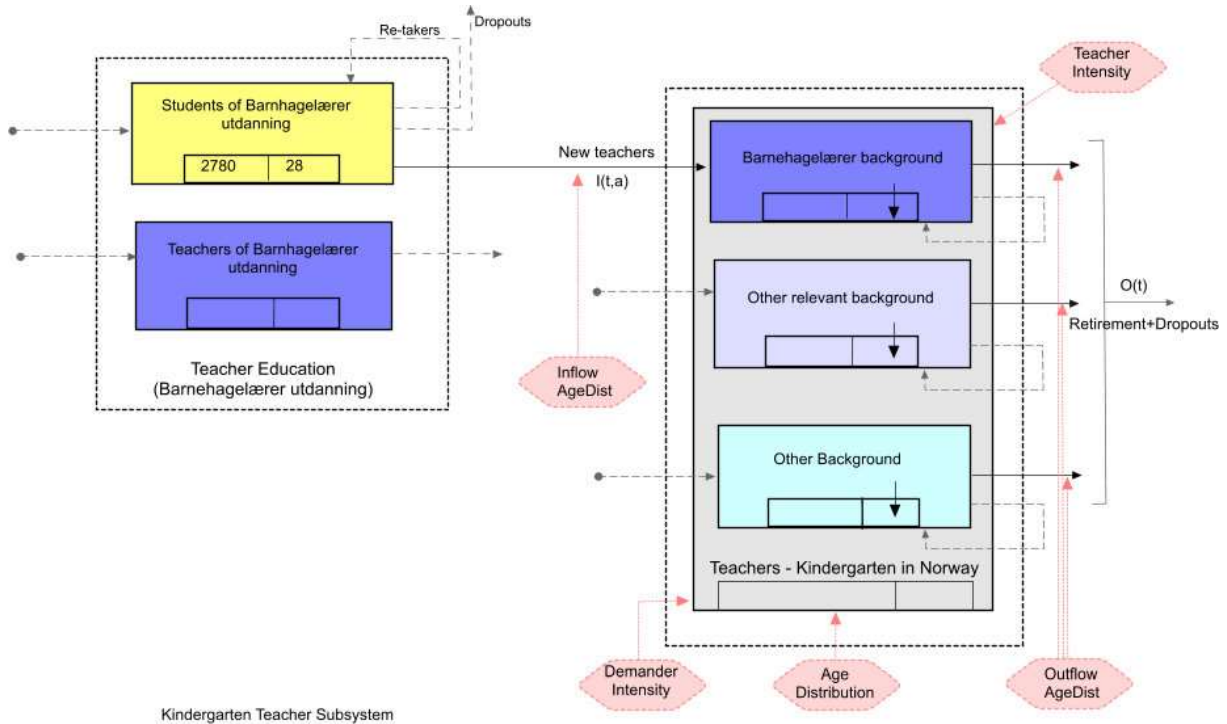
$$I_t = \sum_{j=1}^4 I_{ta}$$

$$O_t = \sum_{j=5}^6 O_{ta}$$

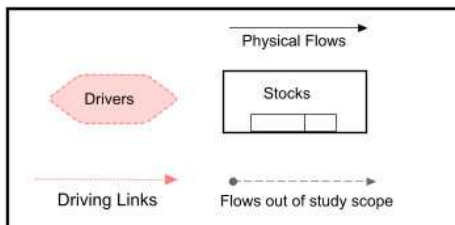
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Subsystem Teachers

Teachers are classified into three types based on the background. SSB reports employees by 11 different background categories. These are classified into three main types: Barnehagelærer background, other relevant Background and other background. Table shows the classification approach



Kindergarten Teacher Subsystem



Classification categories	Barnehagelærer background	Other Relevant Background	Other background
<i>Reported Categories</i>	<i>Barnehagelærer (Pre-school teacher)</i>	<i>Education that gives qualifications for working with children</i>	<i>Other college education</i>
		<i>Employees with in-depth study module in toddlers pedagogy</i>	<i>Child care and youth work</i>
		<i>Kindergarten pedagogy, further education</i>	<i>Skilled worker training</i>
			<i>Other background</i>
			<i>Assistants/skilled worker with 15 credit points in child welfare related disciplines</i>
			<i>Exempt from education requirements</i>

The subsystem of teachers describes the teachers in Kindergartens. Information regarding Figure shows the subsystem for teachers

Teachers are described by background (b) and age (a) for a given time (t). Man years (M) of work is collected at an aggregate level.

Barnehagehagelærer utdanning system described the system for preschool education in Norway. Although this system is not formally studied in this thesis. It is described to show the interdependency of education system and the labour market. Further research should include this system to understand the supply side.

The following table gives details about the variables and parameters of the system

Variables	Symbol	Dimensions	Unit	Value	Literature source
Teacher in KG	T	t,a,b	Capita		
Theoretical ManYr Demand of teachers	M	t	ManYrs		
Corrected ManYr demand of teachers	Act_M	t	ManYrs		
Inflow of teachers	I	t,a	Capita		
Outflow of teachers	O	t,a,b	Capita		
Stock Change of Teachers	ΔT	t	Capita		
Paramters					
Age distribution	A	a	%		
Inflow Age distribution	ϵ	a	%		
Outflow rate	μ	a,b	%		
Demander Intensity	α	t	%		
Work Intensity of Teacher	β	t	%		
Correction factor	CF	t	-		
Background distribution	B	b	%		

Table 3 Parameters of Teachers Subsystem

System equations

The system consists of 6 variables calculated using the following mass balance and model approach equations.

Model approach equations

Corrected ManYr Demand (Act_M) is calculated as

$$Act_M_t = M_t \times CF_t$$

Total Number of Teachers is then calculated as

$$T_t = Act_M_t / \beta_t$$

Teachers are then formulated into a time background age model as

$$T_{tba} = T_t \times B_b \times A_a$$

Outflow is calculated using the outflow rate

$$O_{(t+1)ba} = T_{tba} \times \mu_{ba}$$

Inflow is divided into age categories using Inflow Age distribution

$$I_{ta} = I_t \times \epsilon_a$$

Mass balance equations

Mass balance consistency in the teachers is defined as

$$\Delta T_t = T_t - T_{t-1}$$

$$I_t = \Delta T_t + O_t$$

Also,

$$\sum_{a=24}^{74} I_{ta} = I_t$$

$$\sum_{a=24}^{74} O_{ta} = O_t$$

Parameters

The model consists of four parameters: Background Distribution (B), Age distribution (A), Attrition (μ) and Work intensity of teachers (β). These parameters are used in order to develop the teacher subsystem. These parameters are aggregated using different literature sources. Assumptions have made appropriately to use the data in development of the model. These assumptions along with the mathematical equations of calculations are shown subsequently.

Age distribution is the fraction of people in the successive age and sex categories in the total stock of teachers. This parameter is first calculated for the year 2015 using the data of stock by age as reported by LÆRERMOD. It serves as the initial condition for the development of the model. Although this data has been reported for the year 2013; it is assumed that the age distribution in the reference year 2015 is the same. Furthermore, LÆRERMOD reports this data for both genders, male and female. This

$$A_{am} = \frac{T_{am} + T_{af}}{\sum_{a=24}^{74} (T_{am} + T_{af})}$$

8

data is aggregated to derive the Teacher age distribution. Equation 7 shows the calculation of age distribution as shown.

Outflow rate is the proportion of reduction per year of workforce due to retirement, dropouts, sickness and death. This parameter remains the same for both sexes and is calculated as using the information presented in Gulbrandsen(). In this article Gulbrandsen reports the stock of employees in 2007 and their evolution in 2012 by age (). This information is also reported for both employees with and without relevant backgrounds separately.

If τ_{2007a} is the stock of teachers in 2007 by age and $\tau_{2007 \rightarrow 2012a}$ is the stock of teachers in 2012 who were present in 2007 by age as reported by Gulbrandsen. The outflow rate is calculated as

$$\mu_a = \frac{\tau_{2007a} - \tau_{(2007 \rightarrow 2012)a}}{5 \sum_a \tau_{2007a}}$$

Inflow Age distribution is used to categorize the Inflow into different age groups. Information regarding this parameter is obtained from Gulbrandsen. It gives the age at the end of the exam for preschool teachers after the exam year. It is assumed that the age of the employees during their recruitment is the same as when they are graduating. Figure shows the value of Inflow Age distribution by age. Highest percentage of people are shown to be a young audience of 24 years old. However, the parameter also shows that a fraction of people graduate while they are older.

Since the total number of teachers reported under both the sources report different numbers of total teachers, a background distribution is created that solves this discrepancy. Background distribution is the proportion of teachers from a given background in the teacher stock

$$B_{bt} = \frac{T_{bt}}{\sum_b T_{bt}}$$

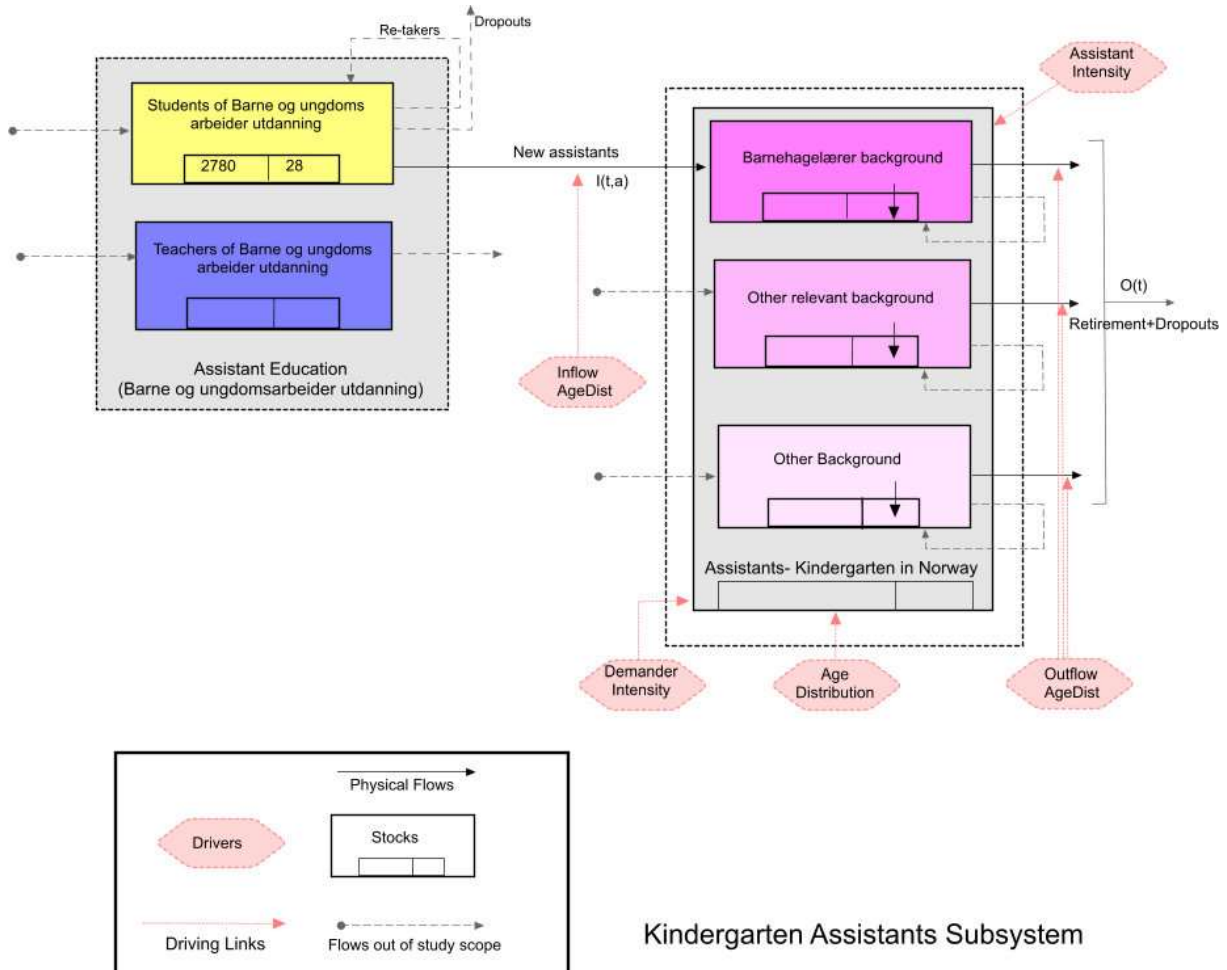
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Teacher Intensity describes the average work output of a teacher in relation to a Man year of work. This parameter is found to be increasing in time followed by a drastic decrease. The total work intensity depends on the number of teachers working part time and full time. A decrease in work intensity means that more teachers are working part time in kindergartens It is assumed that this parameter stabilizes at current levels and remains constant in the future.

$$\beta_t = \frac{Act_M_t}{T_t}$$

Subsystem: Assistants

The assistant subsystem follows a similar outlook as that of the teachers. Assistants are classified into 3 backgrounds, Barne og ungdoms arbeider background, Other relevant background and Other background similar to teachers.



Reported employee categories are reclassified as shown by the table

Classification categories	Barne og ungdomsarbeider background	Other Relevant Background	Other background
<i>Reported Categories</i>	<i>Barne og ungdoms arbeider utdanning</i>	<i>Pre-school teacher</i>	<i>Other college education</i>
		<i>Education that gives qualifications for working with children</i>	<i>Exempt from education requirements</i>
		<i>Relevant additional training</i>	<i>Other background</i>
		Employees with in-depth study module in toddlers pedagogy	
		Kindergarten pedagogy, further education	

The variables and parameters in the subsystem as listed by table

Variables	Symbol	Dimensions	Unit	Value	Literature source
Teacher in KG	A	t,a,b	Capita		
Theoretical ManYr Demand of assistants	$Asst.M$	t	ManYrs		
Corrected ManYr demand of teachers	$Asst.Act_M$	t	ManYrs		
Inflow of teachers	$Asst.I$	t,a	Capita		
Outflow of teachers	$Asst.O$	t,a,b	Capita		
Stock Change of Teachers	ΔA	t	Capita		
Paramters					
Age distribution	A	a	%		
Inflow Age distribution	ϵ	a	%		
Outflow rate	μ	a,b	%		
Demandor Intensity	α	t	%		
Work Intensity of assistants	β	t	%		

Correction factor	CF	t	-		
Background distribution	B	b	%		

System equations

The system consists of 6 variables calculated using the following mass balance and model approach equations.

Model approach equations

Theoretical ManYr M demand is calculated as shown in ___

Corrected ManYr Demand (Act_M) is calculated as

$$Act_M_t = M_t \times CF_t$$

Total Number of assistants is then calculated as

$$A_t = Act_M_t / \beta_t$$

Assistants are then formulated into a time background age model as

$$A_{tba} = A_t \times B_b \times A_a$$

Outflow is calculated using the outflow rate

$$Asst. O_{(t+1)ba} = A_{tba} \times \mu_{ba}$$

Inflow is divided into age categories using Inflow Age distribution

$$Asst. I_{ta} = Asst. I_t \times \epsilon_a$$

Assistants in the future are estimated as

$$A_{(t+1)ab} = A_{tab} - Asst. O_{(t+1)ba} + Asst. I_{(t+1)a}$$

Mass balance equations

Mass balance consistency in the teachers is defined as

$$\Delta A_t = A_t - A_{t-1}$$

$$I_t = \Delta A_t + O_t$$

Also,

$$\sum_{a=24}^{74} I_{ta} = I_t$$

$$\sum_{a=24}^{74} O_{ta} = O_t$$

Parameters

Information regarding assistants is relatively sparse in the literature. Parameters work intensity of assistants and background distribution are unique for assistants are unique for assistants but the parameters Age distribution, Inflow age distribution, outflow age distribution and demander intensity are assumed to be same as that of teachers

Background Distribution is defined similar to that of teachers as the proportion of teachers from a given background to that of the total teachers.

Appendix III – Scenario development

The training system developed henceforth consists of 4 stocks, 8 flows and 5 parameters. Summary of the stocks and parameters are presented in the following tables. Later model approach equations and mass balance equations are presented. The interdependence of this system with the teacher and assistant systems is shown subsequently

Variables	Symbol	Dimensions
Teachers in Training	$Teach_InTr$	t,a
Assistants in Training	$Asst_InTr$	t,a
Teachers for Assistant Training	$Teach_FTr_{(Asst)}$	t,a
Teachers for Teacher Training	$Teach_FTr_{(Teach)}$	t,a
Inflow of teachers in training	$T.Inflow_Tr$	t,a
Outflow of teachers in training	$T.Outflow_Tr$	t,a
Stock Change of Teachers in training	$\Delta Teach_InTr$	t
Inflow of assistants in training	$A.Inflow_Tr$	t,a
Outflow of assistants in training	$A.Outflow_Tr$	t,a
Stock Change of assistants in training	$\Delta Asst_InTr$	t
Inflow of teachers for Teacher Training	$FTr.Inflow_Tr_{(Teach)}$	t,a
Outflow of teachers for Teacher training	$FTr.Outflow_Tr_{(Teach)}$	t,a
Stock change of teachers for Teacher training	$\Delta Teach_FTr_{(Teach)}$	t,a
Inflow of teachers for Assistant Training	$FTr.Inflow_Tr_{(Asst)}$	t,a
Outflow of teachers for Assistant training	$FTr.Outflow_Tr_{(Asst)}$	t,a
Stock change of teachers for Assistant training	$\Delta Teach_FTr_{(Asst)}$	T

Parameters	Symbol	unit
Staffing requirement	ϵ	Teacher/student
Increase in number of seats per year	I	Capita/year
Duration of study	σ	Years
Initial number of seats	K	Capita
Study intensity	θ	%

System equations

Mass balance equations

$$\Delta Teach_InTr_t = Teach_InTr_t - Teach_InTr_{t-1}$$

$$\Delta Asst_InTr_t = Asst_InTr_t - Asst_InTr_{t-1}$$

$$\Delta Teach_FTr_{Teach_t} = Teach_FTr_{Teach_t} - Teach_FTr_{Teach_{t-1}}$$

$$\Delta Teach_FTr_{Asst_t} = Teach_FTr_{Asst_t} - Teach_FTr_{Asst_{t-1}}$$

$$A.Inflow_Tr_t = \Delta Teach_FTr_{Asst_t} + A.Outflow_Tr_{t-1}$$

$$T.Inflow_Tr_t = \Delta Teach_FTr_{Teach_t} + T.Outflow_Tr_{t-1}$$

$$FTr.Inflow_Tr_{Asst_t} = \Delta Teach_FTr_{Asst_t} + FTr.Outflow_Tr_{Asst_t}$$

$$FTr.Inflow_Tr_{Teach_t} = \Delta Teach_FTr_{Teach_t} + FTr.Outflow_Tr_{Teach_t}$$

Model approach equations

$$Teach_InTr_{2017} = K_{Teach}$$

$$Teach_InTr_{t+1} = Teach_InTr_t + I$$

$$Asst_InTr_{2017} = K_{Asst}$$

$$Asst_InTr_{t+1} = Asst_InTr_t + I$$

$$Teach_FTr_{Teach_t} = Teach_InTr_t \times \varepsilon$$

$$Teach_FTr_{Asst_t} = Asst_InTr_t \times \varepsilon$$

$$FTr.Outflow_Tr_{Teach_t} = FTr.Inflow_Tr_{Teach_t} + \sigma$$

$$FTr.Outflow_Tr_{Asst_t} = FTr.Inflow_Tr_{Asst_t} + \sigma$$

Model Constraints

The interdependence of the training system with the teacher training system with the teacher and assistant subsystems is modelled by introducing the following model constraints to the Teacher and Assistant subsystems

$$Asst. I_t = \Delta A_t + Asst. O_t + (\theta)A. Inflow_{Tr_t} - (1 + \theta) A. Outflow_{Tr_t}$$

$$Teach. I_t = \Delta T_t + Teach. O_t + (\theta)T. Inflow_{Tr_t} - (1 + \theta)T. Outflow_{Tr_t} + FTr. Inflow_{Tr_{Teach_t}} - FTr. Outflow_{Tr_{Teach_t}}$$

$$A_{(t)a(otherback)} = A_{(t-1)a(otherback)} - Asst. O_{(t)ab} - (\theta)A. Inflow_{Tr(t)}$$

$$A_{(t)a(BU)} = A_{(t-1)a(otherback)} - Asst. O_{(t)ab} + Asst. I_{(t)} + (1 + \theta)A. Outflow_{Tr(t)}$$

$$T_{ta(otherback)} = T_{ta(otherback)} - Teach. O_{(t+1)ab} - (\theta)T. Inflow_{Tr(t+1)}$$

$$T_{ta(BU)} = T_{(t-1)a(otherback)} - Teach. O_{(t)ab} + Teach. I_{(t)a} + (1 + \theta)T. Outflow_{Tr(t)a} + FTr. Inflow_{Tr_{Teach_{ta}}} - FTr. Outflow_{Tr_{Teach_{ta}}}$$

11.2 Scenario summary

Two forecasting scenarios and one backcasting scenario are developed for the analysis Table summarises the same.

Parameters	Symbol	unit	SC1	SC2
Staffing requirement	ε	Teacher/student	1/20	1/10
Increase	l	Capita	20	0
Duration of study assistants	σ	Years	2	3
Duration of study teachers	σ	Years	3	4
Initial Stock assistants	K	Capita	200	2000
Initial Stock teachers	K	capita	20	200
ECTS/course			180	180
Study intensity	θ	%	100%	50%

Thank you !