Combining Action Research and System Dynamics to facilitate change and improvement processes in healthcare

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ABSTRACT

Background

The healthcare sector is under considerable pressure for cost savings and to increase efficiency. Healthcare is complex with staff of multiple professions and a variety of patient care pathways. Time pressure and minimal margins for errors, as well as tension between the hierarchical structure and the power of the professions, can make it challenging to implement new policies or procedures. Action Research (AR) is frequently used to engage staff in change processes. Outside Sweden, System Dynamics (SD) is often used to model and simulate complex issues in healthcare. Group Model Building using SD has been established to engage staff in the modelling but requires learning of the basics of SD by the participants. To overcome this barrier, it is desirable to develop methods to use SD modelling integrated into AR projects, but little research has been published about this. The overall purpose of this thesis is to deepen the understanding of using SD, by itself or combined with AR, to support groups of healthcare professionals and researchers working with change and improvement processes.

Materials and methods

Two research projects and five improvement cases in healthcare were studied. The research projects used SD methodology to study disease characteristics and preventive effects by different interventions. Epidemiological data from disease-specific quality registers, scientific publications, and hospital systems were used. The cases were re-analysed in depth by a multidisciplinary work group (SD, AR, medical sciences) using iterative abductive qualitative methodology. A structure for studying consultative projects was used to identify

steps in the workflows of the cases. Socio-analytical questions were used to bridge between the AR and SD perspectives.

Results

The two research projects were epidemiological in nature and the simulations made it possible to study phenomena which were difficult to isolate and examine in reality. The projects resulted in models depicting disease trajectories which were used to test different scenarios and suggest relevant clinical interventions.

In the five improvement cases, AR contributed to high levels of engagement among the participants and to the building of confidence in and ownership of the results. AR also ensured that the SD models were adequate, relevant, and rooted in reality. SD provided a coherent and consistent systems overview of the complex and complicated structure of each improvement case, offered causal rigor, and provided ample opportunities for reality checks. During the cases, the two methods were deeply integrated and always present in experiential learning processes.

In both the research projects and the improvement cases, workflows and model development were adapted to each group. All cases went through divergent and convergent phases leading to shared points of reference, "project and case specific multiprofessional knowledge repositories". It was ensured that the voice of each participant was heard and that this inspired engagement, interaction, and exploratory mutual learning activities. The facilitator had an intermediary role, acting as an "interpreter" between the group and the simulation model, ensuring that the model elucidated the issues at hand. Mutually agreed solutions were tested *in silico.*

Conclusions

The two research projects demonstrated that SD is well-suited for policy planning of disease prevention in Swedish healthcare. The methodology is cost effective and allows simulations to be carried out *in silico* for testing without risk to patients or organisational efficiency. It also increases the understanding of systemic interdependencies between various patient-related and intervention-related factors for different diseases. Policymakers can for instance be assisted in choosing the intervention with greatest preventive impact by being presented with likely effects from expected or plausible scenarios.

The five improvement cases showed that integrating SD into AR for problems in healthcare can achieve useful, comprehensive, and robust outcomes. Results by this methodology will, by design, be calibrated to local needs and circumstances and is thereby likely to improve chances of sustained actualisation. The addition of simulations will increase certainty about expected results and speed up the problem-solving process.

Keywords: healthcare, improvement, change, implementation, action research, system dynamics, simulation

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SAMMANFATTNING PÅ SVENSKA.

Bakgrund

Det finns omfattande förväntningar på kostnadsbesparingar och förändringar för att öka effektiviteten inom hälso- och sjukvården. Sjukvården är komplex med personal från olika professioner och varierande vårdförlopp för patienter. Tidspress och minimala marginaler för fel, såväl som spänningar mellan den hierarkiska strukturen och professionernas makt kan skapa utmaningar när nya policys eller arbetsmetoder behöver implementeras. Aktionsforskning (AF) används ofta för att engagera medarbetare i förändringsprocesser. Utanför Sverige nyttjas systemdynamik (SD) för att modellera och simulera komplexa frågeställningar i hälso- och sjukvården. Gruppmodellering som bygger på SD har skapats för att engagera personal i modelleringsarbetet, men kräver att deltagarna lär sig SD:s grunder. För att komma över detta hinder är det önskvärt att utveckla metoder för att integrera SD-modellering med AR-projekt. Det övergripande syftet med denna avhandling är att fördjupa förståelsen av att använda SD i sig själv eller kombinerat med AF för att stödja hälso- och sjukvårdens professionella medarbetare och forskare i förändrings- och förbättringsprocesser.

Material och metod

Två forskningsprojekt och fem förbättringsfall inom hälso- och sjukvården har studerats. De två forskningsprojekten nyttjade SD-metodik för att studera sjukdomskarakteristika och olika interventioners förebyggande effekter. Epidemiologiska data från diagnosspecifika kvalitetsregister, vetenskapliga publikationer och sjukhussystem användes. Fallen re-analyserades av en multidisciplinär arbetsgrupp (SD, AF, medicinska vetenskaper) som tillämpade iterativ abduktiv och kvalitativ metodologi. En struktur för att analysera konsultativa projekt brukades för att studera arbetsflödena i fallen. Socio-analytiska frågor användes för att brygga mellan AF och SD perspektiven.

Resultat

Forskningsprojekten var av epidemiologisk karaktär och simuleringarna möjliggjorde att studera fenomen som är svåra att isolera och undersöka i verkligheten. Projekten resulterade i modeller som återgav sjukdomsförlopp som kunde användas för att testa olika scenarios och föreslå relevanta kliniska interventioner.

AF bidrog till högt engagemang bland deltagarna i förbättringsfallen och till att skapa tilltro och ägarskap av resultaten. AF säkrade också att SD-modellerna var adekvata, relevanta och förankrade i verkligheten. SD tillhandahöll en sammanhängande och konsistent systemöversikt över de komplexa och komplicerade strukturerna i varje förbättringsfall, och gav kausal stringens och erbjöd riktiga möjligheter att testa realismen i resultaten. I samtliga fall var de två metoderna tätt integrerade och på plats vid varje tillfälle i en erfarenhetsbaserad lärprocess.

I både forskningsprojekten och förbättringsfallen anpassades arbetsflödena och modellutvecklingen till varje grupp. Samtliga fall genomgick divergenta och konvergenta faser som ledde till gemensamma referensramar i form av projekt- och fallspecifika multiprofessionella kunskapsmängder. Det säkrades att varje deltagares röst hördes, inspirerade till engagemang, interaktion och gemensamma utforskande lärande handlingar. Facilitatorn hade en intermediär roll och agerade som ”översättare” mellan gruppen och simuleringsmodellen och säkrade därigenom att modellen klargjorde de aktuella frågeställningarna. Överenskomna lösningar testades *in silico*.

Slutsatser

De två forskningsprojekten visar att SD väl passar till planering av policys för förebyggande hälso- och sjukvård i Sverige. Metoden är kostnadseffektiv och möjliggör att testa simuleringar *in silico* utan oönskade effekter för patienter eller organisatorisk effektivitet. Den ökar också förståelsen för systemiska beroenden mellan olika patient- och interventionsorienterade faktorer för olika sjukdomar. De som svarar för att fastställa policys kan till exempel stödjas att välja den intervention som ger högst förebyggande effekt då de presenteras med de troliga effekterna av förväntade eller troliga scenarios.

De fem förbättringsfallen visade att integrering av SD in i AR, vad gäller frågeställningar i hälso- och sjukvården, kan leda till användbara, uttömmande och robusta utfall. Resultat av att använda denna metod kommer genom sin utformning att ha kalibrerats till lokala förhållanden och därigenom vara troliga att genomföras i verkligheten. Att tillföra simuleringar ökar tilltron till förväntade resultat och snabbar upp problemlösningsprocessen.

LIST OF PAPERS

This thesis is based on the following studies, referred to in the text by their Roman numerals.

I. Claeson M, Hallberg S, Holmström P, Wennberg Larkö A-M, Gonzalez H, Paoli J. **Modelling the Future: System Dynamics in the Cutaneous Malignant Melanoma Care Pathway**. *Acta Dermato-Venereologica.* 2016;96: 181-185.

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Lindberg J, Holmström P, Hallberg S, Björk-Eriksson T, Olsson C. **Simulating the Radiation Therapy Process: An Analytical Approach to Enable Quantification of Patient Inflows**. *Oral presentation at ASTRO 61/Int J Radiat Oncol Biol Phys, 2019*. 105(1), S117.

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CONTENTS

TERMS USED IN THIS THESIS

A **project** is a formal undertaking; it may be a project carried out solely in an organisation, a research project, or a project using external resources. A project is planned and has an aim, and a defined start and end. A project can contain processes.

In this thesis the word **process** is used with two meanings

1. A continuous or ongoing action (e.g., group process, learning process or thought process).
2. A systematic series of cycles, phases and/or steps directed to a desired outcome or purpose, each term used as below:
   - A process is an intervention in an organisation, which may in its turn be nested in a larger context such as a project.
   - A process may contain several similar and repetitive **cycles**.
   - A cycle may contain two or more distinct **phases**.
   - A phase may contain any number of **steps**.

1 INTRODUCTION

1.1 HEALTHCARE, THE PRESSURE, AND CHALLENGES FOR IMPROVEMENT AND CHANGE

There is significant pressure for cost savings and changes to increase efficiency in the healthcare sector[1]. The average health spending per capita, in the European Union (EU), increased by 2.7% (inflation-adjusted average per year) between 2015 and 2019[2]. Health spending per capita in the Organisation for Economic Co-operation and Development (OECD) countries is projected to grow at an average annual rate of 2.7% for 2015-2030. Rising incomes, demographic change, and technological progress are key drivers for increased health spending. Braithwaite et al claim that the healthcare sector underperforms and only has 60% reliability of delivery, as compared to standards[3], an issue also addressed in a US National Academies of Sciences report[4]. In addition, as the healthcare sector is labour-intensive and productivity growth is lower than in other sectors[5], it can be assumed that the pressure for change and the potential for improvement in the healthcare sector will remain high.

Workloads in healthcare are considerable. Patient flows are notably variable, which makes planning difficult and can lead to queues and a perception of even higher workloads[6]. The consequence is that even if there is pressure for change, there is often not enough time to fully explore new methods[7,8]. In a highly complex system such as healthcare, it is difficult to foresee the reverberations of specific changes in the larger system[9]. Patients pass through a complex network of different specialties and domains of work, where a number of different health professions work alongside each other[10]. Often there is more coordination between occupations than actual collaboration. However, any change of policies or procedures requires working together to define new routines and handovers. There can be a sense of having to abandon established clinical routines of the respective professions for new procedures that are perceived as uncertain. Many senior physicians have reduced engagement in development activities through experience of the significant inertia in healthcare and its difficulty to change[11-13]. The consequence of the both complex and complicated interactions between the different actors in healthcare is that there rarely are quick solutions to change and improvement processes in healthcare.

This thesis explores methods to address the pressure for change and improvements in healthcare given the complex environment. The introduction presents the key topics which are studied and addressed in the later sections. In paragraphs 1.2 ***Action Research*** (AR) and 1.3 ***System Dynamics*** (SD) are presented; two methods with different approaches to change and problem solving in disparate domains including healthcare. In paragraph 1.8, combinations of the two methods are put forward; the use of ***AR in SD processes*** (addressed in Group Model Building or GMB) and the gap in knowledge regarding the use of ***SD in AR processes*** (addressed in this thesis for the healthcare domain). The intermediate paragraphs 1.4-1.7 proffer aspects of identifying, testing, and implementing new or revised policies or procedures to actualize change with the support of these methods: the role of ***facilitation***, effects by ***group size and composition*** in group processes, and ***experiential learning*** from reality, models, and simulations as well as from interactions within a group.

1.2 ACTION RESEARCH AND ITS APPLICABILITY TO HEALTHCARE

AR is based on actively engaging participants, willing to share their own perspective on a problem, to collaborate with colleagues so as to find a mutually acceptable solution to that problem, and to pragmatically test how this solution actually works in practise[14,15]. Any AR project is specific to the work context of the participants, focuses on their perceived problems, and is oriented towards developing their workplace here and now. The term is usually attributed to the psychologist Kurt Lewin[16].

Analysis and actual change in an AR process is carried out in small successive steps in cycles of planning, acting, observing, and reflecting[16], bridging the gap between knowing and doing[17]. If the results obtained are not as expected for the problem at hand, the group typically asks, “what have we missed” and works through yet another cycle to find a more functional solution to try out. The process continues until a satisfactory result has been obtained. It is a method that is likely to produce insights about practical and functional local improvements, which cannot be found in any other way[18]. The collaborative effort by people directly involved in the daily work means that the step from discussion to actualization is short.

AR is situational and time-sensitive, that is, if the process is repeated it would neither be identical, nor would it produce identical results[19]. This means that a planned sequence of actions, even if it has been pilot tested, refined, and put into practice exactly as tested, will not necessarily lead to the realization of the intended changes[20].

A systematic review of AR studies in healthcare shows sustained effects in 54% of the reported cases[11], demonstrating that AR can contribute to change of policies or procedures. The aims of the projects studied in the review were predominantly to improve existing situations, to develop and implement innovations or interventions, or to evaluate project outcomes. The review identifies eight pivotal factors for sustained results in healthcare: participation, key persons, action researcher–participant relationship, real-world focus, resources, research methods, project process and management, and knowledge. Key persons were staff with relevant knowledge and skills and who could initiate or undertake change. The study noted that key persons cannot be assumed to approach AR without any prior agenda. It was also found that there were participants who limited the ability to collect data or curbed or blocked the actualization of change. The involvement of physicians was found to be important as, otherwise, groups tended to work on issues less relevant to the central problems to be addressed[21].

Rowbottom describes four stages of AR processes: (1) what is formally *expressed* as how things are intended to work, (2) how those involved *assume* that things work, (3) the discovery of what is *extant*, *i.e.* how things actually work, and (4) working out what is *requisite*, *i.e.* how things ought to be[22].

1.3 SYSTEM DYNAMICS AND ITS APPLICABILITY TO HEALTHCARE

Operations research (OR) encompasses many advanced analytical methods, such as problem structuring, modelling, simulation, and optimisation to find the best practical course of action for a given problem and support decision-making to that end[23]. OR and systems approaches can contribute to efficiency and quality improvement in healthcare at the levels of strategy development, policy design, and decision making[24,25]. OR is applied to healthcare in varying degrees across many countries.

SD may be considered a subset of OR[26,27]. It is applied in the study of complex, dynamic problems produced by non-linear feedback processes and is based on modelling, simulation, and analysis in cases where experimental strategies, policies, and decisions may fail or have unintended consequences, which in healthcare may expose employees or patients to risk[28]. SD allows such strategies, policies, and decisions to be effectively and safely tested *in silico*, prior to their actualization[29].

SD offers an aggregate and continuous approach, which is particularly useful when addressing complex problems, as well as strategic challenges, and when aiming for a coordinated design of policies that guides and governs operational decision making. Problems in need of integrated well-coordinated solutions typically arise in healthcare, such as disease epidemiology and trajectories, patient flows, manpower requirements, care capacity and planning, and inter-regional cooperation across organisational boundaries[30,31].

Mathematically, an SD model is a system of coupled, non-linear, first-order differential (or integral) equations. Circular dependencies are handled by partitioning simulated time into short discrete time steps across which an integration takes place. The symbol language and equations of SD simulations have three basic types of entities: flows, stocks that integrate their corresponding flows, and auxiliaries that contribute to the expressions of relationships between stocks and flows[32,33]. In healthcare, examples of flows are patients or disease trajectories, and examples of stocks are accumulations of patients in queues, staff work satisfaction or disease status.

An SD process starts by identifying the origin of the problems at hand and results in structural solutions aimed at changing the work or organisational dynamics in such a way that the original problem is alleviated or eliminated without producing unintended effects. There are typically four systems characteristics that govern the dynamic development of complex systems and that give rise to problems which SD can help to solve for healthcare organisations: (1) At the core of any dynamic system are accumulation processes that integrate any change over time into the state of the system. Such integrations unfold over time, *i.e.,* they consume time and are thus often considered the origin of delays (in healthcare commonly recognized as queues). (2) The structures of most dynamic systems are characterized by feedback; reinforcing feedback that contributes with divergent dynamics and balancing feedback that contributes with convergence. The dynamic development of a system is typically governed by such feedback loops, and, over time, there are commonly shifts in feedback loop governance that cause the dynamic development to change in nature (mode). If unrecognized, such feedback loops may cause the development of dynamic systems to change unexpectedly; often considered unintended consequences (*e.g.,* in healthcare, how delays in discharge to community care keep patients in wards, thus delaying admissions of new patients). (3) In complex systems, feedback loops are interacting non-linearly. The implication is that the impact of the dynamics caused by one feedback loop is conditioned by the impact of some other loop. The impacts synergize. If both these loops are subject to management, this implies that the management of one such loop needs to be coordinated with the management of the other loop; in order to obtain the most favourable synergy between the two (*e.g.,* in healthcare, the interaction between disease progression and treatment, on one hand, and patient logistics on the other). (4) Stochasticity with strong variation causing uncertainty (*e.g.,* in healthcare, the flow into emergency departments and obstetrics, as well as disease trajectories). In studies of healthcare systems, all four of these structural characteristics are found in abundance and cause the dynamics of such systems to pose major challenges to those involved. In SD modelling, simulation, and analysis these characteristics and their dynamic consequences are being explicitly addressed. As a result, SD is utilized extensively in strategy development, policy design, and decision making in the healthcare sector, predominantly in the UK, USA, Australia, and the Netherlands[28,31], but less so in Sweden.

SD-based modelling usually encompasses five major phases: (1) problem articulation, (2) expressing a dynamic hypothesis, (3) formulation of a simulation model, (4) model testing, and (5) policy design and evaluation[33]. Such a modelling process requires substantial expertise in the method and related techniques, as such, as well as in the use of associated software tools. In an expert-driven modelling process, members or groups from the target organisation are typically not directly involved in the building of the simulation model. Models may be developed iteratively by modelling experts working in close cooperation with domain experts. The typical purpose of such modelling is to form a basis for understanding the dynamics that have unfolded over time and often involves the investigation of the potential dynamic consequences of major systemic (structural) changes in strategies and policies that govern decision making. The SD process is initially divergent, aimed at defining problems and identifying key variables of relevance to the issue at hand and the causal interrelationships between these variables; relationships that altogether make up the systems structure. Then, the process converges into the formation of a consistent and rigorous simulation model of the identified systems structure upon which a formal analysis can be based.

For an SD model to be useful, it must represent the structure underlying the relevant (problem-specific) dynamic interactions of the reality, as well as the structure characterizing the alternative set of policies to assess the effectiveness of various strategies (combinations of policies)[34]. In general, models are being developed to understand specific aspects of the reality under investigation. A model can be defined as useful if it is appropriate for the situation at hand and if it has properties allowing for scaling down (size and complexity), transfer across (actual parts represented in their relative positions) and has workability (works in principle like the studied system)[35].

The accuracy of an SD model may increase with the number of flows, stocks, and variables as it approaches a complete representation of reality. However, a model of high granularity, *i.e.,* with many variables and relationships, may well be difficult to comprehend, making it less likely to be used in practise[36]. Also, larger models require more data that may be hard to obtain, particularly in healthcare[7]. Consequently, size (in terms of number of components) and usefulness need to be optimally balanced for a model to be useful in a real context (Figure 1). Given a certain model scope, the creation of a model with few variables may well require less effort and time and can be made available to decision makers in a shorter time than a more comprehensive model. It may also be just as (if not more) useful[37]. There is a risk in attempting to build "the ultimate model", one that either will be almost unachievable to populate with data or will take too long time to build. The scope and usefulness of a model, and the relationship between the two, is a matter of discussion with the end-users of the model, through successive iterations[38].

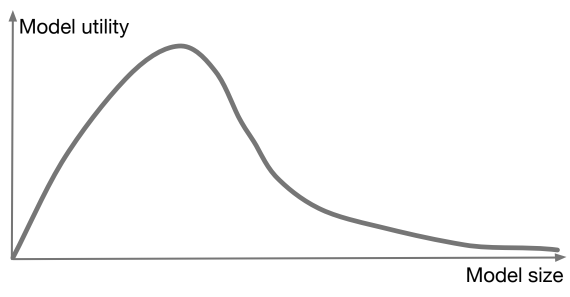

Figure 1 Model usefulness initially increases with the number of variables. However, after some point, usefulness decreases as the model become difficult to understand and overview (based on Lane[36]).

Modelling in healthcare faces specific challenges, such as capturing the high complexity as noted above (*cf* paragraph 1.1). Also, some data may not have been recorded, data may be held in different formats and in a variety of databases. There may also be abundance of some types of data, making it difficult to decide on the level of detail necessary for model building[7]. There is the risk of continuing with the available data and missing structurally important parts of the system where data is difficult or impossible to obtain.

1.4 FACILITATION AND THE ROLE OF THE FACILITATOR

Facilitation is concerned with supporting a group of people to work together, in ways better than when working by themselves. Schein's definition of process consultation is useful in understanding the basic approach to facilitation: "[Process consultation is] *a philosophy about and attitude towards the process of helping individuals, groups, organizations, and communities. It is based on the central assumption that one can only help a human system to help itself*[39]. Facilitators signal their willingness to help but does not take the client´s problem on their shoulders[40].The role of the facilitator is not prescriptive, but elucidatory[22], they ask questions and make comments with the aim of being helpful in structuring a client's thinking further. The process reveals information about what Schein describes as "what is really going on"[41]. Thus the structural causes of the problems experienced are uncovered, thereby enabling the client to take on a useful perspective when reviewing and analysing the information available[40]. Facilitators continually ask themselves, and sometimes the group, "what is needed here, what should we do next?"[42].

The facilitator stimulates exploratory activities, collects impressions and views to analyse existing situations and problems and even to proffer alternative re-interpretations of the available information[22]. Participants bring in different perspectives, at times very different personal understandings of their shared work situations, meaning that the process of the group can be defamiliarizing and turn personally "evident" things into puzzles[43].

Facilitators are usually transparent about what they are to do, but not necessarily explicit about the theory and practise of their work. The most skilful facilitators rely on preventions, making their work invisible or unnoticeable, so that participants appreciate their own work rather than that of the facilitator[44]. Experienced facilitators are aware of the fact that non-action is an intervention. Even silence, when the facilitator remains attentive affects how participants think and feel[45,46]. Facilitators need specialized, in depth training in communication, negotiation, group process design, and facilitation methods[47].

1.5 LEARNING FROM EXPERIENCE – IN REALITY AND FROM SIMULATIONS

Most learning that influences our actions takes place based on our direct observations and experience of reality. Experiential learning involves going through cycles of four steps: (1) concrete experience of doing something in reality, (2) reflective observation of that experience, (3) abstract conceptualization of other possible actions, and (4) active experimentation, testing the other possible actions, then repeating the cycle[48]. Figure 2 shows how cyclical learning can become an expanding spiral over time as gained experience results in increased knowledge. Each cycle builds on former cycles and comes to be part of the foundation for the next cycle. The process is an interaction and alignment between the individual mental models of the participants and the external formal simulation model[49].

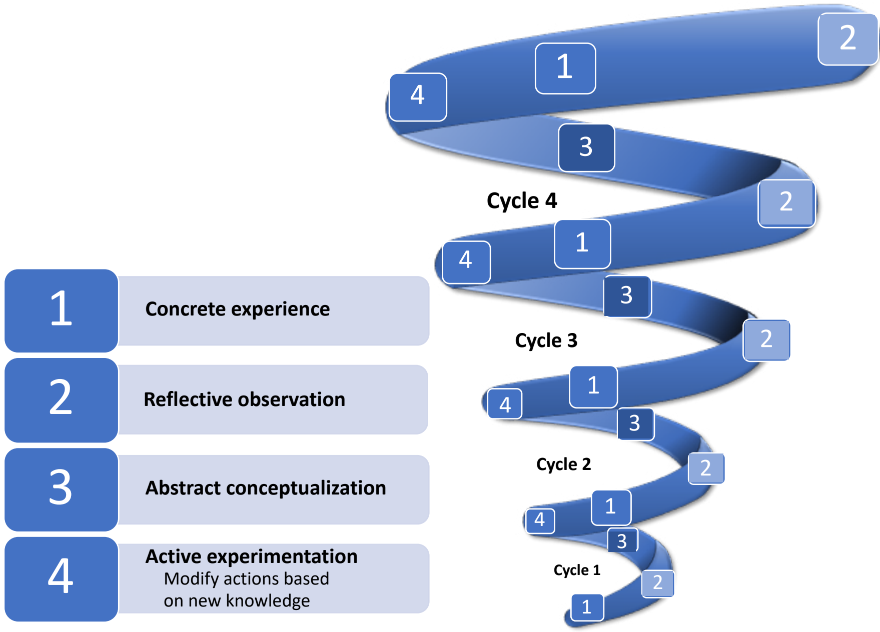

Figure 2 Concrete experience of the current reality is reflected on and leads to abstract conceptualisations, which are tested in reality by active experimentation. The cycle is repeated in a development spiral, where the body of knowledge and experience is expanded with each new cycle (adaptation of Kolb's cycle of experiential learning[48]).

Each individual has a continuously ongoing learning process. The work in a group becomes a shared learning spiral conflated with the individual learning spirals of the participants. When the group has completed its work, it has contributed to the extension of the experience and knowledge of each participant which influences their future actions. In AR, a group goes through complete cycles as described above with interactions between reflection in the group and learning from testing in reality.

When participating in the development of an SD model, participants bring their personal experience of reality, reflect on it, and contribute to the building of a simulation model that constitutes an abstract representation of that perceived reality. They then actively experiment with the model as a laboratory; thus, learning and gaining new experience from a surrogate of reality. It is a process that can help people clarify explicitly what they already know implicitly[36], as the model requires evidence and rigour to represent the system it intends to depict. SD models can be used to test specific solutions to a current problem in a simulated reality as well as to explore a diverse set of scenarios representing future problems that potentially may arise. Working through scenarios is a learning process by which participants become prepared to observe multiple indicators of change in their environment and to act accordingly[50]. The learning that results from going through a variety of scenarios may be more important than the outcome of a specific simulation and may prepare managers and employees to "make up their minds" about issues at hand[51].

Pre-built SD-models with graphical user interfaces, often called flight simulators or microworlds, can be used as learning environments, where users can test policy options. In such cases the modeller provides an interactive framework that captures participants' models and ideas[36]. Participants actively experiment with the model through the interface and gain concrete experience about how the model reflects their work situation. They consider the simulation results and then suggest and decide on variables and values to test in the next round of experimentation.

Most decisions that we take are subconscious and primed through recognition of patterns[52]. "Libraries" of such patterns are being built in through experiential learning. Experts are able to automate thought processes, allowing them to make use of large amounts of declarative and tacit knowledge in complex situations[53]. Professionals such as physicians and consultants generally go through rapid learning early in their careers during which they expand their experiential "library" by encountering large numbers of patients or client organisations, respectively. Airline pilots encounter rapid learning by engagement in simulator training. Role-playing, scenarios or simulations provide learning experiences in surrogates of reality[54]. An advantage of such learning experiences is that learners can be exposed to situations that occur infrequently in real life, may involve high risk, and/or are time-consuming or expensive to reproduce in reality.

Simulations are experiential exercises that may potentially develop peoples' understanding of complex situations[55]. Participants' problem-solving strategies improve as simulations can reveal dynamic relationships of variables whose values change over time and reflect causal processes, and demonstrate complex feedback mechanisms and the effect of time delays between observations, actions and responses[56,57]. The experimentation phase of simulations can be considered a form of gaming or role playing, which is often used as learning experiences. Participants encounter and understand problems that need to be addressed. The simulations highlight the value of interpretating what is going on and allows participants to experience the complexity of decision-making[58].

1.6 ACTUALIZING CHANGE

The literature about implementation of change in organisations is overwhelming, full of checklists, and claims of how to avoid failure. In reality, however, failure to implement changes arises frequently, a systematic review of implementation studies shows a range of failure rates from 7 to 90%[59]. The variation is ascribed to the lack of clear research protocols when estimating the failure rate. However, a study of over 60 implementation efforts of industrial or IT projects using a defined research protocol showed that despite detailed plans, implementations failed, were hampered by major delays, and/or resulted in significant cost overruns[60]. Considering the varied use and interpretations of research protocols, claims of low or high levels of successful implementation of change in healthcare are inconclusive, considering results from AR, GMB, or simulation models[7,61-64] and thus provide insufficient guidance.

Principles that have been proposed for the diffusion of innovations and new ideas, between and within organisations, and individuals, are well-described[65]. The lack of diffusion in healthcare has been given a variety of names such as mis-implementation, de-implementation, non-adoption, or de-adoption[66-68]. As most healthcare organisations continuously work close to their limit of capacity, there is little time available to identify strategies or principles for successful and sustainable change. When time is short, there is also resistance against abandoning what works[66]. Management-led top-down change efforts in healthcare, rolled out without staff engagement, can lead to cynical and dismissive attitudes to any new initiative making it even more difficult to achieve the changes required. Indeed, the word "implementation" has come to be used with scorn by many healthcare professionals[69]. A study of successful implementation efforts in healthcare found no generalizable patterns[20]. However, it was found that systematic approaches were used even as situations evolved. For success, there was a need for a local adaptation of general principles which consider the interaction of different local factors[63]. Each new context *e.g.,* department, practice, skills mix, hospital, region, or system, needed to be approached as a unique challenge[70]. It was more important to engage operational level personnel than senior managers, although the support of the latter was found essential[71]. It is interesting to note that implementation is seldom considered a problem in the AR literature. In AR, a group works with their own issues to find local solutions. Change is achieved as a natural part of the process and is not seen as something separate to "implement".

1.7 PUTTING TOGETHER EFFECTIVE GROUPS

Several professions and organisational units often need to collaborate and be involved when solving problems in healthcare[11]. Who to include in a project group can be a difficult decision. The main priority is to ensure that all stakeholders and knowledge domains are represented either in an actual work group or in a reference group. Managers, physicians, and senior nursing staff have usually been seen as key persons to include when solving problems in healthcare; other professions have often been excluded from the decision-making process[11]. A project group should consist of staff with knowledge and skills relevant to the project, and who can initiate or undertake change in practice[11]. They should also be interested and willing to engage and spend time on the project. Adizes proposes that Coalesced Authority, Power, and Influence (referred to as CAPI) needs to be in place in a work group and/or reference group, for efficient work, decision-making, and to lay the ground for actualization[72]. He defines *Authority* as the legal or formal right to take a decision, usually that of a manager. A person with *power* has a gate-keeper function, who can open or refuse further discussion or expected contribution, *i.e.,* has a stakeholder position to protect. People with *influence* have personal connections, which they can use politically to persuade. They can also be experts by having special knowledge that is convincing in itself.

Group size is a determinant of the quality of the discussion in the group. Steiner found that in groups larger than 8-10, either sub-groups emerge or communication patterns become polarized[73]. Both overly small or overly large groups can lead to gaps in knowledge and lost perspectives about the problem at hand. Table 1 shows that in larger groups more time is taken by few but more vocal people, while others become silent[74]. In a larger group there is a tendency that somebody takes a leadership position. Groups of five to six have been reported to be ideal in terms of group size[75]. When the group is too small, fewer perspectives would be represented in the group as such, and in a group that is too large there would be opinions that were not stated. It has also been shown that smaller groups lead to higher post-meeting engagement in actualizing decisions taken[76].

Table 1 Increased group size leads to skewed participation levels (adapted by Sjölund[74] based on Bales[75]). Participation was measured as the number of acts of talking in groups of people previously not known to each other, solving a task together.

Odd number of participants			**Even number of participants**		
Size	**Participation in %**		**Size**	**Participation in %**	
	Highest	**Lowest**		**Highest**	**Lowest**
3	47	25-35	**4**	35	20-30
5	55	10-25	**6**	43	10-25
7	55	10-20	**8**	40	5-20

Sjölund[74] proposes that six is the ideal group size as it considers a balance between the discussion and the possible number of held views. Sjölund also notes that spatial structures can affect discussions. People at the edges of a table may have difficulties joining the conversation, and passive persons seek such placements. People who are interested in being active and influencing place themselves centrally. Participants also tend to sit in clusters of like-minded. Spatial factors thus need to be considered, such as avoiding seating with sharp corners and matching the number of chairs with the number of participants[74].

1.8 COMBINING AR AND SD METHODOLOGIES

The combination of two or more methodological approaches is often referred to as mixed methods or multimethodology. The terms are often used interchangeably but are at times defined distinctly different. It has been claimed that combining methods forges new pathways and provides innovation by “de-disciplining in contrast to traditional academic disciplines that establishes borders[77]. Combined methods have also been reported to more likely produce a realistic representation of complex challenges that can face an organisation, which, in turn, can lead to better decisions[78]. Most complex problems are better approached using a combination of qualitative and quantitative methods[79]. Howick and Ackermann[80] describe three forms of combining methodologies: sequential, parallel, or interactive. They describe sequential as linearly moving from one method to another, where different methods support different stages in the process. Parallel indicates separate processes which may risk not informing each other throughout but are used for comparison and triangulation afterwards. They state that when something “new” was needed, an interactive approach would be used, where each method informs the other throughout the intervention. Howick and Ackermann[80] conclude that there is little discussion about the generic lessons from combining methods in practice.

The synergy of interactively combining two methods can be illustrated by the principle of figure-ground perception from Gestalt psychology. Both methods may be present all the time, but when examining the process, one method may be brought forward, while the other is in the background. The combination of the foreground and the background adds up to more or to something different, than each part by itself[81]. Rubin's Vase in Figure 3 is often used as an example of such a bi-stable illustration[82]. The foreground can be perceived as either a white vase or two black silhouettes, but neither figure exists without the other.

Figure 3 Rubin's vase, an example of a bi-stable illustration, where the foreground can be perceived as either a white vase or two black silhouettes facing each other[83]. In an approach where two methods are combined, one may be brought forward and discussed, while in fact it only appears in contrast to the method in the background.

AR and SD are both suitable for complex issues where root problems need to be uncovered and understood. AR is a method strongly embedded in the reality of the participants[14,15]. SD is a method where simulation models can be used for experimental and experiential purposes[24,25,28]. Both have iterative learning cycles, SD in interaction with a model under development and AR in interaction with changes in reality. Both have the intent of learning and influencing the mental models of the participants. Mental models are individual persons' constructs of their perception of their surrounding environment, which has explanatory value for them[49,84]. In a combined process, what participants learn through SD simulations can be applied and tested in reality in the AR project. Also, what participants learn in the real world can improve the virtual reality of the simulations[19]. AR ensures that the SD-work is adequate, relevant, and rooted in reality. SD ascertains that the AR-work is affirmed through a formalised simulation model. Any ensuing action recommendations, such as strategies, policies, or procedures, are built on an understanding of the relation between the structure characterising reality (mirrored in model structure) and its dynamic development (mirrored in model behaviour).

Scholl discusses the differences between integrating AR into an SD process and vice versa, with GMB an example of the former[19]. SD modellers hold an expert role, controlling the GMB in a rapid and technically optimal process. Participants need to learn the basics of SD modelling, the more well-trained they become, the better the outcomes. When integrating SD into an AR process, on the other hand, the iterative development of an SD model can, in theory, facilitate every phase of the AR cycle. The diagnostic phase can include a complete SD model iteration, leading to a formal model of the stated problem that guides the action planning. Learning from experimental insights leads to a reformulated model[19]. GMB has been extensively described in the literature (*cf.* paragraph 1.8.1). However, less is reported about lessons learned when integrating SD into AR.

Howick and Ackermann suggest that the choice of methods and how they are mixed may depend on those doing the combining and their familiarity with the methods[80]. Opportunities for blending methods can further be stimulated by working with different people, offering a variety of skills to the process. Ackermann and Howick also have noted a technical focus of many papers and have researched insights relating to the modelling teams[85]. They observe that using two methods makes it possible not only to play to each other's competencies but also to challenge each other's competencies. They also found that a common language, between modellers, is needed for effective integration.

1.8.1 INTEGRATING AR INTO SD – GROUP MODEL BUILDING

GMB has been developed to allow parties involved to actively participate in the conceptualisation and building of simulation models. The intention is to arrive at more useful models than those built by SD experts alone and to ensure engagement by participants and implementation of identified solutions. Initially the significance of effective group facilitation techniques in engaging participants and eliciting their knowledge was emphasized in GMB[86-88]. Papers containing references to GMB presented at the annual international conferences of the System Dynamics Society during the last 45 years first mention group modelling in 1985, with yearly increases from the early nineties up to topic maturity by 2010 (Figure 4).

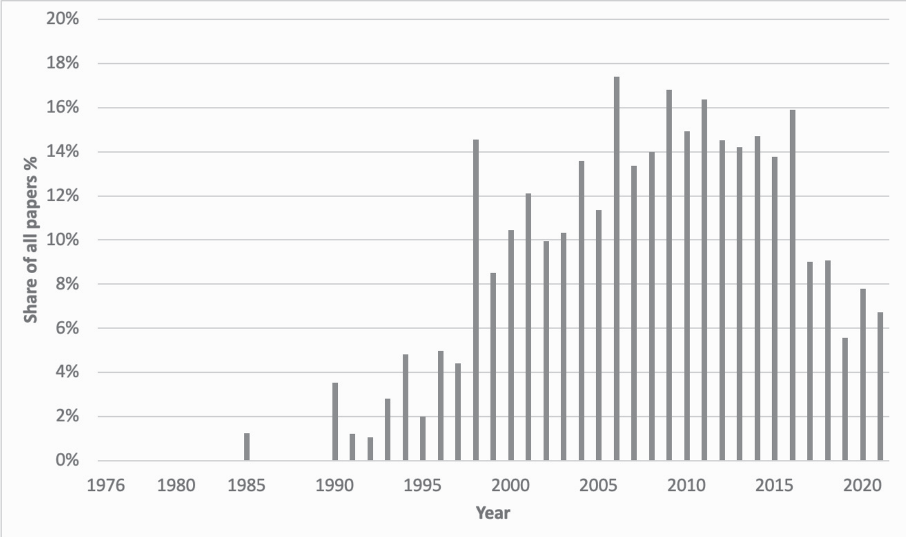

Figure 4 Share of SD-conference papers referring to group modelling. References were identified by searching the conference archives of the System Dynamics Society 1976-2021 (no conferences were held 1977-1980), using the truncated search term "group model". Only complete papers or abstracts were included. The search was conducted by Paul Holmström in April 2022.

GMB is often described as a form of stakeholder participation, where participants may hold conflicting positions or "stakes". Participants can have different perceptions of the problem or may not even be in agreement that there actually is a problem[89] An important aspect of GMB is, therefore, to align stakeholder positions by creating a shared systemic view of the issues at hand. GMB can be an effective tool for researchers from different disciplines when building new theory[90]. It has been shown that in a group employing GMB techniques, the mental models of participants are often enriched by that of the others and, at the same time, converge during the process[91].

Vennix[92] originally positioned GMB as an organisational intervention and a learning process which creates shared social reality and understanding of the problem at hand and its potential solutions. He described what can be seen as an AR process where the primary purpose is not to build an SD model, but to help participants to learn about a messy problem. In turn, this will allow them to develop strategies, design policies and make better decisions. Over time, GMB has shifted from explicitly having this goal towards requiring participants to learn the basics of model building and SD terminology. The more well-trained participants become in SD, the better the outcomes of the simulation work[19]. The work with the groups uses prepared sequenced steps in workshops, so called scripted GMB[93-95]. The scripts enable SD modellers less experienced in facilitation to lead workshops. There are suggestions of non-scripted events with the purpose of creating common ground prior to entering actual GMB. Willis *et al*[96] proposes horizon scanning to focus attention to future issues rather than current problems, as well as developing scenarios. Meinherz and Videira[97] suggest using focus groups to elicit information on the motivations and behavioural drivers of the participants.

1.8.2 THE UNRESEARCHED TERRITORY OF INTEGRATING SD INTO AR

Although it is often claimed that AR has been used together with SD, little is written about the actual work process and the effects of integrating SD into AR. When searching Scopus and the annual international conferences of the System Dynamics Society for relevant references on this topic, only six references surface (Figure 5). Of these, three address the process of integrating SD into AR in some detail, of which one is the appended Paper III of this thesis. The second is presented above and considers the potential of integrating AR into SD in theory (*cf.* paragraph 1.8, Scholl[19]). The third paper addresses an implementation case in healthcare and, while it concludes that the organisational benefits have been significant, it does not discuss characteristics of the combined AR/SD process as such[98]. In summary, little has been reported about the actual process of integrating SD into AR when facilitating change and improvement processes in healthcare.

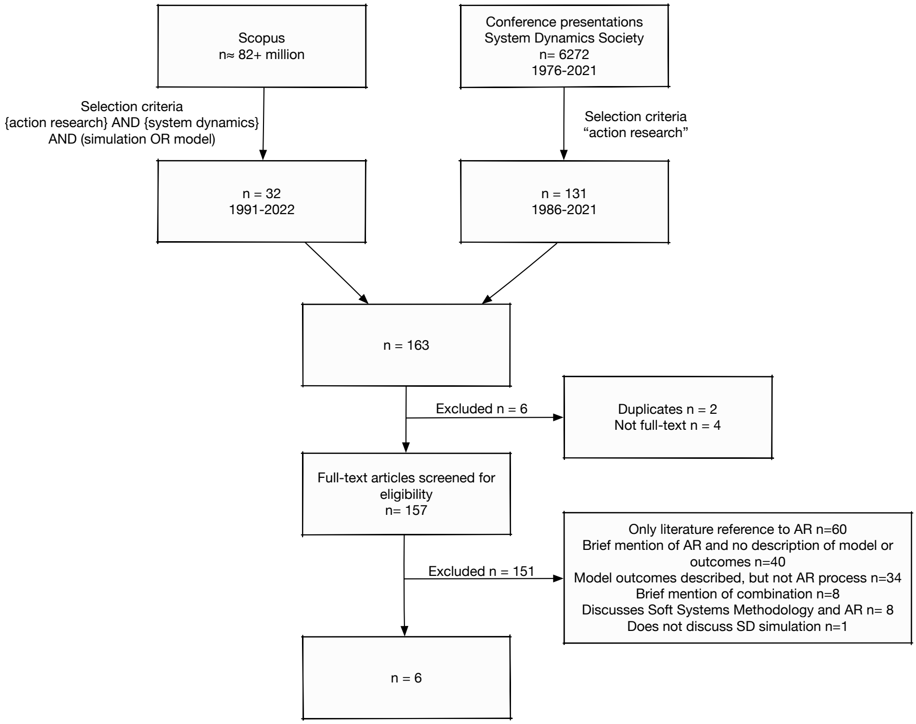

Figure 5 The selection procedure to identify scientific papers describing the process of integrating SD into AR. Two literature searches were conducted by Paul Holmström in April 2022. The first search was carried out in Scopus covering peer-reviewed journals. The second search was conducted using papers available from the annual international conferences of the System Dynamics Society. The search terms are included in the figure.

2 AIM

The overall purpose of this thesis was to deepen the understanding of using SD to support groups of healthcare professionals and researchers working with change and improvement processes.

The research aims were to:

1. Clarify benefits and limitations of using SD in research processes addressing policy planning of disease prevention in Swedish healthcare (Papers I-II).

2. Explore the interplay between SD and AR and identify methodological characteristics when using SD integrated into AR in change and improvement processes addressing work-related challenges in Swedish healthcare (Papers III-IV).

3 MATERIALS AND METHODS

3.1 MATERIALS – TWO RESEARCH PROJECTS AND FIVE IMPROVEMENT CASES IN HEALTHCARE

Papers I-II describe two research projects concerning disease prevention in healthcare. For both, SD methodology was used in a research process to identify effective measures. Five improvement cases concerning change processes in healthcare were studied in depth and are presented in Papers III-IV. The five cases were conducted by integrating SD into AR processes to suggest and study potentially actionable solutions to problems posed.

The timeline indicating when each case/project took place is shown in Figure 6.

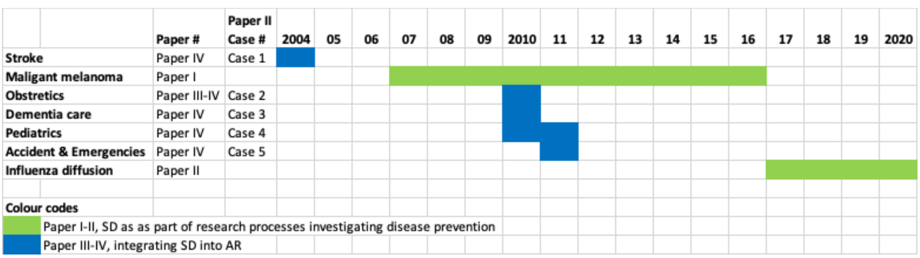

Figure 6 A timeline of the improvement cases and research projects investigated. Note that one of the cases, Obstetrics, was examined in both Papers III-IV. The other four cases were investigated in Paper IV only. Case numbering in this thesis refers to the numbering in Paper IV. The case re-analysed in Paper III will, therefore, be referred to as Case 2 unless specifically referring to results in Paper III.

Since a main focus of this thesis is the usability of SD in Swedish healthcare and general lessons learned when integrating SD into AR, but not the resulting SD models or project-specific results as such, the process perspectives of the five improvement cases are described in detail in the appended papers and their supporting materials (Paper III-IV). Descriptions of the resulting SD models and causal loop diagrams have been published elsewhere[99,100], as have model details for one of the research projects[101,102] (Paper I).

The core data in Paper I came from the Swedish Melanoma Registry. The data extraction was approved by the regional ethics board. Additional epidemiological data was obtained from scientific journals. In Paper II, the project used aggregates of patient data at a large university hospital as well as national level epidemiological data and data published in scientific journals. Neither this project, nor the abovementioned improvement cases, required any ethical approval as no clinical or personal data for patients or staff was used in any way.

3.1.1 THE TWO RESEARCH PROJECTS

The **melanoma project**, described in Paper I, had the overall research purpose to develop SD group modelling techniques for evidence-based learning and development across professional and actor boundaries in healthcare. This met a set of concerns defined by the head of the involved hospital department, regarding patient flows, increased incidence, revised care programs, and the effects of prevention and early diagnostics. The specific research aim addressed in Paper I was to use SD modelling to predict effects on the number of malignant melanoma cases in Western Sweden and to simulate future plausible scenarios in the malignant melanoma care pathway to decrease morbidity and mortality. The overall project resulted in several other papers and conference presentations addressing the stated questions of the department. It was financed by an external research fund (Vinnvård, http://www.vinnvard.se).

The melanoma project was carried out over six years, with in total about 60 meetings of the core research group and the reference group. The core group consisted of a specialist physician (also Ph.D. candidate) and two modellers. The extended group included three additional specialist physicians (also professors/associate professors).

The **influenza project**, described in Paper II, had the underlying research purpose to develop an SD model to illustrate the in-hospital transmission pattern of influenza at the Sahlgrenska University Hospital, a large regional and acute-care hospital in Sweden. The project was positioned in the difficulty and time required to do clinical trials, as influenza recurs in yearly cycles. The specific research aim addressed in Paper II was to use SD to predict the relative impact of modifiable factors and identify the most effective measures for preventing transmission of healthcare-associated influenza. Investigated factors were: 1. Number of patients exposed by sharing room with an infected patient. 2. Share of patients receiving antiviral treatment (patients coming from the Emergency Department or infected with influenza at the hospital). 3. Share of exposed patients receiving antiviral prophylaxis. This study developed an applicable system dynamic model to illustrate the in-hospital transmission pattern of influenza across an entire season. The project was financed by Region Västra Götaland research funds.

The influenza project extended over four years, during which ten meetings were held including three initial scoping meetings. The core group consisted of a specialist physician (also Ph.D. candidate) and one modeller. The extended group included two specialist physicians (also professors/associate professors), one additional associate professor as well as a second modeller.

3.1.2 THE FIVE IMPROVEMENT CASES

Cases 1 and 3-5 were parts of research projects with the objective to study the use of SD simulation modeling as a planning tool in early stages of the design of new health care facilities, integrating knowledge from the caring and the architectural sciences. Departments from three Swedish hospitals in the regions of Dalarna and Västra Götaland as well as the elderly care in a municipality in the county of Småland were engaged. Case 2 was one of several projects in a wider research program with the objectives to develop and test tools and work methods in Swedish healthcare, studying and breaking down barriers or reducing resistance to organisational innovation in large and complex organisations. The specific objective of Case 2 was to test the usability of System Dynamics at the Sahlgrenska University Hospital in that context.

Case 1 concerned a stroke ward, where there was a perceived need of additional patient beds and a wish to determine qualitative factors for improving patient survival and health status after completed medical treatment. This was a research project financed by an external research fund (Formas, https://formas.se) with the purpose of studying GMB and simulation as a planning tool for healthcare premises. **Case 2** was an obstetrics department, where staff and patients were dissatisfied with current scheduling practices. New work principles had been identified that could potentially solve the issues. However, there was strong uncertainty about how to apply those principles without worsening the situation. This case was part of a research project financed by another external research fund (European Regional Development Fund, https://interreg-oks.eu) with the intention of studying the use of SD in organisational development. **Cases 3-5** were part of another research project financed by Formas, with the intention of studying group-modelling in the predesign phase of new healthcare environments. **Case 3** was a dementia care home that was preparing a reorganisation to provide patient-centred care as well as planning for the adaptation of the premises to modern practices of dementia care. **Case 4** involved a paediatrics department where premises were too cramped in periods with high levels of infectious diseases. The current site was also expected to be insufficient due to the closure of a satellite unit and increased child population. **Case 5** concerned an accident and emergencies department with premises crowded by patient flow peaks several times per week to levels where staff perceived loss of full control and risks for patient safety. The department wanted to review work practices prior to rebuilding or planning for new premises.

Each of the five improvement cases was carried out within a time frame of 4-6 months with 4-5 group meetings and continued planning and modelling work in-between. All groups were composed of members from different professions in healthcare. Group sizes varied between six and twelve. Group members of each respective case shared the same workplace, apart from Case 1, where four of twelve participants came from an external department of facilities management and predominantly took part as observers. In all workplaces, patients were handed over from one profession to the next, a process that required coordination between staff members rather than collaboration, as the professions had different roles and accountabilities. All groups were led by a project leader from the respective overall research project/program, who was present and active at all meetings. Meetings in Cases 3-5 were also attended by a researcher in architecture.

3.2 METHODS

SD-models were designed exclusively for the studies described in Papers I-II. The two modelling processes followed similar progressions: 1. Methodological considerations. 2. Identifying key variables 3. Construction and validation of the model with local data. 4. Selecting the model scenarios of interest. 5. Producing the simulations. Papers I-II focus on the usefulness of the simulations from healthcare perspectives. Description of the model in Paper I has been published elsewhere[102]. Paper II includes information on the model and its development.

During the writing of this thesis, contemporaneous notes from the research projects were revisited to contrast the overall work processes behind Papers I-II with the work processes of the five improvement cases investigated in Papers III-IV as described below. Central descriptions relating to interactions between the medical researchers and the modellers are, therefore, reported and commented on when relevant.

The re-analyses in Papers III-IV were carried out by a multidisciplinary group, bringing in knowledge and expertise not only from SD and AR, but also from clinical sciences. Qualitative thematic approaches were used with the intention to arrive at consistent representations of the issues at hand. as suggested by Miles *et al*[103], analyses were iterated until descriptors of phenomena were found that satisfied all members of the multidisciplinary group. The systematic comparison of interpretations by each independent researcher also provided investigator triangulation intended to reduce any bias, as proposed by Flick, Fusch and others[104,105]. The analysis for each paper was carried out over 12-13 months and was done in three major parts. The first part organised, condensed, and refined the raw material to understand the overall features of the case/cases in question. As a second part, analysis of data identified details pertaining to case meetings or process steps as well as other case characteristics. In the third part, all discoveries were interpreted in an AR/SD framework to allow for the identification of key factors of the applied combined methodologies approach.

The workflow description in Paper III was based on descriptors for each meeting with the project group from a facilitator/modeller's perspective, with analysis and modelling carried out between meetings: (1) problem and objectives inventory, (2) factfinding, (3) problem visualization, (4) experimentation and (5) verification. In Paper IV, the meeting descriptors and work between meetings were deconstructed, bottom-up, into component parts, to reveal differences in sequencing, to include modelling work and to enable in-depth comparisons of workflows. The case flow for Case 2, which also is described in Paper III but in terms of meeting themes, came to include modelling work of the initial model, the user interface, and final model. The experimentation and verification steps were split into simulation experiments, action proposals, a workshop, and conclusions and action decisions. For the other four cases causal loop diagrams were added and, in three, case surveys.

3.2.1 QUALITATIVE ANALYSIS OF THE IMPROVEMENT CASE CHARACTERISTICS

The qualitative analysis to identify case characteristics was abductive, iteratively forming explanatory hypotheses and new ideas of how things might be, as suggested by Peirce[106], using displays according to methods proposed by Miles, Huberman, and Saldana[103]. The displays contained organised, condensed assemblies of information intended to allow analytic reflection. Each analysis began with a provisional adoption of an explanatory hypothesis to a specific question relating to some aspect of the case process. At each iteration, the analysis was first carried out individually, then the individual observations were compared and contrasted in the multidisciplinary group. Each iteration led to insights, redirections and revised hypotheses that initiated a subsequent re-analysis of the original data and to revised displays with clarified themes and reflections, as suggested by Dubois & Gadde[107]. Each redirection and new explanatory hypothesis required a revision of the analytical approach, thus providing method triangulation over time, to understand the phenomena in depth[104]. Throughout, the original documentation was consulted.

Paper III went through three major qualitative iterations, shown in Table 2. The initial hypothesis was to analyse the process as a series of plan-do-study-act (PDSA) cycles, which produced detail but insufficient understanding. In the second step participants voices were captured. This led to deducing the interaction between the professions and the coming together of shared knowledge. Finally, Rowbottom's questions provided a common language for describing how AR and SD came together.

Table 2 The three qualitative iterations of Paper III – provisional hypotheses, analyses, and insights by iteration.

Iter-ation		
1	**Provisional explanatory hypothesis**	If the process of the case can be described using interlocking PDSA cycles for the participant group and facilitator/modeller, then the AR-SD interaction can be understood.
	Analysis	Detailed PDSA-descriptions of meetings and intermediary work for the participant group and facilitator/modeller as well as model development.
	Conclusions	PDSA-descriptions did not contribute to understanding of the AR-SD interaction. A cogwheel metaphor was useful to describe the dynamic interactions between all staff, patients, managers, participants, and the facilitator/modeller.
2	**Provisional explanatory hypothesis**	If the voices of the participants can be captured, then understanding of the contribution of the respective professions to case progress will emerge.
	Analysis	Descriptions of voices of participants and facilitator/modeller, brief descriptions of meeting objectives, work, and outcomes. Naming themes of meetings.
	Conclusions	Voices were significant in understanding how the contributions by participants came together.
3	**Provisional explanatory hypothesis**	If Rowbottom's four questions can be described in both AR and SD perspectives, then this can provide understanding of the process of integrating SD into AR.
	Analysis	Extension of Rowbottom's original questions describing their interpretation in an SD perspective.
	Conclusions	Rowbottom's questions are useful in describing the interplay between AR and SD. This, the voices, the cogwheel dynamics, and the identified concept of a *multi-professional knowledge repository* came together in the understanding of the case.

Paper IV went through the four major qualitative iterations shown in Table 3. In the first iteration cases were mapped by meeting and found to differ so much that they needed to be reconstituted into component parts. In the second step each part was mapped on a general structure and differences in case flows noted. Thirdly, each case was analysed using Rowbottom's questions, adding insights as a fourth step. This led to concluding that there were two phases of divergent and convergent stages, which were analysed in the final iteration.

Table 3 The four qualitative iterations of Paper IV – provisional hypotheses, analyses, and insights by iteration.

Iter-ation		
1	**Provisional explanatory hypothesis**	A generalized case map and short case descriptions can provide the basis to understand the used work patterns and principles of the studied AR/SD combination.
	Analysis	Case maps, by meeting, but most meetings split into sub-parts. A generalized description was created building on the component parts.
	Conclusions	Cases did not follow the same workflow. Meetings needed to be deconstructed into constituent parts to allow comparison of cases.
2	**Provisional explanatory hypothesis**	Detailed mapping of case flows and case descriptions based on Rowbottom's questions can provide understanding of differences between cases and shared work patterns and principles.
	Analysis	(a) The flows of each case were mapped on a general structure using the labels as headers with the case descriptions amended accordingly. The step labels, case workflow mappings and case descriptions were revised to ensure consistency. As it was noted that all cases had similar beginnings and endings, the final case flow mappings were constructed to illustrate what was common and what was different between cases. (b) Descriptive answers to Rowbottom's questions.
	Conclusions	(a) Similarities and differences between case flows were important to understand how cases moved forward. (b) Rowbottom's questions should be extended with insights per phase.
3	**Provisional explanatory hypothesis**	Adding insights per Rowbottom question as well as objectives and outcomes per case will provide deeper understanding of work patterns and principles.
	Analysis	Rowbottom's questions extended with insights per phase. Objectives and outcomes per case described.
	Conclusions	Rowbottom's questions should form the basic structure for analysis and granular comparison of cases and include not only insight, but also objectives, outcomes, and model development.
4	**Provisional explanatory hypothesis**	There is a pattern of two divergent and convergent phases that can describe interactions between AR and SD.
	Analysis	Original case notes revisited and analysed. The table using Rowbottom's four questions amended accordingly.
	Conclusions	The pattern of divergent and convergent phases as well as the usefulness of the Rowbottom table confirmed.

To describe the interactions between the facilitator/modeller and the groups of participants, and the resulting learning processes of each, a cogwheel metaphor was introduced in Paper III. The initial illustration was developed to encompass the dynamics between patients, staff, management, the participants, and the facilitator/modeller. A causal loop diagram was also used to further understand the overall iterative process of interactions and model development. In addition, voices of participants were recalled from contemporaneous notes and recollections and were used to illustrate the different perspectives of the participating professions. As the additional cases in Paper IV had variations in group size and composition, this was also described. Principles by Sjölund were used to understand effects of group size and spatial arrangements[74] and principles by Adizes were used to study effects of group composition[72] (*cf.* paragraph 1.7). By extracting information from meeting plans and memoranda after meetings, an estimation of the share of time between facilitated group discussions and modelling work based on the workflow steps was also done in Paper IV.

To illustrate the development of each case from a the perspective of the target organisation, a modification of Kubr's five phases of management consulting[108] and James' five categories of consulting assignments[109] was used in Paper IV. Kubr describes the scope of consultancy assignments as consisting of entry, diagnosis, action planning, implementation, and termination. James takes a skills-based stance and classifies five different approaches of projects: statistical analysis, modelling of key variables, problem identification, implementation of solutions or to be a sounding board, and to select a consultant with matching skills. The cases were analysed in five stages including diagnosis of problems, analysis of facts, modelling of key variables, action planning, and implementation. Kubr's entry and termination were excluded as these were not a part of any of the studied improvement cases and James' sounding board was excluded for being a different type of consultancy work. In addition, the actualisation of case-specific solutions in reality was described using Brailsford's three levels of implementation of simulations[61]. These are categorized in *suggested* (theoretically proposed by the modellers), *conceptualised* (discussed with a target organisation), and *implemented* (actually used in practice). This helped to quantify the degree of actualisation and identify potential barriers to immediate implementation.

3.2.2 THE CASE FRAMEWORK TO BRIDGE BETWEEN AR AND SD

During the work with Paper III, Rowbottom's[22] four questions and descriptions were used as a framework for analysis to understand the empirical material. It was hypothesized that these questions could provide adequate answers to identify key factors of the investigated approach both from AR and SD perspectives. The four questions are: (1) What is *manifest*? (2) What is *assumed*? (3) What is *extant*? (4) What is *requisit*e? Applied to the studied improvement cases, answers to the first question typically related to the original concern or problem of how things were supposed to work. The second question was answered by participants expressing their perspectives and assumptions about how they believed things worked. The third by applying the answers to the first and second questions in such a way that the model reflected how things actually worked, after which the model should be requisite, *i.e.,* answering the fourth question by being appropriate for testing suggested solutions of how things could work.

In Paper III, each of the four questions were answered and interpreted in terms of their meaning in a general SD perspective and their meaning for the analysed case. The resulting table formed the basis for an in-depth analysis of the five studied improvement cases in Paper IV, and of how the different cases moved forward. In Paper III the initial objective and problem description and outcomes by meeting were analysed separately but were added to the framework in Paper IV as starting points for each case and as responses to each of Rowbottom's questions. Descriptions of the initial model, revised models and causal loop diagram, final model, degree of implementation, and barriers to implementation, were also added to provide a structure for comparing the cases and to understand how AR and SD was combined in the studied cases (Table 4).

Table 4 The extension of Rowbottom's questions from Paper III to Paper IV.

Extension of Rowbottom's four questions (Rowbottom's original questions in bold)	**Paper III**	**Paper IV**
Purpose		X
What is manifest? How is it supposed to work?	X	X
Problems and objectives inventory		X
Initial model		X
Insights		X
What is assumed? How do the participants believe it works?	X	X
Revised model/causal loop diagram		X
Insights		X
What is extant? How does it actually work?	X	X
Final model		X
Insights		X
What is requisite? How could it work?	X	X
Degree of implementation		X
Barriers to implementation		X

4 RESULTS

4.1 CHARACTERISTICS OF THE STUDIED RESEARCH PROJECTS AND IMPROVEMENT CASES

4.1.1 ADAPTIVE WORKFLOWS

The melanoma and influenza projects began with problem inventories and ended with experimentation. In the case of melanoma substantial time was needed to understand the medical issues and other details behind the research question. Factfinding, analysis, and initial modelling then followed two tracks (1) disease trajectories and intervention points and (2) patient flows and follow-up programmes after treatment. This required extensive analysis of both the data from the Melanoma Registry and the academic literature in order to meet the causal rigour required for an SD model. Two major models were built where multiple scenarios with combinations of patient's delay (time from disease to first physician visit) and doctor´s delay (time from first physician visit to treatment) were tested. The patient flow and follow-up model were validated by replicating historical outcomes. Scenarios with different incidence rates (primary preventions), scenarios from the disease trajectory model (secondary prevention) and follow-up programmes were tested. The influenza project was narrower in scope than the melanoma project. After several tentative meetings, an initial patient flow diagram was drawn and formed the basis to identify key variables, such as infectivity and points of transmission. The factfinding phase primarily resulted in data on actual patient numbers, viral load over time, and national infection data. The rigour of the model's causality identified key points of transmission that needed additional data that in turn led to model revisions. The key unknown in the model was actual infectivity, which was handled through a calibration factor to match actual hospital-acquired infections.

The improvement cases studied in Papers III-IV concerned work and organisational principles and began with extensive problems and objectives inventories and ended with experimental workshops where a multitude of solutions were tested *in silico*. Intermediary steps were differently sequenced between cases, with order depending on the facilitator's judgement of what best would move the process forward (Figure 7).

All groups worked through a diagnosis of problems (Figure 7, step 1). Extensive factfinding was carried out for all cases except Case 3, which was purely qualitative (Figure 7, step 5). Cases 1 and 5 had complicated patient flows that first were mapped in patient flow diagrams (Figure 7, step 6). Causal loop diagrams were created in all cases except Case 2, which was entirely quantitative (Figure 7, step 2). Model experimentation and action planning was done in all cases (Figure 7, steps 10-11). When the cases were terminated there were conceptualised proposals for how the participants could continue (Figure 7, step 12). In none of the cases had the facilitator/modeller been engaged to participate in the implementation. However, in Case 2, they were invited to take part in introducing the proposals to the entire staff and took part in the final evaluation of the implemented changes. In the perspective of the target organisations, differences between cases were primarily whether patient-flow diagrams (Figure 7, step 6) or qualitative causal loop diagram surveys (Figure 7, step 3) were used.

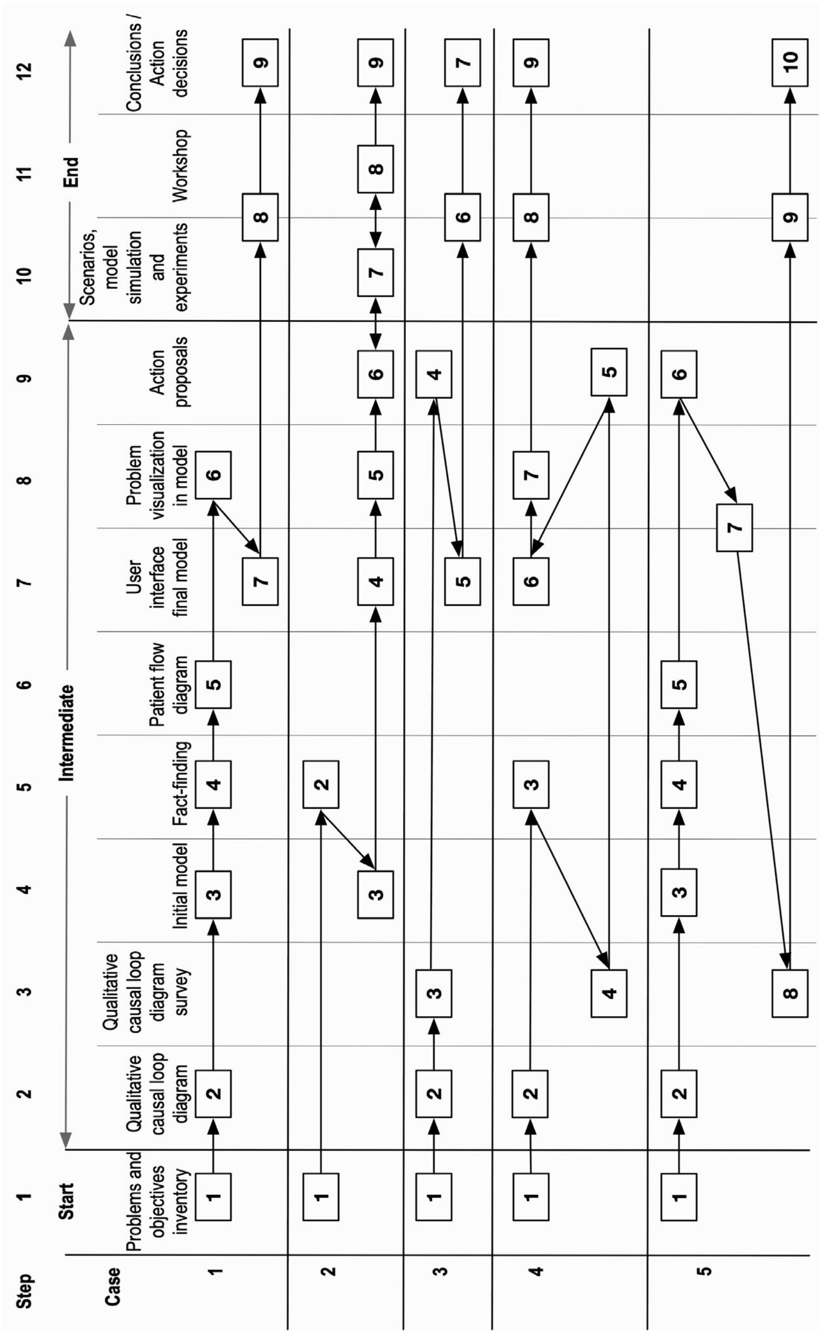

Figure 7 Chronological workflows by case. All improvement cases had similar starts and ends, with intermediary steps sequenced based on pragmatic judgements by the facilitator/modeller regarding how to best move each process forward.

4.1.2 MODEL DEVELOPMENT

4.1.2.1 MODEL BUILDING AND SCOPE

At the first meetings of the melanoma/influenza research projects and the improvement cases, basic simulation models were used to demonstrate the possibilities and dynamics of SD. The purpose was to show how SD can replicate the high variability in patient flows or any other commonly occurring phenomenon experienced in healthcare, thus creating acceptance of the method. In subsequent meetings, small models illustrating problems at hand were shown in order to stimulate discussion about what to include in the next iteration of a more detailed model and which data would be needed to achieve this. Actual model building was done between meetings. For the five improvement cases models were kept narrow in scope as available time to carry them out was short.

In the melanoma and influenza projects, actual modelling did not take place until research questions had been defined, patient flows and disease trajectories understood, and factfinding begun. The project models were extensive in scope and rigorously based on facts as intentions were to influence policy decisions and contribute to the research community by publication in peer-reviewed journals. The melanoma project had a wide research intent and was planned to be in-depth, explorative, and run over several years. Although the influenza project was narrower in scope it had a well-defined research question which could be thoroughly explored.

In the five improvement cases the purpose of the models was to support the groups to analyse and study both the problems at hand and their potential solutions.

4.1.2.2 LANGUAGE AND THE MODELLING PROCESS

The symbol language of SD was typically not introduced in detail to the participants in the early phases of neither the research projects nor the improvement cases. In the improvement cases where causal loop diagrams were built during meetings, participants' sticky notes from the problem inventory were used as basis, discussed one by one, placed for all to see, and connected to already addressed items with arrows indicating the direction of causality between items. When the diagrams had been completed, polarities indicating whether the variables changed in same or opposing directions were added. The formalized causal loop diagrams were created between meetings and then introduced to the respective group, discussed, and agreed on before continuing.

When the modeller expected the SD-diagramming of patient flows to become too extensive or difficult to comprehend for the participants, simplified patient flow diagrams were constructed as a foundation for considering flows and causalities that would need to be reflected in a future model. Such diagrams were constructed for both the melanoma and influenza projects as well as for two of the improvement cases. This allowed the participants and the modeller to establish common ground for the modelling work and ensured that the modeller had understood the key patient flows and interventions. The simulation models were structured congruent to the original patient flow diagrams. They were displayed side-by-side, described, and discussed so that participants and the modeller were in agreement before finalizing the SD model.

Once the model structure was in place, the focus moved towards building a graphical user interface that portrayed the required input and output variables in a format and terminology the participants would easily recognize as meeting the case objectives. In some cases, model-based experiments revealed missing data or structural components such as patient flows, leading to an additional development process until the participants were satisfied. When agreement had been reached that the model reflected the problem at hand, the model formed the basis for the identification and assessment of potential solutions. The models then became neutral, catalytic arenas for discussion, and promoted learning.

The graphical user interfaces enabled the participants to directly interact with the actual simulation model, to rapidly test major scenarios and different settings, including changing multiple variables and studying their interactions. At times, considerable time was spent on naming variables, reconciling their use in the involved healthcare contexts and the causal simulation logic. Interfaces contained output graphs of important variables, such as patient queues, waiting times for specific procedures as well as total time from admission to discharge of patients.

4.1.2.3 SPECIFICS OF THE RESEARCH PROJECTS

The melanoma and influenza projects were epidemiological in nature, whereas Cases 1 and 3-5 had a focus on patient flows and clinical capacity. The disease progressions of the patients were studied using adaptations of a generalized disease trajectory (Figure 8). In the first stage patients become at risk. For melanoma risk is through sun exposure while the risk for contracting influenza is by sharing a hospital room with other patients which may have influenza. Both risks can be prevented through primary prevention, in the case of melanoma by reduced sun exposure or in the case of influenza by being assigned single bedrooms or given prophylactics. In the second stage patients become afflicted and can then be subjected to secondary prevention, i.e., some form of treatment. For melanoma this includes early surgery and medication while only medication is given in the case of influenza. Melanoma may reach a stage where it is irreversible, and patients receive palliative care. Some patients who have acquired influenza at a hospital die of complications.

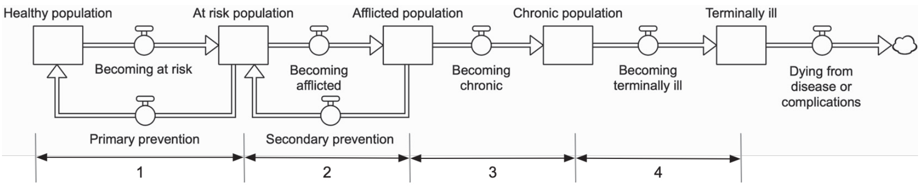

Figure 8 A generalized disease trajectory, from being healthy to becoming at risk, then afflicted, chronically ill and potentially terminally ill (adapted from Homer and Hirsch[30]).

Paper I studies the long-term effects of changes in incidence of malignant melanoma, population growth and preventive interventions. A key element in the model behind this paper is a "patient generator" based on the principles in Figure 8. It is a matrix with disease development, i.e., tumour growth, vertically and patient pathway in the health system horizontally[102]. The melanoma model allows the studying of effects through stages 2-4 in Figure 8 where tumour growth is independent of where the patient is in the health system; effects by primary prevention was not included.

Paper II studies hospital acquired influenza, i.e., patients with other diseases that were infected at the hospital. One set of patients arriving at the wards in question are at stage 2 in Figure 8 but may not yet be diagnosed with influenza. As wards are full during the influenza season, they may come to share rooms with patients at stage 1 of Figure 8. The model depicts patients at different stages of Figure 8 interacting with each other. Key to the development of the model was the patient flow diagram, which does not depict the logistical flow of patients, but the health status of all patients coming to the studied wards from the emergency department. The diagram identifies the points of influenza transmission to other patients, necessary for the actual SD-model. The addition of research data on the development of patients' viral load over time had a significant effect on simulation results and insights.

4.1.3 DIVERGENT AND CONVERGENT PHASES

Although all improvement case workflows in Papers III-IV could be structured linearly by theme or by step, each had a cyclical pattern with multiple feedback loops (Figure 9). Typically, the starting point of the cases was increased dissatisfaction among hospital staff regarding a problem (R1). Once a case was initiated, there were four feedback loops within a workflow. The first loop (B1) iteratively uncovered and described the problems at hand to understand how the different parts were interconnected, thereby creating the prerequisite to move forward. The second loop (B2), related to model improvement, was iterated until the model achieved "reference mode" i.e., replicated the problems at hand (B3). This was followed by experimentation until the group reached a set of solutions which they believed could contribute to the resolution of their problems (B4), in turn leading to increased job satisfaction (B5)

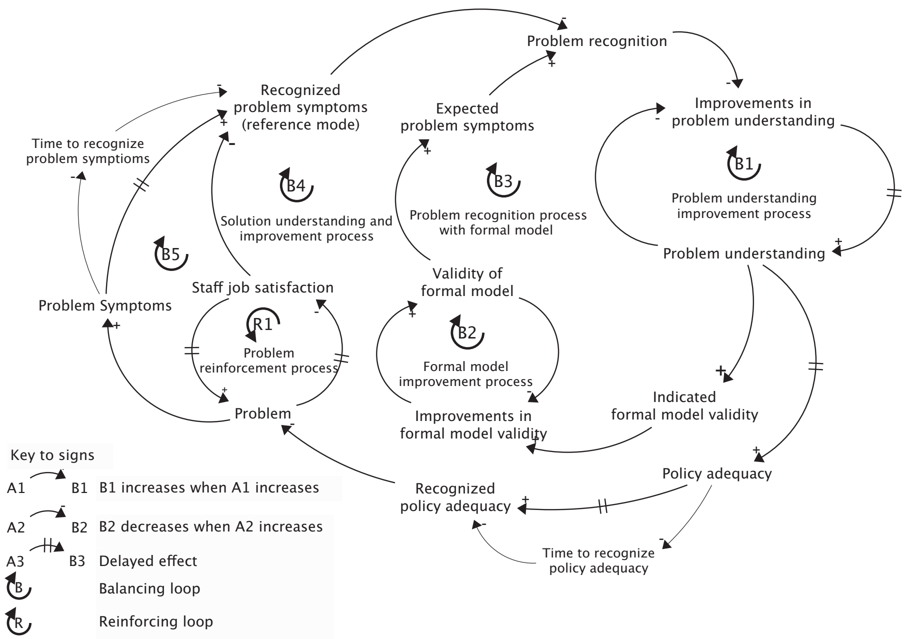

Figure 9 Prior to each of the studied improvement cases, there was a specific healthcare issue at hand typically reinforced over time (R1). The actual problems led to problem symptoms, which over time became recognized as such and typically affected staff job satisfaction. The group iteratively developed its problem understanding until it formed the base for the next phase (B1). The model went through several iterations until it had sufficient validity to replicate the expected problem symptoms (B2 and B3). It then formed the base for testing solutions (B4) and increased job satisfaction (B5).

Two key loops were identified in Paper III and further explored in Paper IV, in the context of an overall work pattern of divergent and convergent phases when integrating SD into AR (Figure 10). The first phase started with a brainstorming-like divergent phase listing all problems and issues (Loop B1 in the causal loop diagram of Figure 9). Problems were clustered, and in four of the five studied improvement cases, used to build causal loop diagrams, which showed how the issues were interconnected. This process led to a convergence of mutually agreed problems, guided by the causal rigour requirement of the SD model (*cf*. paragraph 4.3.1). Similarly, in the second phase suggestions for all possible solutions were brought forward in a divergent process and then tested using the simulation model finally converging on a set of solutions to potentially be tested in practise (Loop B4 in the causal loop diagram of Figure 9).

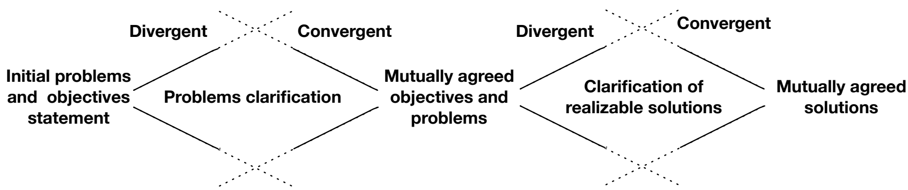

Figure 10 All studied improvement cases went through two major divergent and convergent phases. The first began with an initial problem statement, which was extended in a creative process ensuring that all issues were under discussion, then prioritised into a set of mutually agreed problems. The second phase began in creatively proposing a variety of solutions, which were tested in the simulation and converged into a set of mutually agreed solutions to potentially be implemented in reality.

For the melanoma and influenza projects, the loops B1, B2 and B3 (Figure 9) were iterated between model development and collection of data and previous medical research. Each such iteration included a divergent phase where insights led to the expansion of suggestions and hypotheses, followed by convergence on how to continue. Each iteration led to further understanding of the problems at hand, to changes in model structure and in turn to further insights about potential solutions.

4.1.4 THE MULTIPROFESSIONAL KNOWLEDGE REPOSITORY

In Paper III, the voices of the participants from different professions are described. The participants at no point acted as being stakeholders by protecting their own interests or by persuading others. Instead, they cooperated and strived to understand all perspectives and how those fitted with their own. In all improvement cases, the problem identification process and the model were used to uncover aspects that initially were unexpressed by the participants and unknown to some of them. This led to widened and deepened individual understanding and to shared points of reference for each group, referred to as *multiprofessional knowledge repositories* in Papers III and IV. Both the SD model and the AR process contributed to this in-depth and collective understanding of what went on in the system associated with the problem under study.

For the melanoma/influenza research projects of Papers I-II, *multiprofessional knowledge repositories* arose in the interaction between the clinical experiences and research domain knowledge of the physicians (and medical researchers) and the OR/SD knowledge and healthcare experiences of the modellers.

4.2 INSIGHTS FROM THE STUDIED RESEARCH PROJECTS

Papers I-II demonstrate the outcomes of research-based learning processes where project-specific SD models were used. In all phases of the research projects that were epidemiological in nature, additional OR analytics were used for the purpose of interpreting available data relevant to the phenomena under investigation. The analytics supported decisions on how to develop the SD models structurally and provided parameter values in the context of the epidemiological research questions posed.

In both the melanoma and influenza projects, the SD and research perspectives were intertwined. Table 5 compares the research phases to the phases of Kolb´s experiential learning cycles[48] (*cf.* Figure 2, paragraph 1.5). Both research projects resulted in scientific papers, published in peer reviewed journals, and conference presentations, contributing to the body of knowledge of both fields[100-102,110-113]. However, the learning outcomes from the projects did not lead to immediate action since acting on the results required policy decisions elsewhere in the organisations.

Table 5 The learning cycle in the melanoma and influenza projects

	Phases according to Kolb[48]	**Corresponding research phases**
1	Concrete experience.	Factfinding (clinical data, previous medical and SD research).
2	Reflective observation.	Reflective observation and discussion of the intersection between the medical and SD disciplines.
3	Abstract conceptualisation.	OR analytics of data and SD models resulting in analytical displays as described by Miles *et al*[103].
4	Active experimentation (modify actions based on new knowledge).	Active experimentation in models.

The simulations in Paper I allowed for the studying of phenomena associated with the melanoma disease that are difficult to isolate and examine in reality. If skin cancer is suspected, the tumour is excised as soon as possible to avoid local recurrence or metastasis. Therefore, there are no direct studies of tumour growth. One of the challenges with this project was, therefore, to find data that would enable estimations on tumour growth and to replicate that growth in a model, which one then could experiment with without risk to patient health outcomes. Collected data on general patient flows, risk of recurrent melanoma between follow-up screening, treatment costs, societal costs caused by morbidity or mortality, and referral quality were also used to develop another melanoma model presented at a conference of the Operational Research Society[101]. Other OR analytics were not sufficiently conclusive to be directly included in either model, *e.g.,* the effects of risk for metastasis or a new melanoma during follow-up programmes, as well as differences between regions in Sweden. The results from these analyses led, however, to the subsequent inclusion of risk levels during follow-up programmes in the abovementioned conference presentation. Altogether, there were two main results from the melanoma project. Paper I found that a reduction in patient´s delay had a more significant impact on patient health outcomes than focusing on reducing the already short doctor's delay. It was also found that if the incidence of malignant melanoma in the population of Region Västra Götaland in Sweden would continue to increase at the current rates, the present organisational capacity for treatment in the region would be highly insufficient[101].

The simulations in Paper II allowed for the study of phenomena associated with influenza that, similar to the phenomena for melanoma mentioned above, are difficult to investigate in reality. In the case of influenza, the wards involved are filled to full capacity during the influenza season. Patients cannot be assigned to single, double, or quadruple bed rooms, in randomised controlled clinical trials on the effects of various space-utilization policies on patient safety. The simulations allowed for testing the effects of stand-alone interventions, with everything else kept constant. Effects of seasonality and policies for room allocation, vaccination rates, timing of medication, and medication efficiency could be tested separately or in combinations, and recommendations issued. Paper II also reports on analytics relating to the influenza research project. Here, it was considered desirable to include a parameter representing leading indicators signalling a trend shift in the number of cases early on in the influenza season. This would have allowed for the study of early awareness as a potential intervention so as to increase precision in suspected cases. In the end, the main result from the influenza project was that patients with influenza should receive medication as soon as possible even without a laboratory confirmed diagnosis, as they are most contagious during the first days of their infection. In addition, such patients should be assigned to a single room if possible. Otherwise, patients who share the same room, should receive prophylactics.

4.3 INSIGHTS FROM THE STUDIED IMPROVEMENT CASES

4.3.1 STUDYING THE INTERACTION OF INTEGRATING SD INTO AR

Across the five improvement cases of Paper IV, there were key structures in the analysis based on the extension of Rowbottom's four questions (*cf.* Table 3 in Paper III, summarised in Table 6 below). In all cases, the starting points were based on issues or problems where work instructions did not lead to intended outcomes. All cases went through an AR-based inventory of problems and objectives. Initial factfinding was carried out and an initial SD model with narrow scope was built and/or a causal loop diagram was created based on the problem statements. This led to a first overview of the interconnectedness of the issues at hand. In several cases, the early model did not replicate reality as perceived by the participants prior to this phase. In the next phase, the participants brought in their assumptions in the form of their respective knowledge and experience about their work situation and what was missing in the models. The models were finalized and became extant as they replicated the realities perceived by the participants. In all improvement cases there were forms of aha-moments and strong recognition when the simulations pinpointed problematic situations and their causes. Once the root issues and causes were present in the model and the insights were shared and perceived as clear to all, the participants moved to suggesting solutions. Proposals could be tested *in silico*, discarding those that were deemed to have no or little effect, before finally arriving at requisite proposals of solutions. It was also concluded that Rowbottom's four questions provided a theoretical framework that was effective in describing the AR and SD perspectives and their combination.

Table 6 Patterns in the improvement cases demonstrating the interaction between AR and SD, using Rowbottom's questions as an analytical framework.

Extension of Rowbottom's AR questions	**General patterns**
What is manifest? How is it supposed to work?	In all improvement cases there was a mismatch between manifest intentions and actual work practices or resources. In Cases 1, 4, and 5 the available beds or rooms were insufficient as patients overflowed to other wards (Case 1) or the over-filled waiting rooms caused risk for patient health outcomes (Case 4 and 5). In Case 2 patients and staff were highly dissatisfied with patient waiting times when arriving for scheduled appointments. In Case 3 there was dissatisfaction with out-dated work practices.
Problems and objectives inventory	In all improvement cases a facilitated AR-process extensively listed problems and issues in a divergent phase.
Initial model	The model for Case 1 showed that significant patient inflows other than the intended primary flow had not been discussed or included. The model for Case 2 highlighted a significant mismatch between required patient flows and staff scheduling by weekday, the realisation of which became an aha-moment for the group. The models for Cases 4 and 5 showed sufficient basic functionality for further development. For Cases 1 and 3-5 causal loop diagrams were developed with the groups.
Insights	In all improvement cases insights converged into how problems and factors were interconnected and affected each other and to an understanding that single factors could not be handled in isolation.
What is assumed? How do the participants believe it works?	In all improvement cases participants from the different professions contributed divergent additional facts that incrementally converged to a fuller model.
Revised model / causal loop diagram	In all improvement cases the models and causal loop diagrams were amended until all participants were satisfied that they had converged to a satisfactory whole.
Insights	How all perspectives fitted together, contributing to a multi-professional knowledge repository.

Extension of Rowbottom's AR questions	General patterns
What is extant? How does it actually work?	Participants of all improvement cases were satisfied with the outcome of the integrated process as their knowledge and experience were acknowledged and used. Their current realities and perspectives were converged, consolidating the multiprofessional knowledge repository with the model.
Final model	In all improvement cases the model was complete with a graphical user interface including all identified potential inputs and graphs with key variables. In all cases the participants suggested multiple potential solutions that were tested.
Insights	In all improvement cases there were forms of aha-moments, consolidating the multiprofessional knowledge repositories. For example, in Case 1 when it was clear that additional beds were not needed if the inflow of other patients could be stemmed. In Case 2 when simulations showed how staff scheduling and patients' desired arrival times could be matched. In Case 3 when the interconnectedness of factors became clear, and participants could use that knowledge to a greater effect. In Cases 4 and 5 the realisation that the simulation model could replicate overcrowding in periods of high patient flows, enabling the participants to test coping solutions.
What is requisite? How could it work?	Case 2 and 3 had clear sets of solutions to move forward with. Case 2 immediately moved forward to implementation. Case 3 used the results to plan reorganisation of work. Cases 1, 4, and 5 found mechanisms to cope in the short term. Case 1 needed to involve the hospital management to reduce the inflow of other patients by adding beds elsewhere. Cases 4 and 5 needed new or extended premises and initiated the investment process required for that.

4.3.2 THE FACILITATING PERSPECTIVE

When integrating SD into AR, the resulting combined approach contained key principles of both AR and SD but also excluded some elements (Figure 11). A "pure" AR process often has a high focus on reflexivity, group development, and iterative testing of actions in reality[114]. A "pure" SD process has a focus on building a fully formed and rigorous model with a strong emphasis on feedback loops and non-linear interaction effects and the complex dynamics that result from them[115]. In the five improvement cases elements from both AR and SD were pragmatically combined to move the group processes forward in short time. Table 7 lists the key elements from each method that were included. Table 8 lists elements that were excluded from the investigated AR/SD combinations as their contribution to final results were deemed to be low.

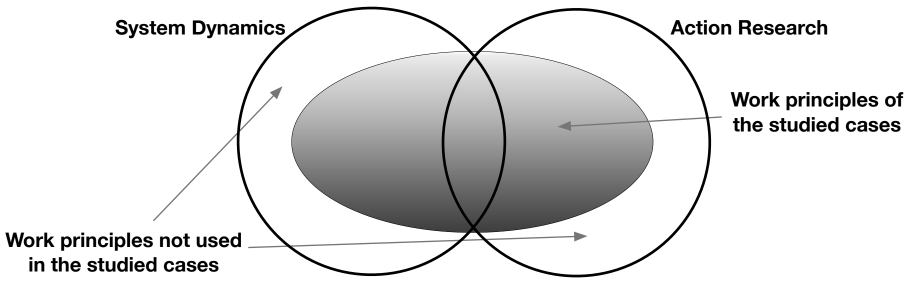

Figure 11 The work principles in the studied improvement cases used significant elements from both AR and SD, but also excluded elements from AR and SD, respectively.

Table 7 Included elements from SD and AR in the investigated AR/SD combination.

Included elements from SD	Included elements from AR
Balance between model size and its utility for the group. Causal rigour. Formulation of dynamic hypothesis (reference mode, replicating history and present). Iterative formulation of a simulation model. Problem articulation. Systems overview of the studied system. Testing.	Development of final proposal. Exploratory/ diagnostic/ factfinding phase. Evaluation/ reflection phase. Group facilitation. Iterative cycles of testing proposed solutions. Meaning and purpose for participants. Planning/ decision/ action phase. Practical reasoning. Reflections at beginning and end of meetings. Re-planning and re-implementation of action. Situated in the reality of participants. The group owns its issues.

Table 8 Excluded elements from SD and AR in the investigated AR/SD combination.

Excluded elements from SD	Excluded elements from AR
Complete model documentation. Rigorous "complete" model with minimum of exogenous variables.	Critical personal reflection on process, data, and learning. Reflexivity on the work of the group and personal feedback. Taking action in reality during the project itself.

AR and SD were combined throughout the entire processes, although this was not made explicit to the participants. Early in each improvement case, the focus was on a group process that contributed to the uncovering of problems and to the development of a shared view on the current situation. However, already during the initial steps, the outline of a model was considered by the modeller; including decisions on which variables to incorporate and what data was needed and available to populate a model. As an overall work principle, the process moved from mainly AR methodology to incorporating more and more SD elements, ending in what could be described as mainly SD work. As each improvement case progressed, the model and simulations became explicit and took more of the meeting time. During the experimental phase and final workshop, the participants were fully absorbed by the model and simulations, but the ongoing group process was still considered central and the focus of facilitation in line with AR principles.

It was found that problem awareness and understanding with respect to model development and its contributions progressed over the course of the identified project phases. Neither the participants nor the facilitator/modeller had complete understanding of the problem in the beginning, but they built understanding together. It was a mutual learning process for participants as well as for the facilitator/modeller.

In all the improvement cases, participants' understanding of SD was relatively low, however, they understood sufficiently to view the simulation results as credible and useful. The development of problem awareness is shown in Table 9, which is a generalization built on specific findings in Paper III and patterns seen in Paper IV, Table 1.

Table 9 A generalization of the development of problem awareness and understanding by project phase for the studied improvement cases.

Project phase	Participants	Facilitator/modeller
Problem and objectives inventory	High awareness of problems, but unaware of some key issues. Little understanding of systemic interconnectedness. Sensed that SD could contribute to problem resolution but no understanding of SD methodology.	Asking questions to develop problem understanding. Beginning to see which facts are required for a model and a basic patient flow. Forming hypothesises about the stated problems in context and systems perspective.
Factfinding	Increased awareness of the problem and related interconnections.	Additional key problems identified, analysed, and illustrated. Patient flow diagram drawn to confirm structure to be used for model.
Problem visualization	High problem awareness and some understanding of interconnections. Beginning to see potential of SD simulation model use, but no real understanding of SD techniques.	Basic model developed to illustrate perceived key problems and interconnectedness between issues at hand. Clear conceptualization of requirements for the next iteration of the model.
Experimentation	Passed a barrier through insights of problems, potential solutions, and their interconnectedness. High understanding of contribution from simulation model. Posing relevant questions to the model and asking for further details. Understanding the model principles without knowledge of SD methodology.	High understanding of problems as expressed by participants and uncovered by the simulations, in order to fine-tune the next version of the model.
Final workshop	Very high understanding of problems and solutions, high understanding of simulation model contribution.	Very high sense of model contribution to the problem solving of the group.

4.3.3 THE INFLUENCE OF GROUP SIZE, COMPOSITION AND SPATIAL FACTORS ON GROUP DYNAMICS

Cases 2-5, which were close to Sjölund's ideal group size of 6 participants[74] had high levels of engagement and moved rapidly forward through the process. The groups in Case 4 and 5 were slightly larger, but this had no observable effect on participation levels between individuals. Cases 2-5 also had CAPI (*cf*. paragraph 1.7, Adizes[72]). As managers and physicians were present at meetings and could immediately support the direction that the conversations were taking, the groups could rapidly move on. Seating arrangements were such that participants could converse naturally. Group size, spatial factors and group composition for the investigated cases are shown in Table 10. The group in Case 1 was large and had less active participants. The group did not have CAPI since the manager only attended the first meeting and the medically responsible physician never took part. Spatial arrangements in this case were also such that there was substantial distance between many participants. The interaction of group size, non-direct participants, and spatial arrangements led to a skew in communication between participants, *i.e.,* some participants were more active than others. Discussions tended to be less between participants themselves and more between the project leader or the facilitator/modeller and the participants. When it was determined that the initial problem definition was incorrect, the group was left without managerial support in how to proceed, as the manager of the department and the chief physician were not present.

Table 10 Group size, spatial factors, and group composition by case.

Case	Group size	# not directly involved	Spatial factors	CAPI*
1	12 (meeting 1) 11 (subsequent meetings)	5	Tables and chairs in U-shape, with substantial distance between participants in a very spacious room. Breakouts by clustering round the tables.	No
2	7	0	Initial meeting with tables and chairs in compact U-shape. Subsequent meetings around a table in small room with sufficient space. No breakouts.	Yes
3	5	0	Comfortable chairs closely placed around low table in an otherwise spacious dayroom. Breakouts by moving chairs.	Yes
4	8	0	Tight placing around a table. Little space to move in a small room. Breakouts to nearby rooms.	Yes
5	9	1	Seating around a large table. Sufficiently large room with ample space. Breakouts to nearby rooms.	Yes

*Coalesced Authority, Power, and Influence

Keep the same structure when describing each case. 1. Structure of seating; 2. Spacious or cramped room; 3. Empty chairs or not; 4. Breakouts or not.

5 DISCUSSION

5.1 INTRODUCING THE MAIN THEMES

The overall purpose of this thesis is to deepen the understanding of using SD to support groups of healthcare professionals and researchers working with change and improvement processes.

Papers I-II focus on two research projects which were epidemiological in nature with the purpose of clarifying the benefits of using SD in healthcare research. Both followed processes with cycles containing factfinding, reflective observation and discussion, analytics and SD model development, and active experimentation. In each cycle, medical research and facts influenced the SD model and the ensuing model in turn informed the continued learning process of the participants. Thus, the SD model and medical perspectives became intertwined throughout each project. The interaction between researchers, their respective domain knowledge as well as the use of methods from both medicine and SD/OR contributed to the understanding of the underlying data and research from new angles. In both projects, SD contributed by being able to isolate and test different influencing factors that otherwise would have been ethically impossible or too time consuming to examine in reality.

Papers III-IV explore the interplay between SD and AR and identify methodological characteristics when integrating SD into AR. The ***processes*** of the five improvement cases were found to be based on an underlying AR approach which actively interacted with the building and use of the SD simulation models, each method informing and influencing the other throughout the processes. SD contributed to the AR process by providing a neutral catalytic arena, accelerated by testing of suggestions *in silico* instead of in reality, and by adding precision as data in the model provided evidence to the AR process. Every step in the processes was pragmatically adapted to the needs of the group in question and its current assessment of the issues at hand.

The identified ***work patterns*** of the studied processes in Papers III-IV are primarily related to the group learning perspectives of integrating SD into AR. The findings from Paper IV show that the improvement case workflows consisted of two major phases where the participants were encouraged to non-competitively bring their individual perspectives into a systemic description of the problem and solution at hand.

The first phase accepted that problem awareness could be incomplete and thus produced ***divergent*** and exhaustive lists of all relevant problems as described by participants. Next, through facilitation, these were typically ***converged*** into causal loop diagrams to illustrate how the problems were interconnected. In the second phase, ***divergent*** potential solutions were extensively listed and tested in the simulation model helping the group to ***converge*** on solutions considered favourable. This approach resulted over time in a ***multiprofessional knowledge repository*** where the role taken by the participants was extended from stakeholders to “shapeholders”.

The ***work principles*** identified in Papers III-IV uncover the facilitating and modelling perspectives of the studied integration of SD into AR. Significant ***facilitation*** and modelling expertise was found to be present in all situations. The facilitator/modeller acted as a “translator” between the group and the model and vice versa, leading to a time efficient overall process. Initially a minimum viable ***model*** was built to illustrate a key phenomenon, or part of the problem described by the group. This engaged the group in providing direction for the next iteration of the model. Throughout the process, problem awareness increased, and the problem definition evolved. This resulted in solving a more fundamental problem compared to the initially stated problem in the final model for many of the improvement cases.

Paper IV introduced a schematic of various degrees of AR and SD in a mix of methods applied to the modelling and analysis of complex, dynamic problems (Paper IV, Figure 1). Figure 12 acknowledges the continuum between AR and SD, positioning Papers III-IV to the left (integrating SD into AR) and Papers I-II to the right (pure SD).

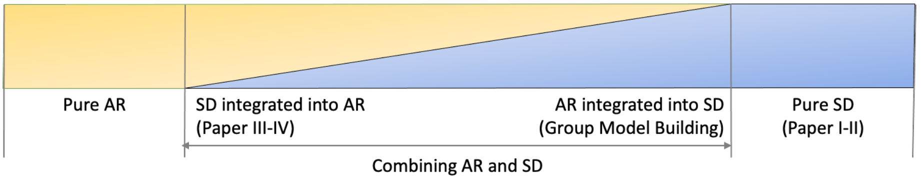

Figure 12 A continuum of possible ways to combine AR and SD.

5.2 AR AND SD IN RESEARCH PROCESSES

Retrospectively reflecting on the research-driven processes of Papers I-II where SD was used as a tool for analysis, these followed another logic compared to Papers III-IV. Although there are similarities between when SD is integrated into AR to solve mainly organisational healthcare problems and when SD is used to solve medical research questions arising from existing empirical evidence, they both contain learning cycles where simulations add to the growing understanding about the issue at hand. In Papers I-II, researchers were engaged over a longer period of time (years) whilst in papers III-IV, groups of healthcare professionals were engaged during a shorter period of time (months).

Papers included in systematic reviews of the use of SD in healthcare include simulations in clinical as well as research contexts[31,116]. The reviewed papers tend to focus on final outcomes, not describing the overall process of combining methods or how SD contributed to the research process as such. Papers I-II found benefits from using SD for policy planning of disease prevention in Swedish healthcare from the perspectives of the medical community. A key value demonstrated in Papers I and II is how SD simulations contributed to the research process by isolating and studying specific treatment alternatives and their interactions. These aspects would otherwise have been difficult to identify without resorting to randomised controlled clinical trials, which would have been ethically implausible for the cancer patients and time consuming for the influenza patients.

For the two research projects, OR-based analysis and model development was particularly useful for the information gathering cycle as relevant previous research from both the medical and SD perspectives were studied and reflected on in a closely intertwined process. This is in line with Heinze's findings that a variety of disciplinary backgrounds has a positive influence on creativity in scientific research[117]. Papers I-II specifically highlight how SD added to the medical perspectives with a different approach to understand the underlying data and introduced opportunities to interpret the problem and its solutions from new angles.

5.3 INTEGRATING SD INTO AR

Scholl[19] discusses the respective merits of AR, SD, and joint applications of both. He makes a distinction between GMB as AR which is used in an SD process and the potential of integrating SD into AR. The processes of pure SD[33], GMB[88,118], and pure AR[119] are well described in the literature, as well as their applications to problems in healthcare[11,28,31,116,120]. There is, however, little knowledge about why, when, and how SD is combined with any method[121]. In addition, there appears to be little discussion about generic lessons from mixing methods in practice[80].

The main characteristics of the above-mentioned approaches are presented in Table 11 to contrast the studied integration of SD into AR with the three other methods. As AR usually is conducted incrementally in repetitive cycles with each cycle identifying potential change, actualizing the change, and evaluating it in practise, the entire process may consume considerable time[11]. On the other hand, the merits of AR are that working with local issues creates engagement among the participants which creates a willingness to actualize identified solutions[120]. SD can compress the process by the testing of potential solutions *in silico*. However, if the model is built by an SD expert without the involvement of participants from the studied organisation there is a risk that the model does not answer the actual problems[122] and may not necessarily lead to implementation of suggested change in reality[86]. The insertion of AR into SD (GMB) attempts to address this by eliciting the domain knowledge of the participants[92]. However, GMB requires spending time teaching participants the basics of SD modelling and can make participants shift focus from the actual problem to model building[19].

As noted in the introduction regarding the principle of figure-ground perception from Gestalt psychology (*cf.* paragraph 1.8), in the studied cases both AR and SD were present all the time and interacted in inseparable ways. Both perspectives were examined as if separate from the background of the other method, as well as if inseparable and interactive. However, either AR or SD were typically more explicit depending on the time point in the process. When integrating SD into AR, as found in Papers III-IV, core principles of AR were used and SD was added to create useful evidence for the participants, systems overviews, and understanding of healthcare problems, organisational as well as clinical, without engaging participants in actual model building, as in GMB. The incremental small changes carried out in AR processes has the potential of managing risk[11], which is critical for patient safety in healthcare. In the studied processes of all papers included in this thesis, the testing of solutions in reality, as in AR[119], was replaced by the testing of solutions *in silico*, as in SD[19]. This led to considerable time savings and risk reductions since favourable alternatives could be selected and less functional solutions disregarded. As specifically found in Papers I and II, SD also allowed for rapid testing of scenarios as well as multiple changes of parameters and their interactions. This allowed for the possibility of identifying comprehensive rather than incremental change, another aspect that also saves time. When SD was integrated into AR, the domain knowledge of the participants was elicited, but they did not have to spend time learning the basics of SD. They could keep their own language and vocabulary and could thereby focus on contributing with their expertise to the processes. In all papers of this thesis, the model building was done outside the group by the facilitator/modeller, but the model structure was verified together with the group for them to also take ownership of produced results, as in AR.

Table 11 Comparing the main characteristics of pure AR, integrating SD into AR, GMB and pure SD.

Pure AR	**SD integrated into AR (Papers III-IV)**	**AR integrated into SD (GMB)**	**Pure SD (Papers I-II)**
Groups facilitated to work with their own issues and problems, in incremental cycles. Divergent phase suggesting solutions. Convergent phase selecting actions to test. Testing actions in reality. Evaluation. Repeat the cycle above.	Groups facilitated to work with their own issues and problems. Divergent phase identifying problems to be addressed. Convergent phase where group facilitated to build causal loop diagram of issues. SD expert introduces minimum viable model to illustrate key issue(s). Iterative model development aligning to local needs. Divergent phase suggesting many possible solutions. Convergent phase testing actions in model and selecting which to try in reality. Group continues work to actualize change.	Group supported by SD expert to learn SD and to build a model. Divergent phase regarding which elements to include in the model. Iterative model development. Convergent phase consolidating model and establishing solutions. Handover to target organisation(s) for action.	SD expert modelling. If group involved, then as reference. Divergent phase regarding which elements to include in the model, determining model boundaries. Complete model built or iterative model development aligning to local needs. Convergent phase consolidating model and establishing solutions. Handover to target organisation for action.

5.4 WORK PATTERNS

5.4.1 UNCOVERING THE PROBLEM AND THE SOLUTION

A key finding in Paper IV is that when integrating SD into AR, the studied processes differed between the improvement cases (Figure 7). All processes began with problem inventories, then took different pathways, but all ended in workshops of similar character where solutions were tested *in silico*. The processes were emergent, as in AR, which supports groups to discover and follow their needs[119] rather than primarily focused on building an SD model as in scripted GMB[95]. Paper IV also found the divergent phases of the processes purposively exhaustive, so that all participants were satisfied that enough time had been spent to capture everything they felt a need to share enabling them to go forward. This avoided premature closure about the actual problem, where sub-optimal outcomes or low acceptance otherwise could have been the result, a phenomenon also noted by Basadur *et al.* who advocates that the divergent phase needs to be exhaustive to counteract converging too early[123]. If a facilitator focuses on the problem that the group initially believe they have, as may be a risk both in GMB and in pure SD, the underlying problem may never be uncovered, and the end product can be a solution that solves the "wrong" problem.

Papers III-IV identified effects of insight when the individual understandings of the participants took significant qualitative jumps, from particulars to a coherent whole. The incorporation of new information challenged and transformed current mental models[124]. This can be illustrated as in the left of Figure 13, where "reality" is projected as shadows on the inside of a box. Each shadow represents how a participant has perceived and constructed a mental model of their perception of "reality", before the change process begins. This perception and the associated mental model results from the point of view taken by each participant. Thus, the diversity of perspectives and the resulting mental models may explain the challenges of organisational change, described effectively by the term radical constructivism by Watzlawick[84] and others. They emphasize, that such challenges must be met with a reconciliation of the various mental models held by the participants and by the realization that they all are reflections of the same reality. It is when the individual mental models are being consolidated into a common understanding of that reality that an alignment across the participants can take place, allowing the organisational change process to move forward in a direction defined by that alignment. The shadows can be counted and described by their geometrical similarity, but whatever is causing the shadows cannot be reconstructed by "adding up" the individual projections, as shown to the right in Figure 13. The group process needs to uncover how different perspectives may be shadows of the same. The simulation model becomes the instrument in this process as it will not produce acceptable results until it has assimilated all perspectives. Papers III-IV found that the overall process of integrating SD into AR assisted the participants in taking distinct qualitative jumps in thought and in shared insights. Each participant could agree that the systemic overview that emerged was complete and included their personal and professional perspectives. At times, the process also resulted in uncovering a blank space, which also contributed to a more consistent and coherent comprehension of the problem at hand and its potential solution. Once the collective, coherent, and consistent whole had been seen, it could not be unseen, leading to a change in the conversation, a reshaping of the participants' mental models and often also a redirection of the continued process. Striving for the aha-moment of coherent systemic insight is key when working with groups from multiple professions in healthcare to find solutions to their work-related challenges.

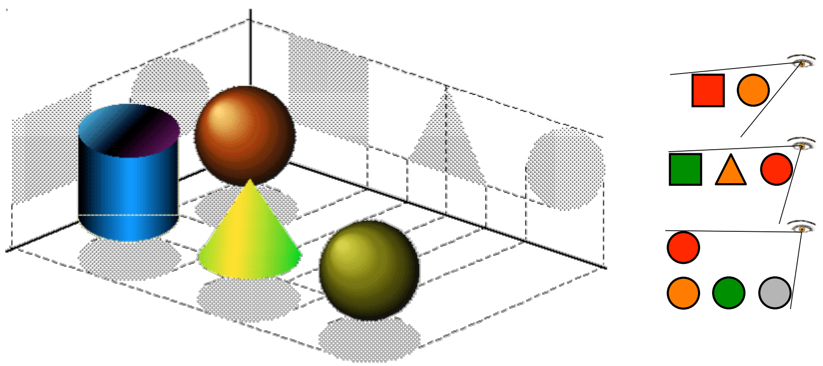

Figure 13 (Left) Shadows of what? What participants perceive as a problem, or a solution may be mere grey shadows of the actual colourful reality. (Right) The individual perspectives shown as shadows in figure to the left cannot simply be added up and said to be the "reality". An SD model will not work until how all perceptions that result from each of these perspectives fit together are uncovered.

5.4.2 THE MULTIPROFESSIONAL KNOWLEDGE REPOSITORY

Papers III-IV found that *multiprofessional knowledge repositories* evolved during the course of the studied cases. Both AR and GMB are often described as "stakeholder participation" processes[15,88]. Stakeholders have a "stake" in the strategic direction and the actions of the organisation to which they belong, particularly when their personal aspirations are impacted[125]. "Stakeholders" is translated into Swedish as "intressenter", which can be translated back to English as "interested parties". The semantic difference between holding a stake or sharing a mutual interest can be significant and influences how a project is approached. In the healthcare context, there is also an added dimension, defined by the hierarchy of the professions, that influences how the statements of different professionals are perceived and adopted[11].

Papers III-IV found that integrating SD into AR provided a neutral learning ground. Participants became more like interested parties, intent on uncovering additional dimensions of the problem at hand, contributing to the SD model and potential solutions. They were not potentially adversarial stakeholders. By way of their participation, the domain-specific knowledge of the individual participants evolved to become a coherent and consistent representation of reality upon which a consolidated strategy development, policy design, and decision making could take place. The processes encouraged participants from different professions to discover how their particular aspect of work corresponded to or conflicted with those of others. Instead of seeing those sets of perceived realities as stakeholder positions to be argued for or against, participants challenged their case-specific SD model as an integrated part of the process and shaped it collectively until it represented the shared experience and knowledge of the group. This is in line with the acting of shapeholders as described by Kennedy[126]. Consequently, the resulting SD model and its associated documentation contributed to the creation of a *multiprofessional knowledge repository* representing a shared understanding of the reality, experienced and observed by the stakeholders. Gergen *et al* describe similar situations where groups create a joint understanding, also termed "a shared social construction"[127].

5.5 WORK PRINCIPLES

5.5.1 THE ROLE OF THE FACILITATOR

The facilitator in the processes studied in this thesis took on multiple roles, including that of a regular facilitator, an expert modeller, and the voice (*i.e.,* interpreter) of the SD model. In addition, roles of participants depended on professional experiences. Different mixes of people and the variety of skills that they bring into a process typically influence the outcome[80].

In Papers III-IV, the facilitator and the modeller were the same person, but worked together with external project members in project leading roles. In such situations, it is important that the participants perceive the facilitator/modeller as being consistent with the other project leaders when communicating with the group. In addition, the facilitator needs to accommodate to the situation at hand when integrating SD into AR. As found in Paper IV, the facilitator adapted each step of the processes studied to support the participants in moving forward while making sure that the beginning and end of each process was the same regardless of context. This kind of mixing and improvisation requires substantial experience in order to be spontaneous, as described by Barret in his paper on management and improvisation in large organisations[128]. In scripted

GMB, there is less room for improvisation and facilitators may feel less comfortable with going outside the stipulated principles.

Papers III-IV demonstrate how integrating SD into AR supports the transition from the divergent phase, dominated by individual, creative contributions to a collective, to the convergent phase with an emphasis on analysis, cohesion, and consistency. In the first divergent/convergent phase this was typically accomplished by involving the group in the building of causal loop diagrams while in parallel challenging them to ascertain strict causality. The resulting diagrams demonstrated how issues were connected and indicated potential leverage points where change efforts could provide improvement. In the second divergent/convergent phase, the SD models, voiced by the facilitator, provided neutral de-politicised grounds for analysis, and engaged debate.

5.5.2 THE ROLE OF "LANGUAGE"

Pure SD is carried out by expert practitioners conversant in SD "language". In GMB, participants learn the basics of SD and take active part in model building. The resulting model quality is thus dependent on how well the participants learn and understand SD[88]. In AR, participants use their workplace and professional "languages" and are at all times familiar with the terminology that is being applied. The work principles found in Papers III-IV, allowed the participants to use their own terminology, as in an AR process, to build first versions of causal loop diagrams and patient flow diagrams. The facilitator/modeller translated what was expressed in the participants' own terminology into SD language for the purpose of modelling. In this process, the participants built sufficient understanding of SD principles, to understand and interpret the resulting model and its outputs. Ackermann and Howick note the need for a shared language between the modellers[85]. There is also a need to discuss how modellers and participants communicate. In GMB the language used is that of SD. In AR and the five cases described here the language is that of the participants.

If a group is not required to learn the basics of SD they can focus on the AR perspective of describing and structuring their work situation in relation to the model in terms of their respective professional terminologies. Richmond[129] describes processes where groups work and experiment with pre-built models that are improved by the modeller between meetings. He notes that, what in Papers III-IV is named the *multiprofessional knowledge repository*, allows group members to contribute with their profession-specific expertise and domain knowledge to the process. Richmond also states that this, in turn, leads to shared understanding of how the organisation works as a system, resulting in major policy changes. His research indicates that a group working with a model concurrently built by a modeller can be as effective or more effective than the group building a model. Papers III-IV demonstrate that participants contributed to the direction of the building of their model and that they found the simulations useful. Their domain knowledge could be fully used without them to first learn SD principles and methods before taking active part in the building of a model. The patient flow diagrams, the user interfaces, and the facilitator/modeller were "translators" between the participants and the model, as well as vice versa, so participants could still be challenged in how to interpret model outputs.

5.5.3 THE ROLE OF THE MODEL

The SD models in this thesis served the purpose of catalysing the process of gaining insights and understanding regarding the problem as well as its solutions. This involved shaping and challenging the initial mindsets of the participants as well as the facilitator/modeller. As such, they facilitated the accumulation of a coherent and consistent multiprofessional knowledge repository.

In AR, a group may, during the divergent, creative phase, have filled the walls of a room with flip-over charts, typically followed by convergence and prioritization. This part of the AR process can become relatively subjective because interconnectedness of the topics listed may be unclear and there is insufficient evidence at hand[129], creating room for a variety of interpretations. There is thus a risk that formal and informal power as well as personal influence play out in such situations[119]. In the processes studied, the SD model called for explicit specificity so as to narrow the room for interpretation. This reduced the opportunity for power-play and also brought to surface sufficient additional evidence to accelerate the forward movement of the processes.

From Paper IV it is found that, during the problem identification phase, a minimum viable model was built initially to demonstrate a key issue of the problem as understood by the modeller. Typically, unidentified issues and gaps in knowledge were identified in the course of uncovering the associated causalities. The models were then extended based both on specific requests by the participants and what the modeller saw as required in order to capture the issues at hand; whilst at all times making sure that the investigated system's dynamics was validly reproduced. The models were extended iteratively, and graphical user interfaces were added so that the participants themselves, or aided by the facilitator/modeller, could interact effectively with the model, and investigate the results, including robustness, of solutions suggested.

In SD and GMB the intention is to build models as complete as necessary[130], with an initial focus on model boundaries and which parameters to include[33,118]. This contrasts with the needs-based iterative model building when integrating SD into AR. The models in Papers III-IV served as transitional objects creating insights and understanding by way of which participants could observe the enhancement of their thinking. Eden *et al* describe that when a model has fulfilled its purpose as transitional, it may no longer be needed [125]. The reason for that may well be that the model has shaped the mental models of strategy developers, policy designers and decision makers to make the desired impact in reality.

As noted in the introduction (*cf* paragraph 1.3) the acquisition of relevant data in healthcare for model building may be difficult[7]. The gradual extension of the models led the participants to being motivated and engaged in procuring the data necessary to populate the simulation models as well as running them and analysing their results. Simulations can also provide learning experiences in surrogates of reality[54]. Thus, the simulations can become part of a process through which a new "normal" evolves, as described by May & Finch[131] and McNaughton *et al*[132], respectively, through which new routines naturally become embedded in practise.

Change processes can be perceived as threats to entrenched power structures[11] and several authors have also discussed power relationships in general and specifically in healthcare[36,70]. Papers III-IV did not identify signs of power issues hindering any of the processes studied. The participants perceived the modeller and the model as neutral. The modeller strived to encompass all the requisite knowledge and was not content until all participants were satisfied, disarming any potential differences of opinion.

5.5.4 THE ROLE OF SIMULATIONS AS INSERTIONS IN EXPERIENTIAL LEARNING

Paper III used a cogwheel analogy to identify the dynamic interactions between the target organisation, the managers, the project group, and the modeller (Paper III, Figure 1). There was a pre-existing learning process in the organisation, which had already begun to address the issue at hand. The modellers joined the learning process, contributed to it, learned from it, and finally left the process, which then continued in the organisation and led to change. This is illustrated in Figure 14, where the SD simulations (orange steps) were inserted by the modellers into the existing AR process (blue steps). It captures the schematics of the many learning processes of the participants including the facilitator/modeller. The interaction between these ongoing learning processes created reflection and learning between the participants themselves as well as between the participants and the modeller.

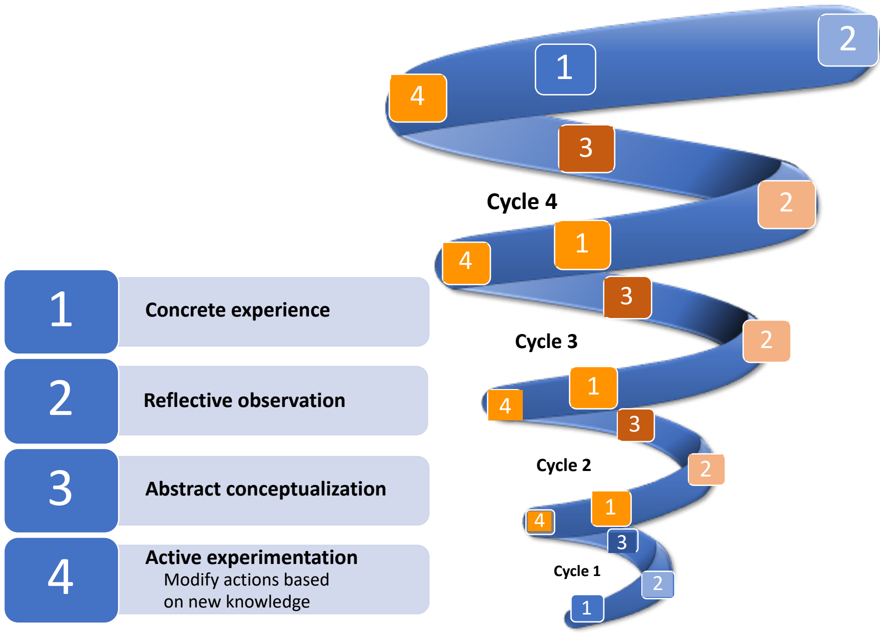

Figure 14 Simulations as insertions (orange steps) into the ongoing experiential learning of participants. The process begins in the participants' concrete experiences of their work situation. They share their reflections in the first divergent phase. The problems are conceptualized in a systemic overview such as a causal loop diagram and forms the foundation for model development and the first experiments. The simulations go through multiple cycles (four in the figure example above) until the participants converge on conceptualizations of solutions to test in reality. (Adaptation of Kolb's cycle of experiential learning[48])

When integrating SD into AR, the simulations fuelled what Scholl refers to as reciprocal learning, in which the AR process informs the SD process and vice versa[19]. This is also in line with what Howick & Ackermann refers to as interactivity between methods[80]. Papers III-IV found that the initial understanding of participants came from the concrete experiences of their realities and their external contexts, both with respect to the problem to be investigated as well as initially proposed solutions. Next, they reflected on the implication of these observations for themselves and their work. Over time, these reflections evolved into systematic abstract conceptualizations in the form of causal loop diagrams and clustered problem descriptions, providing evidence and rigour for their understanding whilst, in parallel, also informing the underlying simulation model structure. This was followed by active experimentation using the graphical user interfaces of the SD model where systemic effects become clear as the experiential learning of the participants grew when testing different scenarios. At this point they have concrete experience *in silico*, which they again reflect on in a new learning cycle continuing in the spiral. It can be concluded that Kolb´s cycle of experiential learning is highly relevant in understanding the role of the simulations in the ongoing learning processes when integrating SD into AR.

5.6 STRENGTHS AND WEAKNESSES

The core data in Paper I came from the Swedish Melanoma Registry, one of currently 33 cancer-specific quality registers where reporting from Swedish healthcare is compulsory. For the studied period, the Swedish Melanoma Registry had an average coverage of 99% resulting in highly representable information as basis for the simulations. Paper II used aggregate patient data from the wards in question as well as national incidence rates from the Swedish Public Health Agency. Papers I and II also use peer-reviewed data published in scientific journals, in turn critically reviewed by medical researchers participating in the respective project. A known limitation of the melanoma study was the use of retrospective calculations for the rate of tumour growth. Also, some demographic aspects influencing future incidence rates were not considered. A limitation of the influenza model was the intentional exclusion of transmission of virus in waiting rooms and when passing through corridors, originating both from staff and visitors. Although the model allowed for testing of the interaction of multiple variables, the purpose of the study was to isolate effects by specific factors. Investigating effects by combinations or by any of the other abovementioned factors listed as limitations were outside the scope of the respective study.

Papers III-IV of this thesis document a re-analysis of five change and improvement cases in healthcare where SD was integrated into AR as a working method. Each process was approached to question both the role and purpose of SD. Should the group contribute to the model, should the model contribute to the group, or both? How much SD terminology should the participants be exposed to? What is the relationship between AR and SD in the studied processes and how may synergy be obtained so that one method may be employed to re-enforce the effect of the other? The consistent underlying approach to integrate SD into AR for multiple and varying questions in the healthcare context is a strength, as it allows itself to be described and analysed.

The re-analyses in Papers III-IV, relied on a large body of contemporaneous notes about the original improvement cases that were revisited and interpreted during the research process. The qualitative abductive approach, using initial constructs as a basis for analysis and preparation of displays that were discussed, triangulated, and reinterpreted in a multidisciplinary setting, iteratively led to new insights and clarifications that caused the perspectives of the research group to meld. Eisenhardt[133] describes how theory evolves in constant iteration backward and forward between steps and suggests that *a priori* constructs can shape the initial design of research intending to build new theory-building. Whereas Eisenhardt describes the development of theory based on multiple cases, Dyer[134] argues for the value of an in-depth study of a single case. Both approaches have been used in this thesis. Paper III documents an in-depth study of a single case where *e.g.,* the analysis of the voices of the participants led to the concept of the *multiprofessional knowledge repository*. Paper III also provided a detailed description of how problem awareness progressed among participants and modeller as well as how the interactions between different parties took place during the course of the process. The insights from Paper III laid the foundation for the analyses in Paper IV and its conclusions. As AR is situational, the outcome when integrating SD into AR is likely to be affected by this feature, *i.e.* if the process is repeated it would not be identical, nor would it produce the identical results[19]. This thesis primarily seeks to identify the general methodological characteristics of the studied combination of SD and AR as applied to the investigated processes with respect to the facilitating, modelling, and learning perspectives. The presented findings should, therefore, be taken as guidance to others to adapt to the situations that they encounter.

The fact that the improvement cases in Papers III-IV were analysed retrospectively, based on documentation retained, may be affected by recall bias on the part of data analysis, and should be considered a possible limitation of the studies. More extensive and clearly structured notes and contemporaneous reflections could have contributed to deeper analysis. However, the support and rigorous questioning from the multidisciplinary group of researchers and the objective handling of the material may have compensated for this. Had the research documented in this thesis been planned in a prospective design, the experiences of the participants could have been recorded through independent observations and interviews. On the other hand, such an act of recording, observing, transcribing, and measuring a process may cause an observer effect, affecting the behaviour of the participants and influencing the process[135].

6 CONCLUSIONS

The overall purpose of this thesis was to deepen the understanding of using SD to support groups of healthcare professionals and researchers working with change and improvement processes.

This thesis reports on the use of SD in two major research projects concerning disease prevention and five cases where SD was integrated into AR to find solutions to work-related challenges in Swedish healthcare.

Aim 1 - Clarify benefits and limitations from using SD in research processes addressing policy planning of disease prevention in Swedish healthcare (Papers I-II).

The melanoma and influenza studies demonstrate that SD is well-suited for policy planning of disease prevention in Swedish healthcare. Benefits are that the methodology is cost effective and allows for simulations to be carried out *in silico* for testing interventions and policies without risk to patients or organisational efficiency. It also increases the understanding of systemic interdependencies between various patient-related and intervention-related factors associated with the studied diseases. SD makes it possible to test alternative research hypotheses and through sensitivity analysis focus data collection. Policymakers may be assisted in their strategic planning when selecting interventions with greatest preventive impact based on the most likely effects originating from plausible scenarios represented by SD-based model simulations. The limitation of both studies was that they could not evaluate the effects of the findings since acting on the results required policy decisions elsewhere in the organisations. This was outside the control of the respective research groups as well as outside the scope of the respective study and the SD method as such. Both models were also limited with respect to certain variables and the handling of interaction effects which possibly could have affected the overall modelling outcomes. Some of these issues are to be addressed in future work. It needs to be kept in mind that the overall usefulness of SD in research processes depends on identifying causality rather than correlation, as well as available data and project setting.

Aim 2 – Explore the interplay between SD and AR and identify methodological characteristics when using SD integrated into AR in change and improvement processes addressing work-related challenges in Swedish healthcare (Papers III-IV).

The studied cases demonstrate that the interplay between the two methods can be captured in an iterative reciprocal learning process where the understanding of the problem grows interactively during the process among both participants and modellers. Mental models converged in the studied cases and a “new” normal emerged, which in some instances also could be actualized in the respective organisation. The facilitator played an intermediary role, located between the group and the simulation model. In the investigated combined methodological approach, AR contributed to a high level of engagement among the participants and to the building of confidence in and ownership of the results. AR also ensured that the SD model was adequate, relevant, and rooted in reality. In turn, SD provided a coherent and consistent systems insight and overview in both studies, offered causal rigor, and provided ample opportunities for reality checks. Rowbottom’s[22] description of the role of an AR facilitator and his set of questions in an AR process was found to bridge between the two fields and can provide a common ground when AR-facilitators and SD-modellers work together on projects in the future.

When SD is integrated into AR, the process begins with an AR-inspired mapping of problems and objectives and ends in an SD-facilitated experimental phase testing numerous solutions *in silico*. Two major divergent and convergent phases characterized the intermediate steps, resulting in a growing understanding of the problem at hand as well as its potential solutions. These phases were adapted to fit each case under investigation, based on pragmatic judgements made by the facilitator/modeller as to what would best move the process forward. In the first phase, all problems were randomly laid on the table as if they were jigsaw pieces and, subsequently, organised to form a causal loop diagram and clustered into topics. In the second phase, potential solutions were similarly brought forward. It was tested whether they could fit together to constitute a final, comprehensive, and consistent solution to the overall problem at hand. By the end of the two phases, all participants and professions had collaborated and contributed to a repository of knowledge (in the form of an SD model) where individual as well as organisational learning came together. Applying this combined methodology to problems in healthcare can achieve useful, comprehensive, and robust outcomes with wide acceptance. Identified results will, by design, be calibrated to local needs and circumstances with the simulations creating certainty about expected results and guide in how to move forward.

7 FUTURE PERSPECTIVES

There are a number of papers that discuss combining AR and SD, but these only describe model development or final outcomes. Given that AR is situational, and the combined processes need to be adaptive, it cannot be assumed that the improvement cases described here can be generalized into a set of instructions. Instead, it would be helpful for others if the actual AR processes and the act of combining them with SD were described by more researchers, providing a wide repertoire of experiences. Some papers indicate that SD and AR practitioners worked together. Descriptions of such cooperation in the planning and execution of projects would also be beneficial. As AR is pragmatically situational, a variety of research into the perspectives and learnings of participants during and after projects could contribute to improved design of combined AR and SD engagements.

This thesis describes work with small groups. Research into how to integrate SD into large group AR interventions would also be valuable. There is software that can be used for identifying and connecting issues, providing input for large scale GMB[136]. There is also a multitude of organisational development interventions and group exercises that could be used in connection with combined SD and AR projects[137]. One example is World Café, originally used for community development, where participants' perceptions of issues at hand are scoped and aligned before entering a more structured large-group process[138].

Simulation modelling needs to find a role uniting the general and the local specifics. Brailsford[7] poses the question: ”Do we really need 1,008 different simulation models of Emergency Departments?” On the one hand useful simulation models could be generalized, so that they easily can be adapted, explored, and used locally. On the other hand, people working in healthcare could use general findings and apply them locally without detailed modelling. Ideally commissioning units and hospital management could utilize SD at policy levels, providing generalized models which can be used in local AR projects. In addition, several software applications for SD simulation are available. These were previously incompatible, but a protocol for sharing, interoperability, and reuse of SD models and simulations between applications has been developed[139]. This could facilitate sharing of generic models and modules to reduce model development costs and to ease local adaption of generalized models. Such libraries would be of great interest for end-users.

Spreadsheets are commonly used for planning and analytical purposes. They are easy to use but lack granularity. If resources are distributed based on averages and patient flows are highly variable, critical moments will not be captured in a spreadsheet. But these will be seen in a simulation model. Healthcare has circular dependencies, such as how patient discharges influences the intake of new patients. Circularity results in error messages in a spreadsheet but this is a basic function in SD models. Taken together, SD can often better reflect the complexity found in healthcare. However, the learning threshold of SD and the software used is relatively high. Ideally interaction design of SD software applications could be developed so that SD becomes as ubiquitous as spreadsheets so that lay persons can carry out simple SD simulations after a short introduction. Some attempts in this direction have been taken. Both Silico Studio (https://www.silicoai.com/) and Insightmaker[140] provide slightly simplified simulation tools and somewhat more intuitive interfaces. The latter also contains a learning platform and tools for exploring causal loop diagrams.

There can be little doubt that pressures for change in healthcare will continue in the foreseeable future, due to factors such as ongoing demographic changes, digitization, artificial intelligence, individualized and personalized medicine, as well as the pent-up demand for healthcare after the current pandemic. Workloads in healthcare organisations will remain high. Commissioning units and hospital management will continue to strive for cost savings and organisational efficiencies resulting in attempts to implement top-down change. However, change initiatives need to find a pathway considering both top-down needs and policies as well as the necessity of local adaptation, co-opting the professionals. Using SD can provide efficiency and reduce risk for patients given the high workloads in healthcare. AR provides effective processes to work across professions to find local solutions. The ability of a group with multiple professions to use simulations to better understand and together create a “new normal” is powerful and could significantly be leveraged. There are already methods for employees to use AR in their own organisations[141]. If SD can be democratized so that it can be used by non-experts, groups could adaptively combine AR and SD as needed to facilitate change and improvement processes in healthcare. With this combination, it is not unlikely that the overall commitment to development activities among professionals will increase and that some of the current challenges for change in this important area can be alleviated.

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